IARI Perspective Plan

VISION-2025

भाकृअनुप
ICAR

भारतीय कृषि अनुसंधान संस्थान
IARI 1905

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

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FOREWORD

Indian agriculture must continuously evolve to remain ever responsive to manage the change and to meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. In order to capitalize on the opportunities and to convert weaknesses into opportunities, we at the ICAR attempted to visualize an alternate agricultural scenario from present to twenty years hence. In this endeavour, an in-depth analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) was undertaken to place our research and technology development efforts in perspective so that we succeed in our pursuit of doing better than the best. Accordingly, the researchable issues are identified, strategies drawn and programmes indicated to have commensurate projects and relevant activities coinciding with the launch of the XI Five Year Plan.

Established in 1905 at Pusa, Bihar and relocated at New Delhi in 1936, the Indian Agricultural Research Institute (IARI) is the country's premier national Institute for agricultural research, education & extension. It has served the cause of science and society with distinction through first rate research, generation of appropriate technologies and development of human resources of par excellence. The successful journey of India's Green Revolution began from IARI fields in the form of several popular high yielding varieties of almost all major crops, especially rice and wheat which brought about multifold increase in our agriculture production. The Institute has developed the landmark wheat varieties, viz., Sonalika, Kalyansona and HD 2329 which have occupied several million hectares and substantially increased the total wheat production. The first high-yielding dwarf aromatic (*basmati*) fine quality Pusa Basmati 1 rice was developed by the Institute in 1989. In 2002, Pusa RH 10, the first aromatic rice hybrid and Pusa Sugandh 4 (Pusa 1121) have enhanced the international agri-business potential. The Institute also developed an improved *basmati* rice (IET 18005) resistant to bacterial leaf blight through marker assisted selection. The success achieved in wheat and rice was repeated in other crops such as pulses and oilseeds, coarse cereals, vegetables, fruits and flowers. The Institute has isolated cDNA clones encoding AVPs from *Celosia* and *Amaranthus*. These clones characterized and expressed in *Escherichia coli*, have opened avenues for developing transgenic crop plants with broad spectrum resistance against viruses in the country. The Institute has prepared the first set of comprehensive soil type and soil fertility maps of India. The research conducted in water management has led to the development of adaptable technologies like drip, sprinkler, etc. Several technologies developed at IARI like integrated nutrient management provided the input for practising organic agriculture in India. The Institute has also designed and developed agricultural implements such as aqua-ferti-seed drill, potato planter, okra planter and animal feed block making machine. Besides these, IARI also pioneered the development of biogas plant, solar energy-based dryers and desiccators for post-harvest management of vegetables and fruits for adoption in rural India. Building on the rich past and in order to carry forward excellence in the agriculture research and education, the IARI has formulated Perspective Plan Vision-2025.

It is expected that realizing the Vision embodied in the document would further ensure that the IARI, New Delhi continues to fulfill its mandate to make Indian agriculture locally, regionally and globally competitive. The efforts and valuable inputs provided by my colleagues at the ICAR Headquarters and by the Director and his team at the Institute level for over an year to develop Vision-2025 deserve appreciation.

(**MANGALA RAI**)

August, 2007

Secretary, Department of Agricultural Research & Education and
Director-General, Indian Council of Agricultural Research
Dr. Rajendra Prasad Road, Krishi Bhawan, New Delhi 110001, India

PREFACE

Agriculture in India is the means of livelihood of almost two thirds of the workforce in the country. It employs nearly 62% of the country's total population and occupies 42% of its total geographical area. From a nation dependent on food imports to feed its population, India today is not only self-sufficient in grain production, but also has a substantial reserve. The progress made by agriculture in the last four decades has been one of the biggest success stories of free India. Agriculture and allied activities constitute one of the main contributors to the Gross Domestic Product of the nation. The increase in agricultural production has been brought about by bringing additional area under cultivation, extension of irrigation facilities, the use of seed of improved high yielding varieties, better production technologies evolved through agricultural research, water management, and plant protection through judicious use of fertilizers, pesticides and cropping practices.

The Indian Agricultural Research Institute (IARI), a centenarian, is the country's premier national Institute for agricultural research, education and extension. It has served the country by developing appropriate technologies through basic, strategic and need-based research resulting in crop improvement and agricultural productivity in harmony with the environment leading to the Green Revolution and served as a centre for academic excellence in the area of postgraduate education and human resource development in agricultural sciences.

Agriculture in India is at a critical turning point. Stagnation of production in fine cereals, erratic behavior of climate, higher input cost, lower farm income, degradation and depletion of natural resources, inadequacy in the availability of quality seed and planting material are some of the issues where concerns have been expressed at various fora. The Institute has geared up with research progrmames to address some of these issues with the available manpower and resources using cutting-edge technologies like biotechnology and molecular biology, information and communication technology, physical sciences and nanotechnology.

As in the past, the Institute has taken the initiative to meet the challenge of globalization/economic liberalization and issues related to WTO. The revised perspective plan document (Vision-2025) has been prepared based on the basic structure of Vision-2020 keeping in mind the recent developments in international agriculture. This provides the framework for new priorities, new programmes, participatory modes of action, and organizational adjustments for effectively addressing the challenges and opportunities before us and for ushering in an ever green revolution.

The leadership of Dr. Mangala Rai, Secretary, Department of Agricultural Research and Education and Director-General, Indian Council of Agricultural Research, in initiating and guiding the preparation of the perspective plan has been most inspiring. The inputs of joint directors, heads of divisions/nodal officers of five schools and other scientists, particularly, Dr. A.K.Ganguly, Principal Scientist(PPI) of the Institute, have been most helpful in preparing this document. The document was edited by Mr. Chacko Thomas, Editor (English), IARI. Valuable assistance was given by Mr. S.C. Upadhyaya, Technical Officer, PPI Unit, in the preparation, and proof reading of the document. Dr.(Mrs.) Manorama Chawla, Technical Oficer, PPI Unit, and Mr. D.K. Parashar and Mr. G.K. Kaushik, Technical Officers of Publication Unit have shared the responsibility of reading the proofs. Mr. Shyam Lama, Private Secretary to the Principal Scientist (PPI) did the computer typesetting. The arrangement for printing this document was made by the Project Director, Directorate of Information and Publications of Agriculture (DIPA). My thanks are due to all of them.

September 3, 2007
New Delhi

(S.A. PATIL)
Director, IARI

ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
AGR	Division of Agronomy
AIIMS	All-India Institute of Medical Sciences
AIS&LUS	All India Soil and Land Use Survey
AIT	Asian Institute of Technology
AOAC	Association of Official Agricultural Clomists
APAU	Andhra Pradesh Agricultural University
APIDA	Agricultural and Processed Food Products Export Development Authority
AVRDC	Asian Vegetable Research Development Centre
BARC	Bhabha Atomic Research Centre
BHU	Banaras Hindu University
BIO	Division of Biochemistry
CAGR	Compound Annual Growth Rate
CAZRI	Central Arid Zone Research Institute
CDRI	Central Drug Research Institute
CFTRI	Central Food Technology Research Institute.
CGIAR	Consultative Group on International Agricultural Research
CHE	Division of Agricultural Chemicals
CIAE	Central Institute of Agricultural Engineering
CIAH	Central Institute of Arid Horticulture
CICR	Central Institute for Cotton Research
CIMAP	Central Institute for Medicinal and Aromatic Plants
CIMMYT	International Centre on Maize and Wheat
CIPHET	Central Institute for Post Harvest Engineering & Technology
CISH	Central Institute of Sub-tropical Horticulture
CITH	Central Institute for Temperate Horticulture
CPC	Centre for Protected Cultivation Technology
CPRI	Central Potato Research Institute
CREC	Citrus Research and Education Centre
CRIDA	Central Research Institute for Dryland Agriculture
CRRI	Central Rice Research Institute
CSAUAT	Chandra Shekhar Azad University of Agriculture and Technology
CSHL	Cold Spring Harbor Laboratory
CSIR	Council of Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSSRI	Central Soil Salinity Research Institute
CSWER&T	Central Soil and Water Research and Training Institute
DBT	Department of Biotechnology
DMR	Directorate of Maize Research

DNAFP	DNA Finger Printing
DOR	Directorate of Oilseeds Research
DRR	Directorate of Rice Research
DSR	Directorate of Seed Research
DSS	Decision Support System
DST	Department of Science and Technology
DU	Delhi University
DWR	Directorate of Wheat Research
ECO	Division of Agricultural Economics
ENG	Division of Gricultural Engineering
ENT	Division of Entomology
ENV	Division of Environmental Sciences
EPA	Environment Protection Agency
ESA	European Space Agency
EST	Express Sequence Tag
EU	The European Union
EXT	Division of Agricultural Extension
FAO	Food and Agriculture Organization
FCI	Food Corporation of India
FHT	Division of Fruit and Horticulture Technology
FLS	Division of Floriculture and Landscaping
GAU	Gujrat Agricultural University
GBPUAT	GB Pant University of Agriculture and Technology.
GEN	Division of Genetics
GHGs	Green House Gases
GIS	Geographical Information System
GPS	Global positioning System
HAU	Haryana Agricultural University
HPKVV	Himachal Pradesh Krishi Viswa Vidyalaya
HRI	Hydraulic Research Institute
HSPs	Heat Shock Proteins
IAEA	International Atomic Energy Agency
IAHS	Indo-American Hybrid Seeds
IASRI	Indian Agricultural Statistics Research Institute
IBSRM	International Board for Soil Research and Management
ICARDA	International Centre for Agricultural Research in Dry Areas
ICGEB	International Centre on Genetic Engineering & Biotechnology
ICID	International Commission on Irrigation and Drainage
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crop Research Institute for Semi-arid Tropics
ICT	Information Communication Technology
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute

IGFRI	Indian Grassland and Fodder Research Institute
IGIDR	Indira Gandhi Institute of Development Research
IIHR	Indian Institute of Horticultural Research
IIMI	International Irrigation Management Institute
IIPR	Indian Institute for Pulses Research
IISc	Indian Institute of Science
IISS	Indian Institute of Soil Science
IIT	Indian Institute of Technology
IITA	International Institute of Tropical Agriculture
IITD	Indian Institute of Technology, Delhi
IIVR	Indian Institute of Vegetable Research
ILRI	International Land Research Institute
IMD	India Meteorological Department
INRA	Institute National de Researche Agronomieque
INTECH	Institute for Microbial Technology
IPFT	Institute of Perticiale Formulation Technology
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated Pest Management
IPTRID	International Programme of Training and Research in Irrigation and Drainage
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
ISRO	Indian Space Research Organisation
ISSR	Intersimple Sequence Repeat
ISTA	International Seed Testing Association
IWMI	International Water Management Institute
JNKVV	Jawaharlal Nehru Krishi Vishwa Vidyalaya
JNU	Jawaharlal Nehru University
JSA	Japanese Space Agency
KAU	Kerala Agricultural University
KKV	Konkan Krishi Vidyapeeth
LEA	Late Embryogenesis Abundant
MAZ	Maize Directorate
MIC	Division of Microbiology
MKU	Madurai Kamraj University
MNES	Ministry of Non-conventional Energy Sources
MOA	Ministry of Agriculture
MOEF	Ministry of Environment & Forest
MPKVV	Mahatma Phule Krishi Viswa Vidalaya
MSU	MS University of Baroda
MW	Micro-Wave
NAFED	National Agricultural Co-operative Marketing Federation
NAFP	NASA Administration Fellowship Programme
NARS	National Agricultural Research System

NASA	National Aeronautical and Space Agency
NBAIM	National Bureau of Agriculturally Important Microorganisms
NBPGR	National Bureau of Plant Genetic Resources
NBRI	National Botanical Research Institute
NBSSLUP	National Bureau of Soil Survey and Land Use Planning
NCAER	National Council of Applied Economic Research
NCAP	National Centre for Economics and Agriculture Policy
NCBC	National Centre for Biological Control
NCIPM	National Centre on Integrated Pest Management
NCL	National Chemical Laboratory
NCMRWF	National Centre on Meteorology Research and Weather Forecasting
NCOF	National Council of Organic Farming
NCPGR	National Centre for Plant Genome Research
NCRIP	National Coordinated Rice Improvement Project
NCWM	National Centre for Wheat Management
NDRI	National Dairy Research Institute
NEERI	National Environmental Engineering Research Institute
NEH	North Eastern Hills
NEM	Division of Nematology
NGO	Non-Government Organisation
NHB	National Horticulture Board
NHRDF	National Horticultural Research and. Development Foundation
NIAB	National Institute of Agricultural Botany
NIAE	National Institute of Agricultural Engineering
NIC	National Informatics Centre
NIFTAL	Nitrogen Fixation for Tropical Agricultural Legumes
NIN	National Institute of Nutrition
NPL	National Physical Laboratory
NRC	National Research Centre
NRCAF	National Research Centre for Agro-forestry
NRCBGA	National Research Centre for Blue Green Algae
NRCG	National Research Centre on Groundnut
NRCPB	National Research Centre on Plant Biotechnology
NRCRM	National Research Centre for Rapeseed Mustard
NRCS	National Research Centre on Sorghum
NRCSOY	National Research Centre on Soybean
NRCW	National Resource Centre for Women
NRL	Nuclear Research Laboratory
NRSA	National Remote Sensing Agency
NSC	National Seeds Corporation
NSRTC	National Seed Research and Training Centre
NUE	Nutrient Use Efficiency
ODA	Overseas Development Agency

OUAT	Orissa University of Agricultural Technology
PAU	Punjab Agricultural University
PDBC	Project Directorate of Biological Control
PDCSR	Project Directorate for Cropping Systems Research
PDVR	Project Directorate for Vegetable Research
PHRTC	Post Harvest Research and Training Centre
PHT	Post Harvest Technology
PHY	Division of Agricultural Physics
PIP	Plant Incorporated Protectants
PLP	Division of Plant Physiology
PP	Division of Plant Pathology
PPIC	Potash & Phosphate Institute of Canada
PPV&FR Act	Protection & Plant Varieties and Farmer's Right Act
PRL	Physical Research Laboratory
RF	Radio Frequency
RS	Regional Station
SAARC	South Asian Association for Regional Cooperation
SAC	Space Application Centre
SASCOM	South Asian Planning Committee of START
SAU	State Agricultural University
SCA	State Certification Agency
SFCI	State Farm Corporation of India
SKUAT	SK University of Agriculture and Technology
SNP	Single Nucleotide Polymorphism
SPS	Sanitary and Phyto-sanitary
SSAC	Division of Soil Science and Agricultural Chemistry
SSR	Simple Sequence Repeat
SST	Division of Seed Science & Technology
STLs	State Seed Testing Laboratories
STMS	Sequenced Tagged Micro-satellite Sites
TAU	Tamilnadu Agricultural University
TERI	The Energy Resources Institute
UAS (D)	University of Agricultural Sciences, Dharwad
UPOV	The International Union for the Protection of New Varieties of Plants
USDA	United States Department of Agriculture
USI	Unit of Simulation & Informatics
UTT	Unit of Transfer of Technology
VEG	Division of Vegetable Crops
VPKAS	Vivekananda Parvatiya Krishi Anusandhan Shala
WAMIs	Water and Land Management Institutes .
WSU	Washington State University
WTC	Water Technology Centre
WUE	Water Use Efficiency
YSPUHF	YS Parmar University of Horticulture and Forestry

EXECUTIVE SUMMARY

Established in 1905, the Indian Agricultural Research Institute based in the capital city of Delhi, with its 20 divisions, 2 multidisciplinary centers, 8 regional research stations, 2 off-season nurseries, 3 all India coordinated projects on nematodes, floriculture and pesticides residues, headquartered in IARI campus, 10 national centres under all India network projects, a common set of service units, and two ICAR approved network projects on transgenics in crops and insect biosystematics, constitutes one of the largest research establishments in the world. Having been granted by the University Grants Commission (UGC) the status of a "Deemed University" in 1958, IARI is also the leading Post-Graduate School in agricultural sciences in the country.

The Institute, over the past 100 years, had responded most dynamically to the needs, challenges and opportunities of Indian agriculture and adjusted its mandate, plans and programmes accordingly. The mission of the Institute is to explore new frontiers of science and knowledge, and to develop human resources and policy guidance to create a vibrant, responsive and resilient agriculture. In order to realize this mission, the Institute has the mandate to conduct basic and strategic research and to undertake need based research that leads to crop improvement and sustained agricultural productivity; to serve as a centre for academic excellence; and to provide leadership in its various activities.The vision of the Institute is to steer the policies, strategies, priorities, programmes and activities of IARI to meet the emerging challenges and opportunities and to maintain its leadership role.

Considering that a number of state agricultural universities (SAUs) and ICAR institutes located in different parts of the country have matured and are undertaking effective adaptive and applied researches to solve regional and location-specific problems, the Institute will generally shed off such researches and increasingly move upstream with an increased thrust on strategic and basic researches which will not only keep enriching the stream of scientific knowledge, technology generation and product development, but would also enhance the nation's competitiveness in this age of scientific revolution.

While crop improvement and breeding will continue to be its strong programme, the thrust will shift to new strategic areas such as exploitation of heterosis and development of hybrids, including apomixis, new plant types combining high biomass production with high harvest index, identification and incorporation of genes for resistance/tolerance to biotic and abiotic stresses, transformation of C_3 plants to photosynthesis efficient C_4 plants and creation of pre-breeding stocks combining multiple resistances and other desirable attributes.

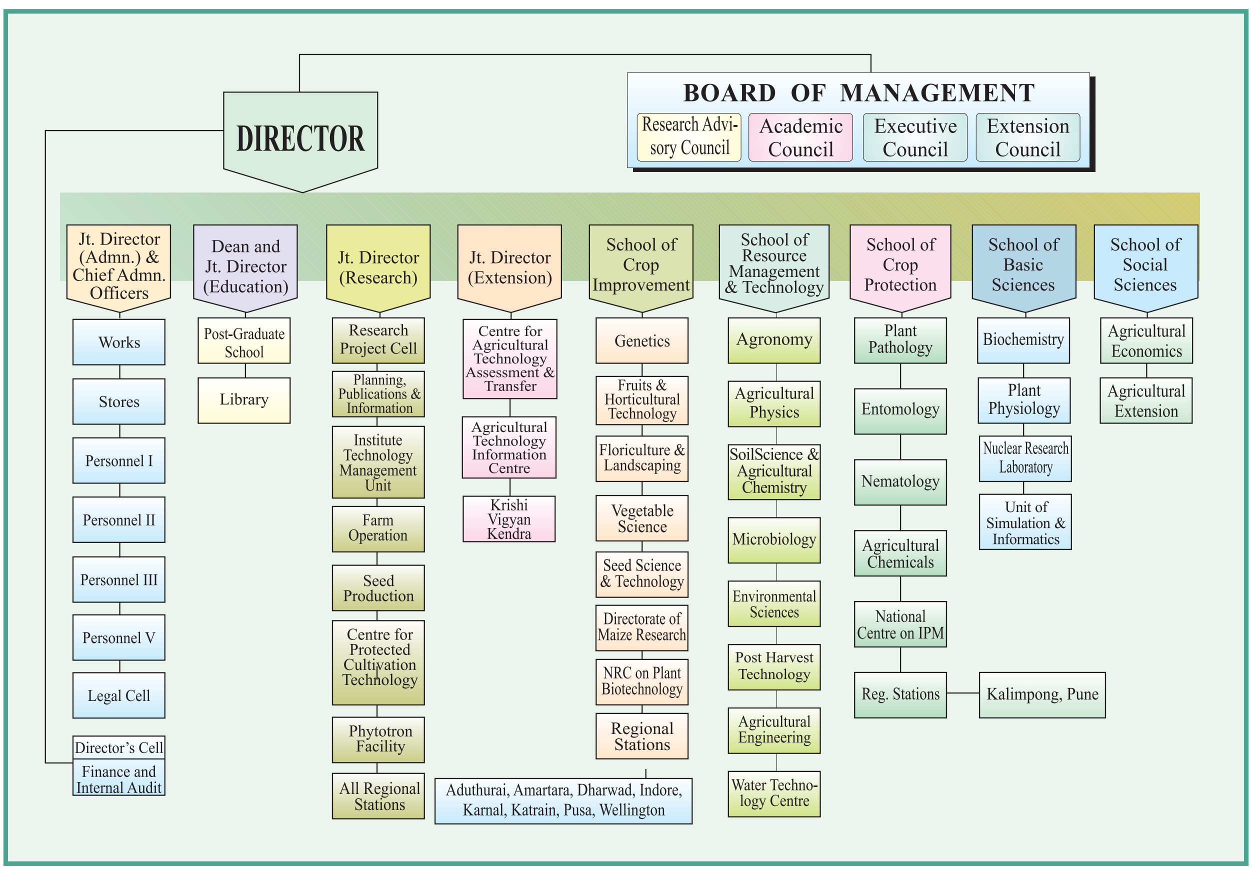
Basic and strategic researches will be strengthened or established also in the areas of resource management. Geographical information system, remote sensing, and crop modeling will be emphasized to generate new concepts, tools and methodologies based on systems approach. Agronomic research will address the needs and opportunities of small farmers through the development of new cropping systems and crop diversification modules consistent with sustainable use of land, water and other natural and purchased production resources. Basic research in nutrient management, soil-plant-water relations, soil physics, soil water dynamics and kinetics leading to the development of integrated plant-soil-water-nutrient management systems will be given high priority. The Institute will continue to provide leadership also in new and emerging areas such as climate change; impact of CO_2 enrichment on crop productivity; methane emission from rice paddies; impact of conservation agriculture and approaches for minimizing emission of greenhouse gases and ways to obviate and mitigate the adverse effects of such gases; application of nanoscience in diagnostics, formulation of agrochemicals and waste water management; policy research on evaluation of agro-biodiversity, protection of plant varieties and farmers' rights, intellectual property rights and biosafety, contract farming, agro-tourism. Programme, mission, and centres of excellence modes will be adopted to ensure inter-disciplinarily, excellence and efficiency in research. Thus, the Institute will lead the country's research for enhanced and sustainable agricultural production for the achievement set for millennium goal.

1. PREAMBLE

Originally established in 1905 at Pusa (Bihar) with the financial assistance of an American Philanthropist, Mr Henry Phipps, the Indian Agricultural Research Institute (IARI) started functioning from New Delhi since 1936 when it was shifted to its present site after a major earthquake damaged the Institute's building at Pusa (Bihar). The Institute's popular name 'Pusa Institute' traces its origin to the establishment of the Institute at Pusa.

The Indian Agricultural Research Institute is the country's premier national Institute for agricultural research, education and extension. It has the status of a 'Deemed-to-be-University' under the UGC Act of 1956, and awards M.Sc. and Ph.D. degrees in various agricultural disciplines.

The growth of India's agriculture during the past 100 years is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country, generation and standardization of their production techniques, integrated pest management and integrated soil-water-nutrient management have been the hallmarks of the Institute's research. The Institute has researched and developed a large number of agrochemicals which have been patented and licensed and are being widely used in the country. Over the years, IARI has excelled as a centre of higher education and training in agricultural sciences at national and international levels.



Organizational set-up

The present campus of the Institute is a self-contained sylvan complex spread over an area of about 500 hectares. It is located about 8 km west of New Delhi Railway Station, about 7 km west of Krishi Bhawan, which houses the Indian Council of Agricultural Research (ICAR), and about 16 km east of Indira Gandhi International Airport at Palam. The location stands at 28.08°N and 77.12°E, the height above mean sea level being 228.61 metres.

2. MANDATE

To realize the mission laid down by the Institute, i.e., to explore new frontiers of science and knowledge, to develop human resources and policy guidance to create a vibrant, responsive and resilient agriculture, the mandate of the institute is as follows:

- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need-based research that leads to crop improvement and sustained agricultural productivity in harmony with the environment
- To serve as a centre for academic excellence in the area of post-graduate education and human resources development in agricultural sciences
- To provide national leadership in agricultural research, extension, and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards
- To develop information systems, add value to information, share the information nationally and internationally, and serve as a national agricultural library and database.

3. GROWTH

IARI is India's premier national institute for research and higher education in agricultural sciences. The Institute received the status of a "Deemed University" in 1958 under the UGC Act of 1956 and was empowered to award M.Sc. and Ph.D. degrees. Headquartered at New Delhi, it is the largest and most prestigious of the research institutes financed and administered by the Indian Council of Agricultural Research (ICAR).

The administrative and technical head of IARI is its Director. The Board of Management, with the Director as its chairman, served by four councils, namely, Research Advisory Council, Academic Council, Extension Council and Executive Council, provides the overall management direction. The Director is assisted by a Joint Director (Research), a Dean & Joint Director (Education) and a Joint Director (Extension), who are equivalent to the Directors of ICAR institutes, which are not deemed universities. A Joint Director (Administration) looks after the day-to-day administrative work. The Chief Finance and Accounts Officer has overall charge of the audit and accounts matters.

Presently the research, education, and extension activities of the Institute are carried out through a network of 20 discipline-based divisions, 2 multidisciplinary centres, 8 regional stations, 2 off-season nurseries, 10 centres of AICRP and a common set of service units. The Institute also serves as the headquarters of 3 All India Coordinated Research Projects. In addition, some of the institutes like National Research Centre on Plant Biotechnology, NCIPM and Directorate of Maize Research are located in the campus.

Infrastructure

Infrastructural facilities

1. ***Specialized Laboratories/Facilities***
   - Nuclear Research Laboratory
   - Water Technology Centre
   - National Research Centre on Plant Biotechnology
   - National Phytotron Facility
   - Advanced Centre for Plant Virology
   - Microbial and Insect Conservation Facilities
   - Quality Seed Production Facility
   - Centre for Protected Cultivation Technology
   - Unit of Simulation & Information
   - Centre for Agricultural Technology Assessment & Transfer
   - Seed Production Unit
   - Institute Technology Management Unit
   - Centre for Conservation and Utilization of Blue Green Algae
   - Agricultural Technology Information Centre
2. ***Instrumentation Facilities***
3. ***Library Services***
4. ***Farm Facilities***
5. ***Building Facilities***
6. ***Guest Houses***
7. ***Students Hostels***
8. ***Regional Stations***
   - RS Pusa, Bihar
   - RS Karnal
   - RS Katrain
   - RS Indore
   - RS Amartara Cottage, Shimla
   - RS Pune
   - RS Wellington
   - RS Kalimpong
9. ***National off-season nurseries***
   - Aduthurai
   - Dharwad

Budget

The total allocations of 'Plan' and 'Non-Plan' funds to the Institute during the past five Five-Year Plans are given in following Table. While from the VI Plan to the VII Plan, the budget increased by 74%, from the VII Plan to the VIII Plan it increased by 124%. The bulk of the increase in the VIII Plan was to meet the enhanced salary and establishment charges, and the proportionate allocation to "Other Charges" and "Works" had declined. As shown for the VIII Plan, the allocations were far short of the demand, especially during the past two years. Under certain heads, such as "Works", due to inadequate allocations, the expenditure, of necessity, had exceeded the allocations.

Table: IARI budget during the last five Five-Year Plans

(Rs. in lakhs)

Sl.No	Period	Plan		Non-Plan	
		Sanctioned	Expenditure	Sanctioned	Expenditure
1.	Sixth Plan	1125.00	1016.03	4146.86	4525.36
2.	Seventh Plan	985.00	1117.63	8872.00	8409.80
3.	1990-91		534.99		2289.06
4.	1991-92		499.72		2349.42
5.	Eighth Plan	3995.00	3905.31	16380.67	16013.42
6.	Ninth Plan	4908.32	4825.36	33551.23	32648.08
7.	Tenth Plan	6024.70	4681.51	41900.36	41676.12
8.	Eleventh Plan	18000.00*			

*Proposed

During the X Plan period, the total allotment/expenditure under Plan and Non-Plan was sufficient to meet the requirements of works, annual repair and maintenance of the buildings and research contingencies. Paradoxically, when the costs of consumables have been escalating and the research is becoming more and more demanding and costlier, the operational funds of individual scientists have been sharply declining which needs to be addressed in future.

Manpower

The Institute has a total sanctioned strength of 3,547 comprising 608 scientific, 548 administrative, 804 technical and 1,587 supporting staff.

Manpower position at IARI

Category	Sanctioned			Filled		
	As on 1.7.2002	As on 31.7.2007	Reduction	As on 1.7.2002	As on 31.7.2007	Reduction
Scientific	654	608	46	510	409	101
Administrative	655	548	107	609	486	123
Technical	1,026	804	222	869	729	140
Supporting	2,134	1,587	547	1,854	1,450	404
Total	**4,469**	**3,547**	**922**	**3,842**	**3,074**	**768**

4. RESEARCH ACHIEVEMENTS

Over the last 100 years, the IARI has contributed substantially to the growth and development of Indian agriculture. This Institute is credited with the success of the Green Revolution and bringing about a radical transformation of Indian agriculture from traditional to modern. Some of the important achievements, the Institute has made in recent time (2002-03 to 2006-07), are highlighted keeping in mind the mandates:

Crop Improvement

- It has released/identified a number of crop varieties in cereals (wheat, rice, maize, etc.), pulses; oilseeds, fibers, vegetables, fruits and flowers.
- The Institute has registered five wheat germplasm, e.g., HW 2002 (INGR 04014), HW 2031 (INGR04015), HW 2049 (INGR04016), Pusa T3336 (INGR 04080, IC 427824), and DT 18 (INGR04084, IC427825). In addition, 17 genetic stocks developed by back cross method with known genes for rust resistance, viz., *Lr24, Sr24, Lr19, Sr25*, and *Lr28* were also registered. The national identity numbers are from IC 408333 to IC 408339 and IC 436068 to IC 436073. A number of rice parental lines have been registered.
- The Institute also takes the credit for developing improved basmati rice (IET 18005) resistant to bacterial leaf blight through marker assisted selection which has been released by CVRC recently.
- Pusa 343 variety in cotton developed by the Institute recorded the highest bundle fibre tenacity of 31g/tex with corresponding highest value for Hermans crystallite orientation factor and average amount of cellulose content. Therefore, Pusa 343 is identified to be the cotton genotype that meets the demand on fiber quality for the high-speed efficient rotor spinning technology. However, the breeders need to break the yield barrier of this variety.
- Significant improvements in storability of soybean seed were recorded as a result of treatment with Polykote (singly or with fungicides) and with the use of super bags. In paddy, coating seeds with Polykote was effective both in maintaining high germination during storage and in improving field emergence in the cytoplasmic male sterile (IR 58025A) and maintainer (IR58025B) line seeds.
- In comparative performance of different priming treatments, namely, hydro, halo, solid matrix and osmo priming, the solid matrix priming gave higher germination and vigor index than those given by the other priming treatments and control in cowpea variety Pusa Komal.
- The Regional Stations, Karnal, Pusa (Bihar), Indore, and Katrain, and the Seed Production Unit(IARI) produced nucleus, breeder, and IARI seeds as per the indents received every year from various central/state govt. agencies for cereals, forage, pulses, oilseeds and vegetables.
- The breeder seed demand by various central/state government agencies is the standard methodology for assessment of the impact of the varieties. The percentage share of IARI varieties in total breeder seed production in the country reached 20.4% to 32.9% in wheat. A series of aromatic rice Pusa Sugandh developed by the Institute spread quickly in Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. The Institute also developed superfine grain, aromatic rice hybrid Pusa RH 10. The variety Pusa 44 rice developed by the Institute became very popular in Punjab on account of its stiff stem, non lodging habit, high input response and

Important IARI varieties released/identified

A. Cereals	Wheat	WR 544 (Pusa Gold), HD 2824, HD2781(Aditya), HW 2044 (Kurinji), HW 2045 (Kaushambi), HD 2824 (Poorva), HD 2864 (Urja), HD 2851 (Pusa Vishesh), HD 2833 (Tripti), HW 2034 (MACS 6145), HW 3094 (COW(W) -1), HI 1531, HD 2888, HI 8627 (Malav Kirti)
	Rice	Pusa 1121 (Pusa Sugandh-4), Jaldi Dhan, Pusa Sugandh 5, Pusa 1460 (Pusa Sugandh 7), Improved Basmati (IET 18005)
	Maize	Pusa Composite 4(composite 8551), AH 421(PEHM5), Pusa Composite 3, PEHM 3, Hybrid AH 58
	Pearl millet	Pusa Composite 383
	Forage sorghum	PCH 109, Pusa Chari 615
	Multi-cut sorghum	SSG 601
B. Pulses	Chickpea	Pusa 1088, Pusa 1103, Pusa 1105, BG 1105, BG 1103, BGH 547, BG 1108, BGM 547 and BGD 128
	Mungbean	Pusa 9972 (Pusa Ratna)
	Pigenon pea	Pusa 991, Pusa 9712, Pusa 2001
	Lentil	L 4594
	Cowpea	V 578 (Pusa 578)
	Field pea	DDR 55 (Pusa Mukta), DDR 27 (Pusa Panna)
C. Oilseeds	Mustard	IGC 01(Pusa Swarnima), SEJ 2(Pusa Agrani), LES 39 (Pusa Karishma), JD 6 (Mahak), (EJ 13) Pusa Tarak
	Mustard(Rye)	NPC 9 (Pusa Aditya)
	Soybean	Pusa 9712 (DS 9712), DS 9814
D. Fibre	Cotton	Pusa 17-52-10
E. Vegetables	Bottle gourd	Pusa Samridhi (Selection P 8)
	Ash gourd	LDAG 4, DAG 1 (Pusa Ujwal)
	Bitter gourd	DBTG 1, DBTG 201, DBTG 202, Pusa Hybrid 2
	Brinjal	Pusa Shyamla (DBL 21), Pusa Bhairav
	Tomato	DT 39 (Pusa Rohini), DTH 41 (Hybrid) TH 317 (Hybrid), DT 1, NSS, FEB 2
	Onion	Sel 402, Hybrid 42, Hybrid S2
	Cauliflower	DC 98-4 (Pusa Meghna) and DC 309 (Pusa Sharad), Hybrid DCH 541 (Pusa Kartik Sankar), FH 598, CH 5113, CH 490, DC113, DC168, H 91, H 92, CH 406, CH 413, Janavon
	Cucumber	DC 1, DC 2 (Pusa Uday), DC 3
	Sponge gourd	DSG 2 (Pusa Sneha), DSG 5
	Ridge gourd	Sel DRG 2

	Snap melon	DSM 1(Pusa Shandar)
	Garden pea	GP 17, GP 14
	Okra	DOV 1, DOV 2
	Vegetable mustard	MR 704 (Pusa Sag 1)
F. Fruits	Mango	Pusa Arunima, Pusa Surya
	Guava	Pusa Srijan
G. Flowers	Rose	Pusa Mohit, Pusa Abhishake, Pusa Manhar, Pusa Muskan, Pusa Urmil, Pusa Ranjana, Pusa Mohit, Pusa Mansij, Pusa Arun, Pusa Ajay, Pusa Komal and Pusa Shatabdi
	Gladiolus	Urmi, Jyotsana, Gulaal, Shabnam and Urvashi

suitability for combine harvesting and very high yield potential. Pusa 44 rice is the most popular rice variety in Punjab occupying nearly 35-40% of the total rice area in the state. In recent past, this variety has also become popular in Orissa, giving yield up to 8-9 t/ha.

- The hybrids of forage sorghum, namely, Pusa Chari 6, Pusa Chari 9, and Pusa Chari 23 developed by the Institute received indents for breeder seed for more than 45% during the last three years.
- During the last three years, the share of breeder seed/parental lines of hybrids in Pearl millet is more than 45%.
- There are several varieties of *Brassica juncea* in the active seed chain (Pusa Bold, Pusa Jai Kisan, Pusa Jagannath, Pusa Agrani, Pusa Bahar). Three years' breeder data indicate IARI share ranging from 20.63% in 2004 to 34.53% in 2005.
- The mungbean varieties Pusa Vishal, Pusa 9531, Pusa Baisakhi, and Pusa Ratna in the seed chain produced breeder seed ranging from 7% to 15% in last three years.
- A number of vegetables, namely, Pusa Meghali (carrot); PEB and Pusa Kasuri (methi); Pusa Red (onion); All Green and Pusa Bharati (palak); PV and Azad P 3, Arkal and Pusa Pragati (pea) PED; and Pusa Gaurav, Pusa Ruby and Pusa Uphar (tomato) were indented for breeder seed production to the tune of 4632.7 kg in 2005.
- The Institute, through its Regional Station, Kartian, has developed a variety of Brussels Sprout, Hilds Ideal, from an introduction, suitable for cultivation under North Indian Plains as well as hills. The seeds of above released variety were multiplied and distributed among the farmers and also sold to the progressive growers.
- The Institute has established a Scion Bank of fruit crops for mango (Amrapali, Mallika, Pusa Arunima, Pusa Surya, Hybrid 1-1, Hybrid 1-6, Hybrid 2-6, Hybrid 8-11, Hybrid 4-12), grape (Pusa Seedless, Pusa Garbasi, Pusa Navarang, Hybrid 76-1, Hybrid 75-32, Centennial Seedless), guava (Allahbad Safeda rootstock, Pusa Srijan variety) and Citrus (Kinnow on Troyer Citrange, Kagzi Kalan lemon).
- *In vitro* culture establishment and somatic embryogenesis were calibered in different mango genotypes. Callus initiations and embryogenesis were better in polyembryonic (82-88%) compared to monoembryonic (56-75%) genotypes. The percentage of bicotylendonary embryo was over 90% in polyembryonic compared to 75% in monoembryonic.

- The bio-hardened tissue cultural grape plants showed marked increments in vegetative growth and came into flowering within one & half year of transplanting compared to cutting derived plant where it was noted only after two & half years. Besides, the bio-hardened plants had improved fruit quality and showed low incidence of diseases.
- A process has been standardized for the extraction of guava, papaya and carrot pulps by hot extraction procedure. Blanching of bitter gourds in an osmotic solution (10% salt) followed by dipping in a solution containing magnesium oxide plus sodium bicarbonate showed better retention of chlorophyll in the rings of Pusa Do Mausmi and Pusa Hybrid-1. The drying with pretreatment of blanching in boiling water for three minutes followed by steeping in solution of 0.1% KMS + 0.2% CA + 6% sugar + 3% NaCl at room temperature for 15 minutes at the microwave intensity of 400W yielded an acceptable dehydrated product in about 45 minutes.
- Application of 50 ppm of benzyl adenine, one week prior to harvest and packaging with cling film before storage was most effective in maintaining the post-harvest quality and colour of broccoli.
- Treatment with radiation was found to be optimum for freshly harvested tomatoes (var. DT 39) in increasing its storability up to two weeks with minimum change in its toughness, and without any rotting or weight loss. Irradiation of mangoes (var. Amrapali) with 0.5 kGy was found optimum to enhance the shelf-life of the fruits up to six days with minimum degree of blackening.

Basic Sciences

- A number of transgenics in crops such as tomato, cucumber, potato, and papaya against various virus diseases are in various stages of development.
- A lectin gene isolated from chickpea cDNA library has been submitted in the Gene Bank with accession No. AY221982.
- A graphic presentation of the genetic constitution of the new plant type of wheat lines has been developed by DNA fingerprinting with STMS markers, which can be used as bar coded molecular tags for identification of the prospective seed samples.
- A novel Bt gene that is expressed during the vegetative phase of the bacterium has been discovered. This is termed as vegetative insecticidal protein (VIP) gene.
- A few differentially expressed partial cDNAs of N 22 (drought tolerant) and Panidhan (drought susceptible) rice genotypes were reamplified and cloned in PCR trap vector. Hybridization of these clones showed that one of these clones, namely, R4A having an insert of 244 bp, is associated with water deficit stress specific to N 22 only
- Level of pyruvate content in dwarf cultivars of wheat was significantly higher (36%) than that observed in tall cultivars (lacking *Rht* genes) of wheat.
- The decrease in soluble starch synthase activity in excised grains of wheat (*Triticum aestivum* L.) was less when grains were exposed to gradual rise in temperature.
- Measurement of membrane injury index (MII) in breeding material (parents and crosses) indicated that measurement of MII could be a suitable trait for improvement of stress tolerance in chickpea. MII has close correlation with CGR, RGR, NAR, chlorophyll content and RWC.
- Elevated CO_2 significantly increased the size and weight of *Brassica* seeds due to greater accumulation of carbohydrate and oil content. The increase of oil content in seeds was due to

increase in fatty acids. Elevated CO_2 also helped in mitigating the adverse moisture stress effect on the chemical composition of seeds. Mungbean cv. PS 16 exposed to elevated CO_2 (600±50 µl l^{-1}) in open top chambers showed significant increase in nitrogenase activity, nodule number and weight per plant and rate of photosynthesis

- Gamma irradiation dose (1 k Gy) has been found to be most effective in controlling the growth of pest infestation for over one year in pulses such as chickpea, lentil and pea.
- Wheat germplasm was characterized using 128 markers. In rice, marker assisted foreground and background selections were carried out in BC_2F_1, plants carrying transgenic for pro vitamin A and similarity to recurrent parent identified. Transgenic Cocodrie line was crossed with Jaya and Swarna and BC_2F_1,seeds produced in both crosses. Seventy-five elite genotypes of chickpea were assessed for STMS based molecular polymorphism and found to be highly polymorphic. A total of 132 elites were found for 46 STMS loci with an average of 2.87 per locus.
- The PCR protocol combining non-phenol chloroform method of DNA extraction, primer pair producing an amplicon of 451 bp and the Klen Taq polymerase enzyme was found very effective in detecting greening bacterium in citrus trees at one-hundredth cost of the DNA extraction compared to that of the commercial kit.
- Molecular characterization of *Chaetomium globosum* was done at intraspecific level by PCR-amplified by ITS region sequences.
- Species Specific Primer for detection of Karnal bunt (*Tilletia indica*) was developed from rDNA-ITS region for the detection of Karnal bunt teliospores by polymerase chain reaction (PCR). The forward ITS KB1, 5′ACGGAGCTCTTCTTCGGA3′ and reverse ITS KB2, 5′TCGATGATTCCGAAGAAT 3′ primers could amplify uniformly all the isolates of *T. indica* only, but not other *Tilletia* species like *T. caries* and *T. horrida*. This is the first report of the development of specific primers for the detection of Karnal bunt from rDNA-ITS region.

Resource Management

- Bed and furrow system has emerged as one of the most promising and sustainable soil/crop management technologies that has reduced input use while maintaining the same or higher level of crop productivity as in conventional flat planting system. Irrigation water applied reduced by 33.3% under bed planted system as compared to that under conventional system.
- Evaluation of neem oil coated urea using industrial expeller grade oil on performance of rice variety ‘Pusa Sugandh 2’ showed that coated prilled urea with neem oil gave a yield advantage of 1.0-1.3 t/ha over that of the uncoated urea. An oil load of 100 ppm was found optimum, and further increase in concentration of neem oil decreased the yield. Mean N response was limited to 100 kg/ha and interaction effects were not significant.
- Evaluation of Zn-enriched urea in aromatic rice cv. Pusa Sugandh 5 showed that Zn enriched urea had a positive effect on grain yield and Zn uptake of rice. Increase in yield was significant up to 1% Zn enriched urea, beyond which the response was marginal. The sulphur coated urea was inferior to Zn enriched urea even at the lowest concentration. A similar trend was observed in Zn uptake. The results suggested that Zn enriched urea had a great potential for increasing yield and nitrogen use efficiency in rice.
- Studies on organic farming in rice-wheat cropping system showed that organic manuring to both the crops was more beneficial than to either of the crops for improving the productivity of

rice-wheat cropping system. Green manuring was more beneficial in rice than FYM alone, but combined use of FYM + green manure + biofertilizers resulted in the highest productivity. Residual effect of organics applied to rice was pronounced on the following wheat. However, direct application of organic manures and biofertilizers was more effective when applied to wheat. The results showed that equally good yield of rice-wheat system could be obtained with exclusive use of organics + biofertilizers as with inorganic fertilizers.

- The combinations of *Sesbania* green manuring, BGA biofertilizers and FYM were found more effective to rice for increased grain yield over that of control by 1.21 t/ha in rice and 0.54 t/ha in wheat. Similarly, application of 10 t/ha FYM, *Leucaena* green leaf manuring and *Azotobacter* in different combinations increased grain yield that over of control in rice and wheat. Application of vermicompost @ 4 t/ha along with VAM and PSB, being on a par with vermicompost @ 4 t/ha alone and FYM @ 10 t/ha + VAM +PSB recorded significantly higher fruit yield of brinjal.
- The Institute has designed a gable shaped greenhouse with a view to lowering the initial cost on materials and construction. The pipe-framed structure could be built without the use of pipe bender. A simple jig was developed to give desired shape to the pipes for the roof of greenhouse. The cost of greenhouse was Rs.150/- per sq meter.
- A positive response for increasing boll number from 6% to 21% and seed cotton yield from 7% to 32% over those of control was recorded on *Gossypium hirsutum* cotton (Var. Pusa 8-6) as a result of application of two growth promoting bacteria (*A. chroococcum*, *Rhizobium*) and VAM are applied together in combination with seed treatment with *Azotobacter*.
- The Institute developed several farm related equipment and technology for optimizing crop production. Fruit and vegetable grader, suitable for grading round and oval shaped fruits has been designed and fabricated. A tractor drawn nine row aqua-ferti-seed drill has been designed and developed for dry land areas to enable the farmers to sow winter crops even under moisture stress conditions. A back-pack type harness has been developed for carrying load which helps in easy lifting with reduced load on cervical spine. A mechanical onion detopper for enhanced capacity and low drudgery has been developed. The estimated capacity of this machine is 300 kg/h with 90% detopping efficiency.
- Inoculation of *Azospirillum* or phosphorus solubilizing bacteria (PSB) or their combination significantly increased both grain and straw yields of rainfed pearlmillet.
- Pounding or impounding of irrigation water for initial 15 to 30 days and further irrigation after three days of disappearance of the standing water gave comparable yield with fully irrigated plots of rice varieties, namely, Sugandh 2, Pusa 1121 (Pusa Sugandh 4) and Pusa Basmati 1. This partially dry cultivation of rice in Karnal saved 24% of the total water requirements of the rice crop (paddy) without any yield reduction.
- Phytoremediation of heavy metal contaminated soils through hyper-accumulator plant indicates that *Brassica carinata* is the most promising hyper-accumulator. The performance of *Brassica napus* and *Brassica nigra* was also found to be encouraging.
- Assessment of waterlogged and saline areas using different Remote Sensing Derived Indices was successfully done. Development of a methodology and generation of cropping sequence of the study area using multi-temporal remote sensing satellite data and validation of the results were carried out.

- A computer-based decision support system, InfoSoil, has been developed to assess the soil quality and calculate fertilizer requirement using commonly available soil parameters.
- The Institute has developed crosslinked hydrophilic polymers, commonly known as super absorbent hydrogels, which have potential to absorb 170-350 times their weight of water at temperatures of 50°C. The hydrogels are semisynthetic in nature, thus contributing significantly towards sustainable green chemistry. Various trials conducted at the Institute have established their potentialities for water management in hi-tech horticulture as well as agriculture.

Crop Protection

- On SPS and Codex issues, initiatives have been made towards characterization of *Aspergillus* spp. involved in Aflatoxin production. Designed a primer-based expressed sequence tag from DNA of *Aspergillus* specific to polyketide synthase gene important for afla toxin biosynthesis pathway.
- Commercial fungal formulations of *Beauvaria bassiana*, *Metarrhizium anisopliae anisopliae* and *Verticillium lecani* have been evaluated against borer complex of pigeonpea and chickpea in field. Plots treated with *B. bassiana* and chlorpyrifos registered 14.21% pod damage as compared to 51.23% in untreated control.
- A number of new molecules, abamectin, betacyfluthrin, emamectin benzoate and spinosad were found to be more toxic than the conventional insecticides against *E.vittella* and *H. armigera*.
- Techniques for mass culturing of *Chaetomium globosum*, an effective biocontrol agent, have been standardized and a suitable bioformulation for soil and foliar application using talc powder as carrier and carboxy-methyl cellulose as sticker has been developed.
- A number of chemical hybridizing agents such as 2, 4-Dichlorophenyl ethyl oxalate, ethyl-B-(4′–fluoroanilino) acetate and N-β-cyanoethyl-4-fluoroaniline were developed as effective chemical hybridizing agents inducing male sterility in field grown wheat.
- Carbon dioxide has been proved to be highly successful in protecting paddy seeds from both insect infestation and fungal attack during storage.
- Cost effective, multiplex PCR diagnostics has been developed for rapid and reliable detection of multiple infections in potato, citrus and rice and for detection of citrus greening bacterium. Occurrence of *Zuccihini yellow mosaic potyvirus* has been recorded for the first time from India on bottle gourd by DAC-ELISA. Association of *Tobacco streak virus* with chilli (*Capsicum annuum*) and a *Nanovirus* with the *foorkey* disease of large cardamom was established for the first time.
- Parthenin, a major lactone isolated from the obnoxious weed *Parthenium hysterophorus*, has been identified as a useful raw material for obtaining potent insect, plant growth regulators and herbicide.
- A search for microbes able to degrade beta-cyfluthrin revealed that *Trichoderma viride* degraded this compound.
- A population dynamics simulation model was used to study the effect of climate change and climatic variability on dynamics of rice stink bug, *Leptocorisa acuta*. It was found that temperature rise up to 2°C would increase the bug population while further increase in temperature would have an adverse effect on its population.

- Secondary metabolites from *Fusarium oxysporum* and *Trichoderma viride* were extracted with 4 solvents and tested against *M. incognita* and *R. reniformis*. Greater activity against both the nematodes was observed with hexane extract of hyphae than with the extract of culture filterate. LC_{50} was calculated to be 129 and 149 ppm against *R. reniformis* and *M. incognita*, respectively.
- Two new fungal genera, namely, (a) *Manohorachariomyces*, characterized by loosely synnematous and fisculate conidiophores, producing solitary, transversely septate conidia, and (b) *Diatrypoidiella*, an ascomyceteous fungus with polysporus asci and allantoid ascospores, were created.
- Two new compounds, namely, 8-allyl-2-chroman-4-one (I) and 8-allyl-2-(4-hydroxy-1-methylene-but-2-enyl) chroman-4-one (II) have been isolated from *Phyllanthus niruri*. Compound (II) has been found to be more active against root knot nematode *Meloidogyne incognita* and reniform nematode *Rotylenchulus reniformis* with ED_{50} of 14.5 and 3.3 µg/ml as compared to fungal filtrate extract of *Aspergillus niger* (48 µg/ml), a known natural nematicide.
- A symbiotic bacterium associated with entomopathogenic nematode species, *Steinernema thermophilum*, has been identified based upon its morphological, cultural, biochemical and molecular characteristics, and found to be a new species of *Xenorhabdus* (Enterobacteriaceae). This new species of *Xenorhabdus* is the tenth species of this genus in the world, but the first species from this country. The bacterium being an insect killer, will be of immense use in exploiting its insect-toxic genes or its toxic metabolites for managing several lepidopteran, orthopteran and hemipteran insect pests of crops, as well as household pests like termite, house crickets, etc.

Social Sciences

- A study on communication visuals indicates that the farmers comprehend messages more easily and with clarity through photographs and line drawings. Thirteen training and management modules in extension organization have been designed and standardized for removal of drudgery suffered by the farmwomen.
- Under Technology Assessment and Refinement (TAR) through Institute Village Linkage Programme (IVLP) and Front line Demonstrations (FLDs), it has been proved that among the short duration paddy varieties, in terms of yield, income and quality parameters, Pusa Sugandh 4 fetched higher returns than PRH-10, Sugandh 2 and Sugandh 3.
- In terms of drudgery reduction of farm women in intercultural operations, the use of wheel hand hoe covered three to four times more area per unit time as compared to that covered by the use of traditional farm implements. More than 200 farm women have used this implement by taking from each other. Complete feed block ration processed by machine has shown trends of improvement in productive and reproductive parameters of health and milk yield of milch animals.
- For peri-urban areas, Pusa Naveen variety of bottle gourd was found to be high yielding and highly market friendly. Pusa A-4 variety of *bhindi* resistant to yellow vein mosaic gave 29% higher yield and income as compared to those given by the local ones. The average yield of vegetable pea was 7.963 t/ha as compared to that of the control (7.803 t/ha). These varieties have captured the maximum area under vegetable cultivation.
- Under limited irrigated and semi-arid areas, the resource conservation technology in growing

crops, like *moong*, *arhar*, sorghum, *bajra*, *guar* and cowpea have been found very promising. By the use of improved technology, *arhar* (Pusa 855), *bajra* (Pusa 605), *guar* (HG 365) and cowpea (V 385) have performed better in respect of yield and income, i.e., 21%, 28%, 16% and 27%, respectively, as compared to traditional varieties.

- In Jhunjunu district of Rajasthan, *Orobanchae*, a parasitic weed, has been a threat to mustard crop and has become acute in the last 5-6 years, causing a loss of 40 to 90%. This weed also affects other crops like tobacco, cumin, raddish, carrot, tomato, brinjal, etc. IARI has initiated a programme to solve this problem through mission mode.
- The Agricultural Technology Information Centre of the Institute is providing "Single Window Delivery System" for the products, services and technologies to the farmers/entrepreneurs, etc., through information museum, exhibits, library, plant clinic and live demonstrations on crop cafeteria. Thousands of Indian farmers and foreign visitors took advantage by way of visits, telephonic helpline (01125841670), toll free Kisan Call Centre (1551), farm bulletins, etc.
- It was found that crop diversification is prominent in rainfed resource starved regions for reasons of risk mitigation; in resource endowed regions, it is minimal, directed towards only high value crops for increased earnings.
- It was found that about 59% knowledge gap exists amongst the extension personnel with regard to management skills and new production practices. Moreover, the job satisfaction of extension personnel was below average. In order to improve the efficiency of extension personnel and efficacy of extension system, there is a dire need of training in management competency, modern communication technology, leadership, creativity, motivation, team building, stress management, planning and monitoring, training management and entrepreneurship development.
- The adoption index of zero tillage of resource conservation technology (RCT) in five states of Haryana, Punjab, Rajasthan, Bihar and Uttar Pradesh ranged from 59 to 77. The economics of wheat cultivation amongst RCT adopters and non-adopters in these states were found beneficial in terms of input cost in the entire transect to the extent of 18% in the case of human and machine labour, 6% in seed, 4% in plant nutrients and around 23% in the case of plant protection chemicals. The zero tillage brought down the overall input cost by around 12%.
- The preliminary results of the study on labour migration have thrown light on the magnitude and determinants of migration and its implications on structural and socio-economic condition of agriculture as a whole and rural households in particular. Among the migrant households, 44.22 per cent members were illiterate while among non-migrant households, 38.48 per cent were illiterate. Thus, poor educational status pushed laborers to move from their native place to other places to generate significantly higher income and employment from non-farm activities.

Human Resource Development

- Three hundred sixty-seven (367) M.Sc. and 432 Ph.D. students were awarded degrees at the convocation of the Post Graduate School during the period under report.
- A number of training programmes were organized in various divisions of the Institute. Some of the important training programmes are briefly mentioned below:

  Plant genetic engineering and molecular breeding; Application of biochemical and molecular techniques for characterization of plant pathogens under CAS; Seed production technology; DUS-testing: principles and procedures, Quick viability test; Wheat seed production and storage; Efficient water management, improved agriculture, mushroom cultivation and floriculture; Watershed based water management on sustainable basis; Irrigation water management; Measurement of technological change in agriculture; Motor rewinding; Gene cloning and sequencing; ICAR-Sri Lanka work plan; Seed testing and quality control; Low cost post-harvest management of horticultural crops, and protected cultivation of horticultural crops; Wheat seed production and storage; Production technology for fruit-based carbonated drinks and beverages; Production technology of *kharif* crops, dress designing, stitching and embroidery; Entrepreneurship development in agriculture; Manufacturing technology of agricultural implements; Detection and identification of designated seed borne diseases; Recent advances in abiotic stress resistance in crop plants; Advances in extension research; Package of practices for increasing the productivity of wheat in Tamil Nadu; Commercial bee-keeping; Seed processing, grading and packaging; Modern technology of protected cultivation of horticultural crops; Techniques in biochemistry and molecular biology; Agricultural extension: methods & approaches.

Miscellaneous

- Website of the Institute is maintained, and updated regularly for effective dissemination of information to end users (researchers, students, farmers and planners).
- The Institute has established a Business Development Cell (Currently known as Institute Technology Management Cell) for looking after the commercialization of IARI technologies, IPR issues, filing of patents, etc. Some of the successful technologies, processes, etc., generated during this period and a commercialized are listed as follows: Neem based pesticide formulations; Additives for improved photo stability of Azadirachtin-A; A herbicidal composition from neem; Synthesis of 4-methyl-6 alkyl-2H pyran-2–ones as potential fungicides; Alkane polyol alkanoates pesticides; Greenhouse environment management and protection system; Micro controller for greenhouse environment control; Animal feed block formation machine; Vegetable and fruit grader; Rockphosphate enriched biogas slurry; Pusa zero energy cool chamber; Whole tomato crush; Ready to eat dehydrated carrot shreds; Fermenter for production of bacterial insecticides; Development of Bio-formulation for biological control; Diagnostics for viruses; Blue green algal bio-fertilizers for rice; Development of heat, light and storage stable reduced azadirachtins and products based on them with pest control properties; Pesticidal oxime esters; Phorate formulation in special matrix for slow release; Manufacture of Mancozeb (Technical); A process for the preparation of mosquito larvicidal formulation.
- The Institute has filed 39 patent applications for various processes and technologies developed during this period.
- The scientists of the Institute have received many prestigious national/international Awards during the period.

5. IMPACT

The Indian Agricultural Research Institute (IARI) is the country's premier national Institute for agricultural research, education and extension. It has served the cause of science and society with distinction through first-rate research, generation of appropriate technologies and development of human resource. In fact, the Green Revolution that has sustained the agricultural economy of the country for nearly five decades was born in the fields of IARI, and our graduates constitute the core of the quality human resource in India's agricultural research and education.

The Institute has all along been acquiring new ideas and improving its policies, plans and programmes to effectively respond to the needs and opportunities of the nation. During the fifties, the advancement of scientific disciplines constituted the core programme and provided the base for its expansion in the 1960's and 1970's in all its three interactive areas, namely, research, education and extension. Besides basic research, applied and commodity research gained great importance resulting in the development of several popular high yielding varieties of almost all the major corps and their associated management technologies, which brought about an unprecedented increase in the national food and agricultural production.

The Institute has been the flagship of India's agricultural research and technology development. It functions on the premise that research is the engine of science-led agricultural growth. The perspective plan sets IARI's path of scientific research, technology development and extension and human resource development leading to the realization of new paradigms for achieving the congruence among enhanced productivity, sustainability, ecological and environmental security and socio-economic equity.

The primary mission of the Institute is to explore new frontiers of science and knowledge and develop human resource to provide leadership to the country in technology development and policy guidance resulting in a vibrant, responsive and resilient agriculture which must be effectively productive, eco-friendly, sustainable, economically profitable and socially equitable.

Ever since its establishment, the Institute has provided an inspiring leadership in the development of agricultural research infrastructure and technologies that led to India's emergence as a food-sufficient country. Having been granted by the University Grants Commission (UGC) the status of "Deemed to be University" in 1958, IARI is also the leading Post Graduate School in agricultural sciences in the country. The Institute, over the past 100 years, had responded most dynamically to the needs, challenges and opportunities of Indian agriculture and adjusted its mandate, plans and programmes accordingly. It has played a key role in transforming agricultural research, education and extension in the country. It has been the harbinger of the Green Revolution and the Flagship of Indian agriculture.

The Institute is moving upstream with an increased thrust on strategic and basic researches which will not only keep enriching the stream of scientific knowledge, technology generation and product development, but would also enhance the nation's competitiveness in this age of scientific revolution. IARI has strengthened its existing key areas of research and education and barged into newer frontier areas such as molecular biology and biotechnology, microbiology, virology, physiology, biochemistry, agrochemicals, precision and organic farming and biofuels and others. While crop improvement and breeding will continue to be its major mandate, the thrust has been shifted to new strategic areas such as exploitation of heterosis and development of hybrids, including apomixes, new plant types combining high biomass production with high harvest index, marker assisted selection, identification of genes for resistance/tolerance to biotic and abiotic stresses, and creation of pre-breeding stocks combining multiple resistances and other desirable attributes.

Basic and strategic researches have been strengthened or established also in the areas for resource management, GIS, remote sensing, and crop modeling, etc., to generate new concepts, tools and methodologies based on systems approach. Agronomic research addresses to the needs and opportunities of small farmers through the development of new cropping systems and crop diversification modules consistent with sustainable use of land, water and other natural and purchased production resources. Basic research in nutrient management, soil-plant-water relations, soil physics, soil-water dynamics and kinetics leading to the development of integrated plant-soil-water-nutrient management systems will be given high priority. The Institute provides leadership in environmental related new and emerging areas such as climate change, impact of CO_2 enrichment on crop productivity, methane emission from rice fields and approaches for minimizing emission of greenhouse gases and ways to obviate and mitigate the adverse effects of such gases. Socioeconomic research includes policy research on evaluation of agro-biodiversity, farmers' rights, plant breeders' rights, intellectual property rights and bio-safety. Programme, mission, and centres of excellence modes are being adopted to ensure inter-disciplinarity, excellence and efficiency in research. Thus, the Institute will lead the country's research for enhanced and sustainable agricultural production well into the current century. The Institute attains its accomplishments through the in-house funded projects, or the externally funded projects, besides the ICAR conceptualized revolving fund and other consultancy and contract research projects and services.

The Institute has been widely recognized as the seat of the Green Revolution in the country. The increased food production through the application of the Green Revolution technologies has been the corner stone of India's food security and overall agricultural success. The area-wise impact of contributions of the Institute are as follows:

Crop Improvement

The new wheat varieties developed by IARI have higher yield potential and better resistance to rusts. These varieties are increasingly becoming popular with farmers in the northern, eastern and central plains of the country. The cultivation of improved varieties has greatly improved as well as consolidated the country's food security by increasing the national production every year. Comparing the wheat area and production scenarios of 1965-66 and 1999-2000, approximately 23 million tonnes (mt) of additional wheat has been produced on the same area of 12.57 million hectares (m ha) planted to wheat during 1965-66. On the basis of a conservative assumption that IARI wheat occupies 50 per cent of the total wheat area in the country, its contribution to wheat production comes to over 11 million tonnes (mt) annually, valued at approximately Rs.6,050 crores (based on procurement price of Rs.5,500/- per tonne). Wheat stocks, which were 5 mt in 1981, sharply rose to 22 mt in July 1999. Further, higher wheat production has increased economic food security by inducing sharp decline in real prices of wheat. The country was losing up to 10 per cent of wheat yield due to rust disease. The strategic research done at the Institute in identifying different wheat varieties resistant to races of pathogens has saved wheat losses to the extent of 6.8 million tonnes worth Rs.25 billions annually. The credit for the development of Karnal bunt resistant wheat germplasm lines goes to IARI. The percentage of share of IARI varieties in total breeder seed

IARI technologies/research products at a glance

Major impact area	**Technology/research product**
Production growth	Wheat: HD 2329, HD 2285, HD 2687, HD 2643, WR 544, HD 2824, HD 2781 (Aditya); *durum* wheat: Malavshakti; mustard: Pusa Bold; rice: Pusa Basmati 1, Pusa 1121 (Pusa Sugandh-4), Jaldi Dhan, Pusa RH 10, Pusa Sugandh 5, Pusa 1460 (Pusa Sugandh 7), Improved Basmati (IET 18005); tomato: Pusa Hybrid 2; brinjal: Pusa Hybrid 6, Pusa Bhairav; pearl millet: Pusa 23, Pusa Composite 383; chickpea: Pusa 256, Pusa 1088, Pusa 1103, Pusa 1105, BGD 128.
Export promotion	Rice Pusa Basmati 1; pre-cooling and CFB packaging technology; mushroom; gladiolus; rose; economic policies for export promotion.
Import substitution	Mustard Pusa Bold; vegetable seed production, neem based pesticides.
Employment generation	Mango cvs. Amrapali and Mallika; tomato Pusa Ruby and Pusa Hybrid 4; brinjal Pusa Hybrid 9; mushroom for processing; germplasm support to seed industry; off-season vegetable production; seed production, processing and distribution; high-tech vegetable and flower production.
Equity	Wheat Videsha for Chhattisgarh and wheat HS 240 for hills; Pearl millet Pusa 23 for arid areas; cauliflower Himjyoti for hills; Jaldi Dhan for rainfed uplands.
Nutrition and biosafety	Chickpea Pusa 256; high carotene content carrot variety Pusa Yamdagini; quality protein maize (QPM); monitoring of pesticide residues in food products; food demand projections; solar dryer; zero energy cool chamber; low toxin somaclones of *Lathyrus sativus.*
Sustainability	Neem based pesticides; resistant sources for diseases of rice, wheat, cotton, mungbean and cauliflower; integrated pest management; neem oil based contraceptive; legumes in rice-wheat system; integrated nutrient and water management; crop diversification.
Nitrogen economy	Bio-fertilizers; neem cake coated urea; calcium carbide coated urea; legumes in rice-wheat system.
Efficient water use	Watershed management; pre-fabricated structures for conveyance loss reduction; irrigation schedules; energizing sick tube wells; sprinkler and drip irrigation, Aqua-ferti-seed drill.

production in the country varies from 20.4% to 32.9% in wheat. High yielding wheat varieties developed by IARI occupy 30% of the area under wheat in India. Many varieties such as HD 2189, HD 2285 and HD 2329 played a major role in increasing wheat production, not only in India but also in other countries of Asia and Africa

The aromatic, fine quality, high yielding rice variety Pusa Basmati 1 developed by the Institute has yielded an advantage of 2 t/ha at farm level and gives a net income of about Rs.20,000 per ha. Due to the consumer acceptance, basmati rice export has increased from 0.24 million tonnes in 1990-91 to 0.71 million tonnes in 2002-03. The corresponding value in terms of foreign exchange earning increased from Rs. 288.13 crores in 1990-91 to Rs.2062 crores in 2002-2003. At present, Pusa Basmati 1 constitutes nearly 60 per cent in terms of volume and almost 50 per cent (Rs. 1000 crores) of the foreign exchange earning through the export of *basmati* rice. Pusa 44, developed by the Institute for Kerala, Karnataka and Tamil Nadu, became very popular in Punjab on account of its stiff stem, non-lodging habit, high input response and suitability for combine harvesting and very high yield potential (10 t/ha). The popularity of Pusa 44 in Punjab and Haryana can be realized by the presence of a large number of farmers of both states during the *kisan mela* at the Institute's regional station at Karnal. The impact of IARI's quality rice variety will now get a higher value because of the new hybrid rice PRH 10, the first *basmati* quality hybrid in the world, which significantly outyields Pusa Basmati 1, and has been taken up by a large number of seed companies. The released varieties like Pusa Sugandha 2, Pusa Sugandha 3 and Pusa Sugandh 5 with improved productivity from 2.5 t/ha to 5-6 t/ha have spread over more than ten thousand hectares. Their early duration makes them ideal for rice-wheat cropping system and reduces their water consumption.

The performance of IARI in terms of key output and impact parameters relating to area of production/productivity in some of the mandate crops of IARI has been tremendous. The production of area under cultivation has increased in all the three major crops, viz., rice, wheat and maize. The development of varieties led to an increase in rice and wheat and maize productivity as well as production. The released varieties like Pusa Sugandh 2, Pusa Sugandh 3, Pusa RH 10 and Pusa 1121 are newer materials becoming popular at a rapid pace. Within one year of their release, Pusa Sugandh 2, Pusa Sugandh 3 and Pusa Sugandh 5 have spread over more than 10 thousand hectares. The Institute also takes the credit for developing an Improved Basmati (IET 18005) resistant to bacterial leaf blight through marker assisted selection which has been released by CVRC recently.

IARI pulse improvement programme acted as the major provider of germplasm and breeding lines, which formed the base for pulse improvement at various centres in the ICAR institutes and SAUs. The contributions of IARI as a trendsetter are no less an achievement. IARI varieties are contributing in a major way to maintain the pulse productivity at the national level. The improved varieties of chickpea, pigeon pea and mungbean have contributed significantly to rain-fed production. These varieties are of short duration and most suitable for crop rotation leading to increase in foodgrains production and improvement in the protein status in Indian diet even for the poor. Summer mungbean in rice-wheat cropping system has the potential to add 5 mt of pulses and 10 mt of cereals, besides improving soil health through nitrogen fixation. The low neurotoxin content varieties of lathyrus developed by the Institute (Bio L 212) with lowest BOAA content help to reduce the incidence of a crippling disease caused by the neurotoxin among consumers. Exploiting biotechnological tools, the Institute has been successful in developing a high yielding mustard variety and creating seven cytoplasmic male sterility and fertility systems, which are prerequisites for hybrid seed production in mustard. Widespread adoption of the IARI variety Pusa Bold was instrumental to the success of the Technology Mission on Oilseeds. Oil seed production went up because of the high productivity of mustard varieties like Pusa Bold, Pusa Jaikisan (Bio-902), and Pusa Jagannath and soybean varieties like Pusa 16, Pusa 20, Pusa 24 and Pusa 9712.The increased production has not only reduced imports of oil but also enhanced foreign exchange earnings through exports of soya meal. Pusa Bold variety of mustard led to a sharp reduction in edible oil imports.In the case of cotton, the long staple varieties (Pusa 761, Pusa 31, Pusa 8-6 and PSS-2) developed at IARI have augmented the supply of raw cotton for domestic textile industry as well as for exports.

Vegetable varieties and germplasm support of the Institute have led to the development of a seed industry which has helped in the spread of IARI varieties to a large area throughout the country. The cultivation of these varieties is highly profitable to the marginal and small farmers and generates direct and indirect employment for the rural and urban population. Further, many of the IARI varieties are early or late sown, giving a price premium advantage throughout the year. This has also diversified the food basket and increased the consumption of vegetables, both in rural and urban areas. Institute has developed 200 improved vegetable varieties of 43 crops. More than 2 dozens hybrids have also been developed by the Institute in commercially important vegetable crops. The Institute has developed improved technology for vegetable production like low cost poly-house for raising off-season nursery, low cost poly-house cultivation technology for high value vegetable crops, easy and economical hybrid seed production technology in important cucurbitaceae vegetables, onion production technology in *kharif* season, cauliflower cultivation in different seasons, cultivation of unusual exotic and under utilized vegetables, etc. More than 50% area is under cultivation of vegetable varieties of the Institute. Involvement of high yielding varieties/hybrids and also the improved production technology in cultivation for farmers are resulting in 25-50% increase in their production. More than ten varieties of vegetables developed by the Institute are considered as check/control in different levels of trial at All India Coordinated Crop Improvement projects on vegetables.

The Institute developed several improved varieties and hybrids of fruit crops such as mango (Amrapali, Mallika, Arunima and Surya), papaya (Pusa Nanha), strawberry and grape, besides a large number of rose, gladiolus and marigold varieties suitable for cutflowers, ornamental purposes and aroma keeping the interest of national and international market.

The Institute provides seeds of different varieties of crops developed by it to the farming community of various parts of the country through its regional stations. In addition, providing nucleus and breeder seeds of the varieties to central and state producing agencies is a regular feature of the Institute.

Basic Sciences

In basic and strategic researches, the Institute has many firsts to its credit. Its salient contributions include: understanding of gene regulation and expression; distant hybridization techniques; identification of desirable genes, cloning, introgression and expression in desired recipients; *Cicer Rhizobium* genes genetically engineered for combating biotic and abiotic stresses; molecular basis of resistance and race characterization; synthesis of agrochemicals and their newer formulations, safety consideration of agrochemicals; improvement of nitrogen and other nutrients use efficiency; mechanism and the genetics of nitrogen fixation; and geographic information systems and crop modeling, to cite a few examples. These discoveries/studies have been pace setters in the country and have stimulated and assisted other ICAR institutes and state agricultural universities in frontline researches. Biotechnology and molecular biological efforts have been fruitful for the development of transgenic materials of various crops. At present, transgenics of potato, cucumber and tomato for viral resistance, and rice, and brinjal transgenics for insect resistance are in pipe line. Pusa Jaikisan developed through tissue culture technique and Improved Basmati (IET 18005) are some of the examples of successful biotechnological intervention.

Integrated Crop Management

In order to harness the high yield potentials of the various IARI varieties in a sustainable manner, the Institute has developed and popularized several production and resource management technologies encompassing integrated soil, water and nutrient management, integrated pest management and efficient cropping systems. The Institute has contributed enormously in the last four decades to the research and development of neem. The chemists joined hands with biologists in unraveling the multifarious actions of neem. Extraction and isolation protocols for various bioactive neem constituents were established for the first time in most of the cases. Bioassay-guided isolation of neem pesticidal constituent was employed in collaboration with entomologists, pathologists and nematologists. The Institute has been the pioneer in research on nitrogen economy, involving research on the use of nitrification inhibitors including indigenous materials such as neem seed or cake and encapsulated calcium carbide, neem derived pesticides and other products, biocontrol agents against pests and diseases, and biofertilizers. The neem based pesticides will go a long way in reducing imports while promoting ecological integrity of the system. Its pioneering efforts to change the strategy of resource and input management in agriculture from input-based to knowledge-based technologies through simulation modeling and systems analysis approach have brought a perceptible change in the country's research strategies

Increase in irrigation efficiency was achieved through techniques developed at IARI through the development of the High Density Polyethylene (HDPE) pipe based sprinkler unit. The spread of this sprinkler irrigation system is expected to generate additional production of pulses and oilseeds. The drip irrigation system developed and popularized by the Institute is contributing significant increases in the area under fruits and vegetables and their production every year. The Institute has designed a prefabricated concrete lining technology suitable for several irrigation projects for the sandy and sandy loam areas of northern India. This technology has the potential to save 5 million hectare meters of surface water which will irrigate 10 million hectare of additional crop area and will increase food grain production by 10 mt annually in the country.

The Institute has made significant basic and applied contributions, through internationally acclaimed hydrological research and investigations, in the development of new stable isotopic techniques, approaches and methodologies for regional assessment of groundwater quantity, quality and pollution dynamics; its judicious development, rational utilisation and its protection from further depletion and degradation, with an objective to enhance environmentally sustainable crop production. The aqua-ferti-seed drill (AFSD) developed by the Institute for making moisture and fertilizer available during sowing time facilitates good germination, initial crop stand and growth under rainfed farming.

The Institute has been actively engaged in developing, producing and supplying biofertilizers, viz., *Rhizobium*, *Azotobacter*, *Azospirillum*, blue-green algae, phosphate solubilizers and vesicular arbuscular mycorrhizae inoculants, to farmers and extension-oriented agencies. Many new materials and formulations of algal biofertilizers have been developed which have improved shelf-life and assured quality. *Rhizobium* cultures for all major crops, with the standard technology of inoculation, are available in the Institute. These inoculants give 9-30 per cent higher yield in the farmers' field.

Work done at IARI established that methane emission by irrigated rice is very low and is not a major contributor towards ozone damage. This clearly proved that the projections made by the western world on the role of rice and global warming are unfounded.

The Institute developed several low-cost technologies such as Pusa cool chamber (zero-energy chamber), Pusa seed bin, biogas plant, solar energy based driers and desiccators for post-harvest management of vegetables and fruits for adoption in rural India.

Social Science

The research findings of the Institute have provided valuable guidelines and directions for future national agricultural planning and policy. Some major findings that have had an impact on strategic planning for food security and agricultural development are as follows:

- Demand projections for food grains and non-food grains made for the year 2020 by the Institute are widely accepted and form the basis of national policies aimed at ensuring food security.
- Complementary to the demand projections, the Institute has identified the regions/states, which need to be targeted to realize future productivity gains to meet the nation's demand; such identification will be useful for national agricultural development planning.
- Analysis of the changing agricultural export scenario induced by the national and global trade policy reforms has helped in identifying the potential products, in the exports of which the country has a competitive advantage, and also the emerging export markets.
- Impact analysis of agricultural research indicated the need to increase the research investment from the existing level of less than half per cent to at least 1 per cent of agriculture GDP. The regions and the commodities in which research investments need to be enhanced were also identified.
- To gear up for the process of agricultural diversification in favour of secondary crops, the Institute has suggested several policy recommendations for equitable and sustainable growth of secondary crops for livelihoods of millions of farmers in rainfed marginal environments.

Human Resource Development

IARI rightly deserves the sobriquet "Mother Institute" as its *alumni* form the backbone of teaching, research and research management of agriculture in the country. The contribution of IARI towards human resources development for the national and international agricultural research and education systems is unparalleled. Today IARI *alumni* comprise the bulk of scientists recruited through the Agricultural Scientists Recruitment Board (ASRB) and, in most cases, the top positions are occupied by our graduates. Our *alumni* today are heading and directing agricultural research, education and extension programmes not only in India, but also in other countries.

The Institute played a key role in training manpower for the expanding agricultural extension system in the states, specially in agricultural universities. It has effectively demonstrated the relevance of new technologies and designed new extension strategies for technology dissemination. In the process, it has also provided valuable scientific feed-back to the scientists. Much of the methodology currently used in the country was derived from the earlier extension initiatives of the Institute like National Demonstrations Project and Operational Research Project for integrated development. In fact, these projects were adopted by the ICAR as major programmes of transfer of technology. The IARI Library, playing the role of National Agricultural Library of India, maintained the tempo of its growth and development with a collection of 6.0 lakh publications—books, monographs, scientific journals, research bulletins, theses and electronic data bases, etc. It serves 2000 registered members of its own besides serving 8000 research scholars visiting the Library and availing photocopying, bibliographic and electronic literature services.

Efforts on Commercialization

Ever since its inception, the Institute has generated technologies and processes of relevance to Indian agriculture. In keeping with the national mandate and to make the country self-sufficient in agriculture, these technologies and processes were passed on to the farm related communities free of cost. In monetary terms, the benefits that accrued to the nation must be to the tune of several trillion worth of US Dollars. This is besides the self respect and dignity that the food self-sufficiency brought to the nation. Lately, resource generation, commercialization and international trade are becoming the key marks of Indian agriculture. The Institute is, therefore, gearing up to meet the future need and enable the country to cope with these requirements.

The researches carried out at IARI have generated an environment for industrialization and exports. For example, Pusa Basmati 1 has led to the modernization of rice mills and exports. The horticultural crops, through increased production, have induced a growth in the processing industry and exports of value added products. The private agro-chemical industries got a boost from the indigenous technologies for pesticides and agro-chemicals developed at the Institute for commercial adoption. The technology in respect of two bioformulations, namely, Kalisena SD and Kalisena SL, found effective against devastating soil borne pathogens, and promoting plant growth and crop yields, has been transferred to M/s Cadila Pharmaceuticals Limited by the Institute for marketing these bioformulations in India and abroad. Other technologies commercialised are: vegetable hybrids and open pollinated varieties of cauliflower, cabbage and brinjal; transgenic brinjal seeds of IX event; parental lines of superfine grain aromatic hybrid rice Pusa RH-10; breeder seeds of IARI vegetable crop varieties for production of foundation and certified seeds; crosslinked superabsorbent/ high absorbent hydrogels; and coat protein gene construct of *Tobacco streak virus*.

Programme Assessment

Despite the development and diffusion of modern technologies, generation of high quality manpower, and the pronouncement of new extension methods and technology transfer procedures by the Institute, the overall efficiency of Indian agriculture has remained low. Even in the Green Revolution crops, namely, rice and wheat, the Indian average yield ranks around 50th in the world. While our technologies have been effective in increasing the total production, these have remained rather inefficient in utilising the vast natural and man-made resources in the country. India has one of the highest average annual rainfall coupled with the second largest irrigation system and the 4th largest fertilizer industry in the world, but our technologies are not judiciously harnessing these resources.

During the Green Revolution era, greater attention was paid to commodity research, and scientific excellence in several disciplines and sub-disciplines was sacrificed in the process. Although some good work continued to be done in basic sciences such as plant physiology, biochemistry and molecular biology, the impact of such work was not realised in strategic or practical outputs. Moreover, the number of scientific papers published in peer reviewed journals of international repute have declined.

Research priorities and orientation in the past few decades, again mostly influenced by the Green Revolution movement, had caused several disparities and inequities. Increasingly greater attention was paid to irrigated agriculture, and support to rainfed agricultural research had eroded considerably. Several poor man's crops such as pulses, and work on forages were generally given lower priority.

No major breakthroughs in yields of pulses and oilseed crops were recorded. Basic and strategic researches in these crops remained disjointed and less rewarding. Moreover, grain legumes continued to suffer heavily from high incidence of pests, especially pod borers and viral diseases. Research priorities in maize were misplaced as, despite a tremendous demand for early maturing hybrids, especially in the north, which accounted for about two--thirds of the maize acreage, no suitable hybrids were available.

As regards biotechnology, while useful work has been done in *in vitro* culture, somatic hybridization and somaclonal selection, significant progress have been made in recombinant DNA techniques, preparation of gene constructs and their faithful expression in the recipients, production of new male sterility systems, etc. and transgenics.

Though, elements of technology packages related to IPM, IPNS and other complex resource management systems were developed by different disciplines, but due to the general lack of programme complementarity and fine tuning of such technology packages, their transfer and adoption have remained poor. However, efforts are currently being made to popularize the technology developed by the Institute through extension units and regional stations located at various parts of the country.

Socio-economic dimensions of research and technology development at the Institute have improved. The Division of Agricultural Economics has initiated research in policy issues and provided guidelines to the process of national agricultural transformation. Research, education and extension linkage has remained poor, so much so that the technology transfer unit had remained non-functional for several years. It has now been reactivated. The extension activities were undertaken in different parts of the country in *ad hoc* manner. Important subjects like methodology for technology assessment, environmental accounting, indicators for impact analysis and development communication had received negligible attention.

The mechanisms for transfer of technologies and products such as prototype testing of machines, tools and agrochemicals and scaling up of the products and processes identified and developed by the Institute are now getting increased attention.

While majority of the scientists have done well, due to faulty recruitment and promotional policies, a sizeable number of scientists in the Institute have generally been recalcitrant to the fast changing national and international scenarios and are basically handicapped in absorbing, let alone keeping abreast of, the exciting developments in science. The manpower and facilities have generally aged in several of the Divisions. The situation has been exacerbated due to the lack of lateral entries at higher levels. The promotional policy in the past had also encouraged fragmentation and isolation of activities through operationalisation of disjointed projects by individual scientists.

Allocation of resources to individual pro-grammes has always not matched with priority needs and often there is a mismatch among equipment, operational funds and trained manpower. Over the years, operational/contingency grant per scientist, in real terms, has declined while costs of consumables and labour have escalated several folds. The vast and often old and ageing buildings and other infrastructures have not been kept in view while allocating maintenance and development grants to the Institute. In actual terms, there is serious erosion in our financial outlay, especially in the operational funds.

6. SCENARIO – A SWOT ANALYSIS

(**Strength, Weakness, Opportunity and Threat**)

National Agricultural Scenario, Research Needs and the Role of IARI

The agricultural sector presently accounts for about 24% of the national GDP, and about 60% of the national employment. During the past six decades, the country has witnessed spectacular progress in agricultural production, increasing its total food grain production from 51 million tones in 1950-51 to 216 million tonnes in 2006-07. The bulk of the growth was essentially due to rapid increase in production of rice and wheat. Considerable progress has taken place also in cotton, sugarcane, potato and fruit and vegetable production. It is gratifying to note that the major portion of the increase in the total production has accrued through increases in yield levels. The rate of growth during the past six decades in total production of various commodities had outstripped the rate of growth of population, thus increasing the per capita availability of food from about 400 g per day to over 500 g per day and the average kilo calories intake from about 1900 to 2250.

Despite the unprecedented increase in food production during the past 60 years, about 200 million people in the country, almost one of our every five persons, is hungry and malnourished. This is essentially due to the lack of access to food on the part of a large section of Indian population. Although during the past six decades the percentage of people below the poverty line had declined substantially, the number of poor people has increased. It is this poverty which is the main cause not only of food insecurity but also of environmental degradation. Thus, even though India has attained apparent food security, its one-fifth of the population is chronically food insecure. This must not continue. Our Perspective Plan must be geared to eradicate this hunger and provide a framework to develop technologies, human resources and policies which will improve our economic and physical access to sufficient food, primarily by increasing our food production and income through establishing efficient, effective and sustainable agricultural production systems.

Demand and Supply Projections for the Year 2025

Domestic demand for food grains including seed, feed, industrial use and wastage will increase annually by 2.5 per cent during 1999-2025. The demand for non-food grains and non-crop commodities will increase much faster than the growth in population. Therefore, the intensification of production and quality of non-food grains and non-crop commodities will be the future priorities of the nation. It is anticipated that in the year 2025, total food grains demand will reach 291 million tonnes comprising 109 million tonnes of rice, 91 million tonnes of wheat, 73 million tonnes of coarse grains and 18.0 million tonnes of pulses.

Future increases in the production of food and non-food agricultural commodities have to be essentially achieved through increases in productivity as the possibility of expansion in area and livestock population is minimal. To meet the domestic needs and export potential, on an average at the national level, the country should attain a per hectare yield of 2.4 tonnes for rice, 3.4 tonnes for wheat, 1.4 tonnes for coarse grains, 1.02 tonnes for pulses, 2.22 tonnes for food grains, 0.42 tonnes for oilseeds, 20.99 tonnes for vegetables and 23.18 tonnes for fruits by the year 2025. The productivity needs to be doubled for horticultural, livestock and fisheries sectors. The growth target for productivity needs to be fixed at about 1 per cent for cereal, 2 per cent for pulses, 2.5 per cent for edible oils, 3.5 per cent for vegetables, fruits, and milk, and 4 per cent for meat, eggs and fish. This calls for a serious effort on the part of agricultural scientists and extension agencies to improve production. More than half of the required growth in yields must be met from research efforts by developing appropriate technologies. IARI, being the national institute with its Regional Research Stations located in different agro-ecological zones of the country, should develop improved varieties of its mandate crops and associated production technologies to achieve the desired growth rates, especially in the case of pulses, cereals, oilseeds and cotton.

Growth in yield of food grains

Food	**Yield (t/ha)**		**CAGR (%)**
	2000-01	**2025**	
Rice	2.03	2.44	0.73
Wheat	2.59	3.36	1.05
Coarse cereals	1.07	1.40	1.09
Total cereals	1.94	2.43	0.91
Pulses	0.63	1.02	1.93
Food grains	1.74	2.22	0.97
Roots & tubers (dry equivalent)	4.24	5.40	0.97
Edible oils	0.23	0.42	2.44
Vegetables	11.08	20.99	2.59
Fruits	12.52	23.18	2.49
Sweeteners	6.51	8.67	1.15
Production (tonnes)			
Milk	109.1	205.4	2.56
Meat	7.15	15.1	3.04
Eggs	2.29	4.8	3.02
Fish	8.20	16.90	2.94

Policy Scenario

The states of Bihar, Orissa, Madhya Pradesh and Assam should target 6.9 per cent growth in rice yield per annum. For wheat, greater efforts are needed in Uttar Pradesh, Madhya Pradesh and Rajasthan with a target of annual yield growth of 2.9 per cent. For coarse cereals, major emphasis must be given to Rajasthan which occupies 20 per cent of all the coarse cereals area. To meet the demand for pulses, great emphasis is needed in almost all the states with particular focus on Madhya Pradesh, Maharashtra, Rajasthan, U.P., Orissa, Andhra Pradesh, Karnataka and Tamil Nadu which have a share of 74 per cent of total pulse area. The target growth in pulse yield from these states annually must be 6 per cent; otherwise, the nation will experience shortage of pulses for all times to come. In the case of oilseeds, greater emphasis is needed for all the low yield states which occupy

92 per cent of the area with special emphasis on Andhra Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and U.P. with a targeted yield increase of 4.7 per cent annually.

Cotton is emerging as a potential export commodity. It requires a greater yield improvement emphasis on 81 per cent of the cotton area in Maharashtra, Gujarat and Rajasthan. Concerted efforts are to be made in these states to increase the yield per hectare at a rate of more than 8 per cent per annum during the Eleventh Plan. Hybrid cotton has yet to make significant impact in the North. IARI should concentrate on hybrid cotton for northern states. It should also develop male sterile and restorer lines as well as other prebreeding materials to be shared by the country.

Vast untapped potential exists for all the commodities. Serious efforts are needed on the part of scientists, extensionists and development agencies to attain the targeted growth in yields in the low yield states (LYS) and transcending the yield levels in the high yield states (HYS). Most LYS have low level of irrigation. Thus, greater research emphasis is needed for dry land agriculture to attain self sufficiency.

Declining Total Factor Productivity Growth

The growth in total factor productivity (TFP) is observed to be declining, especially in the irrigated rice – wheat production system of the Indo-Gangetic Plains. Indiscriminate groundwater utilization and declining biodiversity have severely affected the TFP growth in the region. Unless new varieties of crops are evolved, yield breakthrough cannot be realized. Thus, the first priority for crop research ought to be breaking the current irrigated yield ceiling. Besides the depletion of ground water resources in this region, the region is also facing several ecological problems as a result of the existing production practices which call for a greater emphasis on production systems oriented research supported by extension, infrastructure, and education.

Credit and Risk Management

Access to financial resources enables the poor to exploit investment opportunities, reduces their vulnerability to shocks, and promotes economic growth. But lack of credit at reasonable rates is a persistent problem. The failure of the organized credit system in extending credit has led to excessive dependence on informal sources usually at exhorbitant interest rates, leading to excessive indebtedness and distress among farmers.

As farmers adopt new and untried technologies and increase input intensities, they also face larger risks. Farmers should be protected against such risks by appropriate measures. Insurance is one way of doing this, but only 4% of the farmers are currently covered by any crop insurance. The current insurance schemes are only against yield risks and do not cover price risks or any other risks.

Land Reforms

Land right issues can have a major impact on agricultural productivity and production. Land reforms that make tenancy legal and give well defined rights to tenants and to women are now more necessary than ever, not only to reduce distress but also to increase agricultural growth. Lack of recognized tenancy rights makes it difficult for *de facto* tenants to get credit from formal sources. Tenants without legal rights do not have proper incentive to develop the land and this partly explains the problem of yield gap. Similarly, women without property title are unable to get credit when the male member is away. There is also a need to record land titles properly where these are weak.

Natural Resources

Land, water, biodiversity and climate are the fundamental resources for agricultural development. The country is richly endowed with these resources and the variability of agro-ecological settings confers the advantage of supporting multitudes of crops and other vegetation and production of almost all crops within the country. Unfortunately, the resources are rapidly declining under various biotic and abiotic stresses. The loss of agro-biodiversity in the form of land races of all those crops which have particularly been improved by genetic manipulations in the last three decades is rather alarming. The list of endangered species is ever lengthening but reliable data on the genetic erosion at species and intro-species levels are not available. IARI should assist NBPGR and other concerned national agencies in developing methods, including the use of biotechnology, to quantify the ermplasm resource and other biodiversity losses.

It is estimated that about 170 million hectares of land area suffers from wind and water erosion, and about 10 million hectares are affected by salinity; 7 million hectares are under water logging and 3.5 million hectares constitute ravines. Due to intensive cropping and imbalanced fertilizer use, nutrient deficiencies are becoming common. In the rice-wheat cropping system, the most predominant cropping system in the North, it is estimated that 4 to 5 million tonnes of nutrients are depleted every year. India has one of the largest irrigation systems in the world, over a land area of 48 million hectares, but because of faulty management of water at the farm as well in water courses, often due to the lack of drainage systems, irrigation related problems of soil salinization, water logging, decline in ground water depth and quality are very common. Siltation of reservoirs is also shrinking our irrigation potential. Faulty and irrational use of agro-chemicals, specially fertilizers and pesticides, has further accentuated the degradation process of soil and water resources and has damaged our environment.

Sustainable management of resources is of great significance, especially under rainfed agriculture, which accounts for about 57 per cent of the total cultivated area in the country. Even if the total irrigation potential in the country is fully realized, about 50 per cent of the cultivable area will continue to be rainfed. General productivity in the rainfed areas is not only low but the overall production varies considerably from year to year due to associated vagaries of weather. Another feature of this area is that these are inhabited mostly by resource-poor farmers and crops grown by them are generally not so glamorous and these include often neglected crops like coarse cereals, oilseeds and pulses, although in some pockets, cotton and other cash crops are also important. Irrigated areas, which account for about 34 per cent of the total cultivated area, produce about 57 per cent of the total food requirements of the country, the remaining 43 per cent coming from the rainfed areas. The Green Revolution had generally bypassed the rainfed areas, causing socio-economic imbalance and inequity. Considering the vast share of rainfed regime in Indian agriculture, and keeping in mind the low productivity and high instability of such areas, future researches and development programmes must be geared to improve both productivity and sustainability of rainfed areas.

Effective utilization of irrigation facilities and efficient water use are essential for ensuring optimum utilization of water which is a critical input in agriculture. Therefore, systems that enhance the efficiency of water use need to be developed. Systems that ensure equitable distribution of irrigation water such as participatory irrigation management through democratically organized water users' associations, will be required to be put in place. In rainfed and unirrigated regions, water conservation methods are essential. There is also an urgent need for discipline on groundwater use to avoid the deepening agricultural crisis in dry land areas. Watershed management, rainwater harvesting, and groundwater recharge can help augment water availability in rainfed areas. Micro-irrigation is also important to improve water use efficiently.

Given its multi-disciplinary set up, including national centres such as the Water Technology Centre, the Nuclear Research Laboratory and Coordinated Projects on Water and Fertilizer Use, IARI is ideally suited to undertake inter-disciplinary holistic research and technology development on natural agricultural resources.

Agricultural Diversification and Export

Having achieved for security and accumulated sizeable buffer stock, the country must intensify its efforts to diversify its human and natural resources, to meet the challenging needs of the consumers and also to capture new opportunities presented by global market liberalization. The diversification is already in vogue as evident from increasing rates of growth of production of horticultural crops, livestock and fisheries. India has already emerged as the second largest producer of fruits and vegetables, and given the current trends of growth, it is expected that in the near future the country will emerge as the largest producer of horticultural commodities: the country already ranks first in production of cauliflower, second in onion and third in production of cabbage. Increased production of fruits has already pushed up the export of fresh fruits from Rs 188.75 crores in 1994-95 to Rs 811.42 crores by 2004-05. That of fresh vegetables has increased from Rs 79.14 crores in 1994-95 to Rs 813.63 crores in 2004-05. Rapid growth in the export of floricultural products, i.e., cut flowers, cut foliage plants, seeds and tubers and corms of various flowers, was observed resulting in an increase from Rs 30.84 crores in 1994-95 to Rs 205.25 crores in 2004-05. IARI is fully seized of this opportunity and is well on its way to strengthen its research and technology development in the fields of floriculture, vegetables and fruits. A great deal of scientific input is required to sustain this growth and to achieve a greater comparative advantage in the international market which is becoming highly competitive. Given the agro-ecological diversity of the country and the variety of flowers that it can grow, India must exploit this wealth. India has already become an important exporter of fresh grapes by producing high quality raisins and champagne.

Among the annual crops, recent increase in the production of *basmati* rice with the development and release of the first ever high yielding rice variety of scented rice Pusa Basmati 1 from this Institute, has added to our comparative advantage in the international market. The export of *basmati* rice increased from 4.42 lakh tonnes in the year 1994-95 to 11.26 lakh tonnes by the year 2004-05. Similarly the export of rice (other than *basmati*) increased from 4.49 lakh tonnes to 36.46 lakh tonnes in the year 2004-05. IARI has the main mandate to intensify its work on scented rice both through heterosis and conventional breeding methods and develop management practices for increasing the productivity of and profitability from scented rice.

A new trend in wheat export has emerged. Production of *durum* quality wheat is expanding fast in Punjab essentially for export purposes. There is a tremendous scope for increasing its production in other parts of the country, particularly in central India, under rainfed conditions. Concerted efforts would be needed to strengthen our breeding programme on *durum* wheat and improvement of *durum* quality, at IARI Regional Research Station, Indore.

There are bright prospects also of export of maize, including baby corn. Oil cake and oil meal are already the predominant exports of the country but there is a tremendous scope of expanding it by improving quality of these products by way of making them free of toxic substances such as glucosinolates and erucic acid, and *Brassica*. Likewise, overcoming the problem of polyunsaturated fatty acid (PUFA) content and lipoxygenase activity to enhance the use of soybean as food including flour fortification will be a priority area. Increased use of defatted soybean meal will greatly compensate the protein deficit being caused by the decreasing availability of pulses. IARI has already established a central quality laboratory which will further be strengthened to meet the various demands and to capture the new opportunities for value addition and export.

IARI must also take full advantage of its comprehensive crop breeding activities and the fast expanding seed production systems both in public and private sectors. Breeder seeds of almost all crops can be produced at IARI farms spread throughout the country and the Institute is assisting the seed industry in exploiting the varied agro-climatic conditions, availability of technical and scientific manpower and cheap labour. The current and proposed thrust on development of hybrid varieties of a large number of crops, including vegetables and production of their quality seeds, would provide a boost to the national seed industry. A large number of countries, especially in Africa and Asia, have already shown interest in custom production of seeds of selected hybrids for which appropriate mechanisms not only for production but also for quarantine and export are being worked out.

Besides the development of a large number of new varieties, as in the past, IARI will continue to come out with a good number of bioproducts, including *neem* products. In order to take full advantage of the new opportunities and scientific possibilities, IARI has already taken the initiative in undertaking socio-economic research to advise the Government to initiate necessary steps to develop and effectively implement a suitable *sui generic* system for sharing seed and other products in the international system. The Indian economy has faced upfront the opportunities and challenges posed by the WTO regime. The economy's growth and reveals that the country has benefited from the new regime. However, new and emerging challenges demand persistent efforts to understand, analyze, and find solutions to gain leverage from any such situations. The new challenges are meeting sanitary and pytosanitary requirement; improved packaging and processing; certification of the products for compliance with good management practice (GMP); and developing standards and grading system that is in consonance with the standards of the importing nations. Some of the technological limitations in harnessing the new opportunities include the lack of suitable varieties in some of the crops to meet the specific market demands, inefficient production, low productivity, poor quality of produce, lack of appropriate infrastructure facilities such as cool chain, etc. IARI can play a role in value addition and in efficient post-harvest management by researching on the energy aspects, including new and renewable sources of energy, to render the operations cost-effective.

International Agricultural Scenario and the Role of IARI

Between now and 2025, world population will increase by about 40 per cent, to a total of 8 billion people. In other words, every year, 90 million people will be added to the planet earth. Paradoxically, 94 per cent of this increase will occur in developing countries and a considerable part of it will be in the Sub-Saharan Africa and South Asia, which are already most food insecure. A considerable shift in food pattern is expected with the increasing consumption of livestock products, fruits and vegetables and other quality food items which will place further pressure on future food supplies and aggravate the food insecurity and malnutrition problems. If the current trend of food production continues, food insecurity, hunger and malnutrition will not be eliminated and more natural resources will be degraded. If a decisive action is not taken now, the number of chronically under-nourished persons at the global level will remain more or less the same in the next 10 to 15 years. Among the three main developing regions of the world, high concern and greater suffering will be in Sub-Saharan Africa; there will be very marginal relief in South Asia and there will be a substantial decrease in the number of chronically undernourished in East Asia (FAO, 1996).

The aggregate global food supply-demand picture in the next 25 years will, however, remain satisfactory. Cereal production in developing countries will increase from 850 million tonnes to over 1500 million tonnes during the next 25 years. This will result in decline in real world prices, and increase the demand for food which will exceed the supply by about 183 million tonnes. To meet this, the developing countries will have to double their cereal imports by 2020 reaching 183 million tonnes. Despite the overall ability of the capacity to produce enough food to meet the effective demand for food, the food security situation in South Asia and Sub-Saharan Africa will remain unsatisfactory. The per capita calorie intake in Sub-Saharan Africa will remain the lowest in the world, and stagnant. In South Asia, while the availability will grow, it will still considerably be lower than that of the rest of the developing world. It is paradoxical that despite the increasing trends of food production and declining world food prices, about 1/5th population of the developing world will remain chronically malnourished and most of them would concentrate in South Asia (mostly in India) and Sub-Saharan Africa. In order to improve the situation, it will be necessary to stop the declining trend in the rate of growth in crop yields by increasing investment in agricultural research and development. Additionally, increases in farmers' yields should be realized by fully exploiting the potential of the available technologies as there are serious technology transmission losses. Technology assessment and transfer systems should be geared to meet the location specific requirements, and the production inputs should be available to all farmers at the right time, in right quantity and at right place. Steps must be taken to increase the receiving and distribution capacity of resource poor farmers through providing credit and other institutional and infrastructural supports. IARI should undertake policy research to provide effective guidance to the policy makers on this aspect.

If the above suggested timely action is not taken, it is predicted that China's net cereals imports would increase from about 13-15 million tonnes to about 27-30 million tonnes by 2020, and in India, cereals import will be as high as 25 million tonnes, the two together will put high pressure on world prices. The IPFRI (1995) 2020 Vision study has shown that with appropriate investment, there will be a considerable reduction in the number of malnourished in the developing world, from 184 m in 1990 to 117 m in 2020, but this is possible through the congruence of three things:

- Increased income growth to generate effective demand for food;
- Expanded investment in agricultural research to boost productivity to meet the growing demand at reasonable prices; and
- Higher expenditure on health, education and nutrition to translate effective food demand into nutritional improvement.

Shrinking Global Natural Resources

The Vision as described above can be achieved only when degradation of the natural resources and misuse of inputs are halted. Conservative estimates show that 1/5th of the world agricultural land, permanent pastures and forest and woodland have been degraded over the last 50 years. Overgrazing, deforestation and inappropriate agricultural practices account for most of the damage. Poverty, population pressures, lack of access to credit, insecure property rights and inappropriate technology are the main causes of the degradation. A recent FAO study has shown that the availability of arable land per capita will decrease from the current level of 0.26 ha to 0.21 ha or to 0.17 ha or to 0.12 ha depending on which of the three scenarios of population projection of the United Nations materializes. Per capita water availability has declined drastically during the past 50 years and Asia is worst affected. It is painful to note that global studies are predicting that an estimated 15 per cent of the world's plant and animal species could become extinct by 2020. The loss of diversity in the fields of the farmers is rather rampant. It must be emphasized that if we continue to deplete these resources, we shall be depriving ourselves of the options and solutions towards future of agricultural growth and problems.

Global Debates

During the past few years, world leaders at various fora have examined the current global scenarios and future possible actions in the areas of environment and sustainability, human rights, gender issues, social equity, biodiversity, and food security. The famous 1992 Earth Summit (UNCED) held at Rio de Janeiro sensitized the world of the urgent need of conserving our natural resources while moving ahead on the path of progress and came out with an action plan contained in its document- Agenda 21. The Human Rights Conference in Vienna 1993, the Social Summit in Copenhagen 1995 and the World Women Conference in Beijing 1995 highlighted the need for granting human dignity to all the inhabitants of this planet and obviating social, economic and gender inequity widely prevalent in many societies and countries. The World Population Conference in Cairo, 1994, had sensitized the world of the need for checking the monstrous growth of human population which is eating away all the development efforts especially in the already highly populated countries of Asia. FAO's World Food Summit (November 1996), where world leaders had assembled, made a public commitment to action to eliminate hunger. FAO's Global Technical Conference on Plant Genetic Resources 1996, took stock of the state of plant genetic resources in the world and developed a Global Action Plan to conserve and judiciously utilize the world's plant genetic resources in a sustainable manner.

Three other major international developments have bearings on research priorities. The Global Biodiversity Convention 1993, declared that genetic resources occurring in the country are the sovereign property of the people of that country, which puts a high priority on evaluation and valuation of the genetic resources. The UN Framework Convention on Climate Change, 1994, calls for measures on the mitigation of climate change specially management of green house gases. The latest Intergovernmental Panel on Climate Change (IPCC), 2007 report has summarized the scenarios of climate change, impact, adaptation and vulnerability of cliamte change, and mitigation of green house gases. The World Trade Agreement, 1994, and the Trade Related Intellectual Property Rights (TRIPS) have profound implications for the choice of technologies with focus on those which will provide competitive advantages and eliminate non-tariff barriers.

Notwithstanding the profoundness of the goals, declarations and action plans of the above conferences and conventions, the determination shown by most developed countries to help alleviate the global problems had not been commensurate with the needs.

As shown by FAO, external assistance to agriculture of developing countries, has shrunk considerably during the past 6 to 7 years. The total external assistance has dropped from US $ 8.25 billion in 1989 to about US $ 4.7 billion in 1994. In other words, the developing countries must increase their degree of self-dependence in involvement in agricultural research.

SWOT of the Research System

Over the past few years, the Institute has overcome many weaknesses which have been mentioned in the Vision 2020 document. The Institute has encouraged the scientists to reduce the number of projects so that their efforts can be focused. At the same time, more number of scientists from related disciplines are involved in the projects for tackling complex research problems. The scientists have become more competitive and confident that they are attracting large fundings from external sources to support the on-going in-house projects. A large number of scientists have received training in many of the advanced laboratories in the world and developed expertise in frontier areas. The research contributions of many of the scientists have been identified for presentations in international conferences.

Due care is being given by the Institute to set priorities based on problems of national significance. The scientists of the Institute are participating in extension activities beyond the national capital region through outreach programme. The emphasis has now shifted to participatory mode. Research attention is being given to non-Green Revolution crops and management practices so as to usher in a second green revolution, with particular reference to rainfed areas. Emphasis is also being laid on socio-economic and policy aspects.

Strengths

The main strength of IARI is its long established leadership, uniqueness, and prestige. It has been the seat of several new scientific discoveries and technological innovations leading to agricultural transformation and setting new pace and direction in the field of agricultural research. This role of IARI has always to be maintained.

The strength of IARI lies in its comprehensive laboratory and farm facilities. More than one thousand and five hundred scientists and technical staff work at IARI and several of them are leaders of national and international reckoning in their fields. The eight Regional Research Stations and two off-season nurseries located in different agro-ecological regions of the country are a boon to the Institute in hastening its pace of varietal improvement through shuttle breeding and in allowing testing of its technologies in various zones, resulting in rapid and appropriate identification of promising technologies for the regions and the nation as a whole. Being a “Deemed University”, the Institute has a great resource of bright M.Sc. and Ph.D. students who greatly enrich its research capability and environment.

Another main strength of IARI is its library, which has been designated as the national agricultural library. The oldest, largest and most consulted agricultural library in the country, and perhaps one of the best in the world, the library makes continuous efforts to modernize itself both in terms of its electronic capabilities and physical facilities. It constitutes the national window of agricultural information with its comprehensive information networks, databases and national and international linkages.

IARI had a long tradition of international collaborations, thus infusing and assimilating in the national system the latest scientific developments from all over the world, and further sharing it with other institutions in the country.

The Institute has built large active collections of germplasm of most annual and fruit crops which are being used in various genetic improvement programmes. The National Pusa Insect Collection with more than 0.6 million species is one of the largest insect collections of Asia, providing identification services to farmers, agricultural field workers, and scientists. The Institute also has a repository for conservation and utilization of agriculturally important micro-organisms like blue green algae, a national nematode collection, a herbarium collection, viz., *Herbarium Cryptogamae Indiae Orientalis* (HCIO), and an Indian type culture collection (ITCC) for fungus.

The Institute campus houses several national interdisciplinary centres of research such as Nuclear Research Laboatory, Water Technology Centre, National Research Centre on Plant Biotechnology, National Centre for Integrated Pest Management (NCIPM), etc., which provide unique opportunities for harnessing synergistic interplays of several disciplines. These centres provide national leadership in their respective areas through advanced research and training.

Weaknesses

Due to the thrust on developing HYVs for bridging the food gap during the Green Revolution era, basic and strategic researches were somewhat neglected. Greater emphasis was placed on varietal development through conventional breeding, as also on cultural practices of the new varieties; so strategic and basic research on natural resources as well as on cytogenetics, biometrical genetics and evolutionary genetics suffered.

Although there is a revolution in the field of informatics and information management, until recently, the power of this development was greatly underestimated. Despite possessing one of the largest agricultural libraries in the world, IARI, so far, does not have access to several major data bases in the world. There is a general paucity of trained manpower in this field.

One of the main weaknesses of the existing promotional procedure has been the encouragement it gave to individuals rather than to the team.

The most important weakness in the recent years has been the inadequate and irrational allocation of operational grants to the Institute, resulting in erosion of contingency support to individual scientists and deterioration of our laboratory facilities and infrastructure. With the retirement of a large number of scientists, many faculty positions have become vacant. There is also not sufficient infusion of young blood in scientific cadre.

Another weakness has been the tendency to equate IARI with small centres having less number of scientists, which denies the Institute its rightful place among such institutions as IITs and IIMs.

The Institute has completed 100 years. The fact that many of the buildings located in the campus out lived their capacity many times over, upsets the work culture. Many of these buildings being beyond repairs, a lot of money is being wasted in repairs, calling for a one-time catch up grant to onstruct new buildings with modern facilities and infrastructure.

Opportunities

Several uncommon opportunities have emerged in the recent years which are being harnessed to strengthen the research output and overall technology development capability of the Institute. These opportunities include extraordinary advancements in the fields of molecular biology and biotechnology, remote sensing and geographic information system, simulation modeling, space technology and ecological and environmental sciences.

Another equally gratifying opportunity is provided by the revolution in the fields of informatics and information management. Telecommunication has immensely increased the access to global information which must be critically analysed and used for future planning and programming. This field is expanding very fast and India is one of the leading countries in the field of development of softwares and computers. The Institute has taken the advantage of these opportunities and established an informatics centre in the field of agriculture and allied disciplines, which is being upgraded to world class standard.

With the globalization of markets, there are excellent opportunities for coming up with new products of high demands in the world market. For this, our comparative advantages in terms of natural setting, agricultural biodiversity, trained and talented human resources, and relatively low-cost labour should be judiciously harnessed. The Institute has already established a window of commercialization by creating a Business Development Cell, now renamed, Institute Technology Management Cell, and taken the initiative to establish a new division to undertake research in agri-business management and develop pilot scale commercial modules. Bilateral cooperation is being encouraged to take advantage of successful experiences of cooperating countries as well as to establish linkages in research and technology development. The scientists are being encouraged to go for commercialization of their technologies.

There is an increasing appreciation of the need for forging appropriate linkages between public and private sectors. The government has taken several positive steps in this direction. Policy research on these aspects should be undertaken so that the government could be provided with appropriate guidance to make or buy decisions on technologies. For maintaining standard and quality, there is ample scope for the Institute to strengthen its services role for harmonizing the quality of products.

The CGIAR system is strengthening its partnership role with the national programmes. Likewise, several national agricultural research systems, both in developed and developing countries, are keen to establish collaboration with IARI. This is an excellent opportunity for the Institute to strengthen its partnership activity with CGIAR and other countries' institutes with clearly defined responsibilities and accountabilities. Further, there is an increasing appreciation of participatory research, including participatory plant breeding. IARI is taking a lead in this direction to develop systematic approaches for participatory breeding and other researches.

By having its centres in different agro-ecological regions of the country, IARI has the opportunity to have its technologies assessed and refined in the different settings of the country and thus serve truly as a national Institute. In this way, the Institute is able to address both generic and ecoregional problems in a synergistic manner.

For instance, the IARI regional stations working on wheat have provided national multilines of wheat, which have been responsible for checking rust epidemics in the country for the last several decades. The regional stations have also been given the mandate of popularizing the IARI technologies.

Threats

The Institute is facing increasing competition with SAUs and other ICAR institutes in terms of development of new varieties, production technologies, and training of M.Sc. and Ph.D. students.

This will necessitate the Institute to further intensify its efforts to maintain its flagship role both in research and human resources development.

The centres, housed at the campus, have been operating within the technical and administrative control of the Institute. Sometimes, due to one or the other reason, some of these centres work in an independent fashion which gives the apprehension whether these would try to constitute institutes within institute. This tendency should be curbed, and, at the same time, adequate functional autonomy should be provided to these centres.

With the increasing emphasis on commercialization and generation of resources for meeting a part of the budgetary needs of the Institute, there is a threat of reducing the support to research, education and extension activities – the core work of the Institute.

Imbalance in the basic, strategic, applied and adaptive research as well as poor research linkages with education and extension could disrupt the desired output. The Institute must not lose sight of its commitments to produce public goods and its major responsibilities towards the national food and nutritional security.

The above SWOT analysis of research has been kept in mind in developing the Institute's research priorities, and the various research programmes have been designed to operate in an inter-disciplinary manner through programme, mission and centre of excellence modes in the present document.

SWOT of the Post Graduate School

Strengths

The immediate strength of the post graduate teaching at IARI is the availability of a large number of highly trained and dedicated faculty members. The teaching programme of IARI also draws its strength through the infrastructural facilities which match the best in the world.

The courses and curricula of the Post Graduate School of IARI provide a solid background and all round development of the students. The quality of spectra of courses offered in various disciplines as well as thesis research problems assigned equip our students to comprehensively meet the challenges of sustainable agricultural growth. The research contributions of our students have been outstanding as reflected from the various awards and honours received by the students for their research work at the Institute. The Indian Council of Agricultural Research has identified Five divisions of the Institute, i.e., Agricultural Economics, Agricultural Extension, Biochemistry, Biotechnology and Plant Pathology as the lead Centres for Advanced Studies (CAS). These CASs are playing a very important role in imparting higher level training to the faculty and research scientists of the NARS. The remaining divisions are also on their way to be identified as Centres for Advanced Studies.

Weaknesses

Through the years, the Institute has grown from 5 divisions to 20 divisions. The Institute also saw a very fast growth in manpower during the 60's, which was essential for meeting the challenges of that time and change the country from a begging bowl state to food surplus country. During the mid 70's, a large number of scientists who were initially recruited as RAs and SRAs were inducted into the ARS which resulted in an overnight increase in the overall cadre strength of the Institute. This single event was the cause of non-recruitment of scientists for over twenty years, a gap which will have far-reaching implications in the overall development of agriculture in the country. This situation is improving since new scientists are joining the Institute through lateral entries/transfer/ ARS recruitment.

Most of the buildings of IARI were built during the middle of the century or before. These include hostels for students at IARI. Although some efforts have been made to improve these buildings, they are still far from the requirements of modern times. The strength of foreign students has been growing and a new hostel for international students is in the process of construction to meet their expectations. Extracurricular facilities, including appropriate sports and recreational facilities, are rather inadequate.

Opportunities

The Post Graduate School of IARI continues to spearhead the trained manpower development in agriculture in the country. So far, the Institute has been concentrating on developing the manpower to meet the national demands in all he major disciplines of agricultural sciences. Now that the country has developed a much stronger base for higher education in agriculture at the SAUs and deemed universities which are also playing an important role in human resource development, the IARI has a good opportunity of concentrating on the development of trained manpower in frontier areas of agricultural sciences through introduction of new courses and disciplines. The infrastructural facilities which have been developed at IARI during the recent years provide ideal conditions for advanced level trainings in the frontier areas like crop biotechnology, post-harvest technology, integrated soil and nutrient management, integrated pest management, environment management, water management, application of nuclear science in agricultural research, ecofriendly technologies, agricultural management, economic assessment, etc. In the years to come, highly trained manpower would be required for sustainable growth of agriculture in the country in these and other emerging areas, particularly connected with ecofriendly technologies. New 'breed' of human resources would be needed to deal with IPR and bio-safety issues and the uncommon opportunities arising from biotechnological and information system revolutions.

It is expected that the demand for highly trained manpower in the frontier areas, such as molecular biology, biotechnology, systems research, resource modeling, post-harvest handling and value addition, protected horticulture, and policy research, will rise sharply during the next 25 years as the country will have to not only produce more food but also improve its quality to capture the international markets and meet the demand of quality food and other agricultural products in the country. The future recruitments will be concentrating on highly trained manpower in the above mentioned areas.

The Institute has played only a minor role, so far, in human resource development for agricultural research, education and training in neighbouring and other developing countries. It has realized that the demand for highly trained manpower in the developing countries is growing at a fast rate. This is an excellent opportunity for the Institute to cater to the needs of HRD in various parts of the world through the development of M.Sc. and Ph.D. programmes in international agriculture. The course curricula have been modified to meet the demand of new areas of research.

Threats

At the time post graduate teaching started at IARI, it was the only institution imparting post graduate education in agricultural sciences in the country. Today, the country has 41 State Agricultural Universities, 1 Central Agricultural University and 4 Deemed Universities to cater to the needs of trained manpower. These offer a healthy competition to IARI.

Scientific Cadre Management

The management of the scientific cadre of the Institute requires an urgent action. At present, the major constraint of the Institute is the paucity of young workers. The Institute has an approved cadre strength of scientists of 608, and the scientists in position are 419 (as on 31.04.2007). This has put an enormous strain on the system. The situation warrants immediate corrective measures to achieve the required turnover of scientists at various levels and specific specializations.

The number of scientists to be recruited each year will be adjusted to 24 (1/30th of the total cadre, taking the average service period as 30 years) every year for all time to come. This will also help in effective maintenance of cadre strength and reducing the average age of the scientists.

The above strategy will be a great help in the management of the cadre strength of scientists of the Institute and will greatly help us in performing our role for research in frontier areas and development of highly trained manpower for the country.

SWOT of the Extension and Technology Transfer System

Although India has one of the largest extension systems in the world (about 1.25 lakhs extension workers), the system has been sluggish as evidenced by wide technology transfer gaps. The famous extension programmes like Community Development Programme, National Extension Service, Intensive Agricultural Development Programme, Intensive Agricultural Area Programme, and High Yielding Varieties Pogramme have played their roles and vanished. The National Agricultural Extension Programme (NAEP), which operated the Training and Visit system (T&V), is giving way to Participatory Extension. IARI has played, as mentioned earlier, a pioneering role also in extension and technology transfer concepts and methodologies, but there have been gaps in their operationalization.

Strengths

The Institute has a large network of research system, including its RRSs, which provides training and development support to the extension systems like KVKs, State Development Departments, Farmers' Training Centres (FTCs) and several farm advisory centres established by public and private sectors. Being based on the Land Grant University system, IARI has institutionalized the research-extension-farmers linkage and has developed several technology transfer modules approaches which have been widely adopted. The Centre for Agricultural Technology Assessment and Transfer (CATAT) headed by the Joint Director (Extension) draws its personnel from extension as well as research divisions as production unit members.

Weaknesses

Effectiveness of the system is said to be limited to some resource rich pockets. A lot of the Institute's extension work was done on an *ad hoc* basis at initial stage. The extension activities are slowly turning into project mode to give an impact. The RRSs have been involved in popularizing IARI technologies in different agroclimatic zones of the country. The private sector and NGOs have hardly been involved. Our linkage with extension development agencies in the different states has been rather poor. Moreover our emphasis in transfer of technology programme has been on selected crops and agro-based enterprises which can subsequently increase income and employment opportunity has not been exploited.

Another weakness of our extension system is the inadequate involvement of farm women in our farm development programmes. Although they are ‘half the world’, our extension system is unable to reach them for various socio-cultural reasons. While most of the farm activities involving drudgery are performed by them, very little effort is made to make their job easier on the field. Decision making role of women in the farm and home development was underplayed. The role of women in agriculture cannot be ignored as they are an important segment of our farming population. No real change in farming situation can be introduced unless the change is brought about in the knowledge, attitude and skills of the farm women. The potential of farm women being developed as successful entrepreneurs has hardly been exploited.

Opportunities

In spite of the above-mentioned weaknesses, there are several opportunities which can be exploited to improve our extension system.

- There is plenty of room for extensionists to bridge the technology transfer gap and improve the efficiency of various resources
- We have a very strong research base. The system has effectively served us and a good number of useful technologies are awaiting transfer
- Our reach to the farming population is extensive, and being in the capital city, our access to the mass media, T.V., radio as well as to the international community is the best in the country
- Our farmers are very receptive to new ideas. They have already tasted success with the new high yielding varieties of crops. Credibility of the Institute as well as of the scientists is high and so are farmers’ expectations
- The Government at the centre has shown a political will to strengthen extension services for the farmers. There is a favourable policy set up in the Ministry of Agriculture and the ICAR to strike close linkages between research and extension. The recent initiative of the ICAR on NAIP is yet another opportunity
- In the new economic environment of the country, the industry is willing to cooperate with research in developing exportable technologies and products and increase the demand for them in the world market. IARI has unique opportunities of sourcing and sharing technologies offshore, including those of the CGIAR institutes, and several bilateral arrangements. Protected cultivation technologies developed by the Institute can greatly help in development of peri-urban agriculture

Threats

If we fail to recognize the needs of different groups of farmers, we would be developing poor technologies, which will be knocked down by the farmers.

An eminent threat has been that despite IARI varieties and technologies being far superior to varieties/technologies developed by the SAUs, the state system has not only ignored the superior varieties and technologies of IARI but has often tried to run them down. In the absence of appropriate mechanisms of protecting proprietary rights, there is a threat of misappropriation of credit for developing new varieties and technologies. Similarly threat is perceived from MNCs who are interested to play a bigger role in agricultural technology generation and its transfer to millions of the farmers.

7. PERSPECTIVE

School of Crop Improvement

Conversion of the fatigued productivity of rice, wheat, oilseeds, pulses and vegetables into a vibrant and productive phase through hybrid technologies with assured hybrid seed production machinery: IARI's vision is to take up the enormous task of perfecting the hybrid wheat and rice technologies on priority. The public-bred hybrids have reached the farmers of India only in sorghum, maize and pearl millet in crops and a few vegetables. While heterosis has been identified in wheat and rice, the two most land occupying crops of India, there has been limited success in rice and no success in wheat over the last decade. 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. At the same time, the other mandated crops like oilseeds and pulses together will get a boost with mustard and soybean hybrid technologies. The vegetable seed sector has been dominated by the private seed producers with the technologies from Europe. While the hybrids may not be the best for Indian conditions, these are the only available materials for farmers to adopt. This is where scope exists for targeting area specific hybrids in vegetables by IARI with strong linkage for product development with the private sector for commercialization of the hybrids.

Enhancement of crop productivity under medium and medium-low input conditions through cumulative component breeding: Through quantitative improvement of productivity of crop plants, especially, the self pollinating crops and vegetables, by targeting upwards of 20% yield increment, IARI plans to provide the farming community a means to increase the currently stagnating yields. This is planned by molecular breeding for simply inherited traits and an accumulative approach of "cumulative quantitative breeding or CQB" for quantitative traits where the methodology would be stack and pyramid, the quantitative trait loci (QTLs) for component traits associated with yield. 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.

Targeted value addition: Targeted value addition to varieties of crops, vegetables and fruits 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, e.g. β-carotene enrichment in rice, and mustard oil or specialty starch enrichment in maize for industrial application. This approach will have to be adopted for making farming an 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, the crops would be released with a purpose of suitability to replace the 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.

Prebreeding in crops and vegetables on priority to build a national reservoir of gentic stocks and 'heterotic pools' available to feed the different regional breeding programmes*:* With the increasing levels of IPR regime and restricted material transfer, IARI needs to take up the leadership in providing advanced, initial and fixed genetic materials to the Indian crop breeding programmes. This can be achieved through targeted prebreeding activities by incorporating diverse species and genotypes, including underexploited local land races, to mobilize genes of interest by adopting distant hybridization with cytogenetic and molecular cytogenetic tool usage to enable precise transfer of required regions in the suitable genetic background stocks. New plant type character components can be built in for MAS and CQB as base material. Allele-mining would be another activity in this line of vision to pick up allelic variation for their direct usability potential in the breeding programmes. The prebreeding acivity will also be of high relevance when it comes to identifying heterotic pools of genetic stocks of maize, pearl millet, soybean, rice, wheat and vegetables such as cole-crops, brinjal, tomato, cucumber, etc.

Targeting breeding programmes integrated with RCTs*:* Targeting breeding programmes specifically for protected agri-horticulture and organic agriculture integrated with resource conservation technologies (RCTs) will be another major vision for the next two decades such that currently existing position of complete lack of varieties in high-priority vegetables and fruits for protected agriculture and organic agriculture. At the moment, the protected agriculture investments made by farmers are utilizing varieties bred outside India at high seed costs for commercial purposes although these are not best suited for Indian tropical ambient environment supported protection system. Therefore, it is urgent to divide the next twenty years into phases focused at standardizing and characterizing the trait combinations best suited for protected agriculture requirements and reduced sensitivity levels to photo-thermal conditions followed by development of genetic stocks to source-out the required genes in good combinations exclusive for protected agriculture. For organic agriculture, the breeding materials for selection have to be managed under organic agriculture in lands which are maintained at internationally approved standards of organic agriculture conditions. This may mean identifying nutrient medium-genotype combinations in different crops characterized with maximized and yet synchronized source-sink supply-demand levels for generating photosynthates accompanied by efficient translocation. Varieties developed for organic agriculture need to be supported with an organic seed production system also. This will be a challenging roposition for development of organic varieties under RCTs and organic seed production.

School of Resource Management

Development of efficient input management system: Agricultural production system is an integrated and interactive effect of soil-water-fertilizer-climate continuum, superimposed with crop and, therefore, scientific management of the complex system is crucial for enhancing crop productivity. Among the various inputs, land, water and fertilizers (nutrients) are the three key inputs which can be "managed" through human interventions to enhance crop productivity to minimize injudicious use of these inputs. For any crop cultivar to achieve its genetic yield potential, efficient management of these inputs together with synergistic interaction with other appropriate production factors is most critical to keep the green revolution "evergreen" without degradation of the natural resource base. The per capita availability of water and land is reducing day by day and the intensive agricultural activities are mining nutrients from the soil. The adverse impact of climate change is aggravating the situation further by bringing down the agricultural production as has been happening to wheat production in the last couple of years.

Enabling crop diversification with high-value specialty crops and adoption of integrated farming systems with emphasis on resource conserving technologies for improving productivity on a sustainable basis: Technology development for ecologically-handicapped, resource starved and fragile environments requires concerted efforts. Conservation and recycling of rainwater, adoption of alternate land use systems and integrated input management on watershed basis assume high priority in these areas. System-based approach to link all the factors of production in a rational manner and the development of eco-friendly, effective and efficient technologies is going to be the major determinant of our future progress of agriculture. The other areas which demand immediate focus are organic farming, protected agriculture, precision farming, bioenergy, fertigation and other site specific input management practices in specific crops under specified conditions. Currently, only non-organically supported high yielding varieties are being fitted into organic cropping practices only on the basis of economy and not on the basis of resource use efficiency.

Management of land and water resources - the centre of the growth process: The future increase in per hectare yield will depend on the efficient management practices, enhanced cropping intensity, crop diversification and sustained and efficient utilization of natural resources. The problems of future growth will be more complex seeking a comprehensive system based solution. The conventional technologies have still a lot to offer but new state of the art options such as remote sensing, use of GIS, informatics, precision farming, modeling, automation and communication technologies would be required for sustained growth. Automation has emerged as an important area for R&D. Research work on process development and assessment related to sensors and satellites aided precision farming intelligence system in harvesting would be required. Problem areas of the country such as dry land, hilly areas and coastal areas, and a large group of small farmers would require location specific machines. The analysis of climate change and its effect on quality and quantity of natural resources and remedial actions are needed to be taken seriously.

School of Crop Protection

The challenge facing Indian agriculture is to sustain agricultural production and increase productivity without causing ecological damage. An important aspect of sustainable agriculture is the substitution of hazardous agrochemicals with locally available biological inputs and traditional knowledge. Over the years, production of food grains in India has risen steadily partly through the introduction of high-yielding varieties together with appropriate agronomic and plant protection practices. Crop losses due to insects, diseases, and weeds have increased on a world basis from 35 per cent in 1965 to over 50 per cent in 2004 despite the intensification of pest control. The approach of killing pest organisms with toxic chemicals has been the prevailing pest control strategy for over 50 years. The four major problems encountered with conventional pesticides are toxic residues, pest resistance, secondary pests, and pest resurgence. The latter three are fundamental consequences of reliance on interventions that are both disruptive and of diminishing value because of countermoves of the ecological system. Therefore, a mere switch to nontoxic pesticides, such as microbial, transgenic or inundative releases of natural enemies, although helpful in reducing environmental contamination and safety problems, does not truly address the ecologically based weakness of the conventional pest control approach. However, safety problems and ecological disruptions have renewed focus on development of effective, safe, and economically acceptable alternatives. Intensification of production systems for higher sustainable yields has made them more vulnerable to pest damage and the potential losses are higher than under subsistence farming systems. This will require improved plant protection technology and better educated and trained technicians and farmers.

Growing public concern over potential health hazards of synthetic pesticides as well as steep increase in cost of cultivation has led to the exploration of eco-friendly integrated pest management (IPM) tactics aiming at suppressing the pest species by combining more than one method of pest control in a harmonious way with least emphasis on the use of pesticides. It is, in fact, the right combination of cultural, biological and chemical measures for managing diseases, pests and weeds. The primary objective in pest management is not to entirely eliminate a pest organism but to bring it into acceptable levels as interventions that interfere with the restoration of balance are counterproductive.

The major trend in the past has been to replace traditional pesticides with less hazardous chemicals or nontoxic biological products and use of molecular biology and biotechnology. Technological advances in molecular genetics and genetic engineering have resulted in materials that are less toxic and non-hazardous to humans and the environment. These products include genetically engineered plants for stronger resistance to pests, plants, and natural enemies with high tolerance to pesticides. These powerful agents need to be integrated as key parts of sustainable pest management systems.

Among the various alternatives to chemical control, the use of biopesticides is one of the important means for checking pest problems in almost all agro-ecological situations. The agents employed as biopesticides include parasites, predators and disease causing fungi, nematodes, bacteria and viruses, which are the natural enemies of pests. They complement and supplement other methods of pest control. These bio-agents can be conserved, preserved and multiplied under laboratory condition for field release. Once these bio-agents are introduced in the field, they are capable of bringing down the targeted pest population below the economic threshold level (ETL). There is a need to consider natural systems when developing strategies for novel traits such as a gene for producing *Bacillus thuringiensis* (Bt) toxin. More concerted efforts are required towards breeding and engineering plants with traits such as tissue-specific and damage-induced chemical defenses that work in harmony with natural systems.

Genetic engineering and other such technologies are powerful tools of great value in pest management. But, if their deployment is to be sustainable, they must be used in conjunction with increased appreciation of multitrophic interactions. There is, however, a need to develop more cost effective techniques for the mass production, storage, transport and application of biopesticides for sustainable crop protection.

Chemical intervention has a valuable role in ecology based pest management strategies, but they should be viewed as backups rather than as primary lines of defense.

Plants have long been known to possess toxins and other chemicals that serve to discourage herbivore feeding. They play an active role in their defense against insect activities, and their defense responses often are customized for certain interactive, multitrophic situations. The host–plant resistance directed toward breeding plants resistant to pest attack needs to be developed around such knowledge. Some plants respond to insect herbivory by synthesizing defence chemicals such as plant secondary metabolites or releasing volatile chemical cues that attract predators and parasitoids that, in turn, attack the herbivores. This effect enables the natural enemy to distinguish infested plants from uninfested neighbors. There is a rapidly expanding body of knowledge about plant's interaction with herbivores and signaling mechanism that enables injured plants to produce toxins that are directed specifically toward herbivores. Such interactions induce a systemic production of protease inhibitors expressed throughout the plant that interferes with the digestion process and feeding behavior of insects.

A wide array of natural products identified from plants, insects, and microorganisms are being used as such or synthesized and formulated for use as biopesticides. Semio-chemicals such as sex pheromones and natural enemy attractants can be used as baits and lures to disrupt pest activity and promote natural enemy presence. There is thus a need to develop novel approaches based on combinatorial chemistry, as well as biochemical, biotechnological and nanotechnological advances to achieve precise pest control package and develop novel formulations and delivery systems for potential synthetic, botanical and microbial products.

From environment and human safety point of view, studies must be conducted to generate data on safety evaluation, pesticide interaction with the agro-ecosystem, as well as monitoring of pesticide residues in agricultural produce while addressing safety and quality aspects of agrochemicals and agricultural produce to facilitate export/import of products complying with national/international sanitary and phyto-sanitary requirements.

It is expected that in the foreseeable future, a knowledge-based economy will provide the platform to sustain a rapid rate of economic growth to achieve the objectives of Vision 2025. It will strengthen our capability to innovate, adapt and create indigenous technology, and develop new products, varieties and protection strategies for providing strong foundation for sustainable agricultural growth. The Institute shall remain committed to its core competencies within chemical, biochemical and biotechnological crop protection to coexist in the future. The strategy focusing on various crop protection issues would, however, require close cooperation and collaboration with industry.

School of Basic Sciences

Reorientation and consolidation of efforts from the existing compartmentalised disciplinary mode commodity-based research to problem-solving inter-disciplinary eco-regional approaches and knowledge generation: Realising the significance of close inter-linkages with physical sciences, biological sciences, earth and atmospheric sciences, etc, IARI visualizes harnessing the spectacular advancements in the frontier areas of research in plant biochemistry and plant biology making use of modern tools of biochemistry, molecular biology and physical sciences. The School has a vision to conduct integrated need-based basic, strategic, and applied research on physiology, molecular biochemistry, molecular markers aided biotechnology and plant nutrition aspects, related to the current problems in sustaining agricultural productivity in harmony with environment; generate knowledge, develop new research philosophies, concepts, methodologies, materials and technologies related to the parameters, processes, genes or molecular markers, for conferring greater tolerance to abiotic stresses, for alleviating the damages caused by drought, cold and high temperature, and for improving production and productivity of crops; promote, develop and use physical instrumentation, isotopic tools and modeling to achieve greater understanding of the agricultural production systems, the resources, the environment, and their sustainability, to develop capability to reduce risks from/ to the environment, and develop multi-disciplinary centre of excellence with modern instrumentation and foster system research, consciously updating instrumental facilities.

Basic studies on reproductive biology and quality improvement for designing specific protein enriched crop: The studies will be helpful in overcoming hindrances to improve the productivity. Efforts will be made to identify genes and molecular mechanisms controlling the flowering time and assisting the breeders in exploiting the genes for enhancing the capacity, regulation of photosynthesis and partitioning of assimilates to sink for further increasing the total biomass and crop yield. Analyzing the genetic and molecular control of quantity and quality of protein, fats and carbohydrates will be important aspects to develop designer crops in integration with knowledge in the regulation of pre-enzymes. Manipulation of plant metabolism is essential to increase efficiency of enzymatic reactions through the molecular modeling of proteins and enzymes.

Generation of information on the mechanism of controlling nutrient uptake and nutrient use mechanisms in crops under normal and adverse situations: Wherever feasible and possible, efforts will be made to develop isotopic signature markers as diagnostic tools for photosynthesis, water use efficiency and nutrient assimilation characteristics. Genetic engineering tools and integrated use of physical methods, such as *gamma* irradiation, microwave and magnetic field, etc., will also be applied to reduce the post-harvest storage damaged by insects and pests. Magnitude of the increasing carbon dioxide in different agro-climatic regions will be evaluated and its impact on agricultural resources and productivity will be assessed with respect to vulnerability and adaptability, particularly to crop responses and other natural resources. Physiology based conceptual crop models can be developed from the data generated from controlled environment chamber experiments.

Use of nanobiotechnology in real time to understand response to nutrients, water, and agricultural chemicals in an integrated approach for facilitating resource conservation technologies with high input use efficiency: The area is also available to be used in understanding the host-pathogen/pest interaction in successful and completely inhibited infection/infestation. Wherever possible, the nanobiotechnologies would be integrated to maximize translocation during seed formation, facilitate fertilization, and provide signaling tools during crop growth for input management through “advanced mimic expression signaling” or “AMES” of a particular nutrient deficiency, accumulation of a particular pathotoxin, injury by a pest, production of a viral protein, etc., much before the damage assumes an economic proportion.

School of Social Sciences

Facing up to the challenges of increasing competitiveness in trade and growing demand for value added and quality products coupled with stringent food safety requirements in an integrated and holistic approach: The current international policy environment of liberalization and integration of world markets, new intellectual property rights regime, increasing competitiveness in trade and growing demand for value added and quality products coupled with stringent food safety requirements are bound to pose further challenges for researchers and policy makers in near future. To cope with these challenges, Indian agriculture needs to transcend the limits of primary production objective and encompass the broader objectives of market orientation, effective post-harvest handling along with value addition, enhanced competitiveness and food safety regulations and judicious natural resource management. The entire supply chain management needs to be addressed in research, education and extension programmes of the Institute. The Social Science vision, therefore, identifies an integrated and holistic approach of agricultural and rural development relying on market oriented agricultural economy with effective research—extension linkages, natural resource management policies, strengthened capacities of facilitating institutions, enhanced use of information and communication systems and integration of gender perspectives.

India needs to sustain an agricultural growth rate of 4.0 to 4.5 per cent in order to reduce food insecurity and poverty and also to harness the rising export opportunities: There is enormous scope for accelerating growth in agriculture through supply factors, which must be improved and readjusted suitably in a sustained manner. Effective interventions, infrastructure development, strengthening of rural institutions and enabling policy environment can lead to diversification and market orientation. Such a process will, in turn, lead to improved farm income, greater employment security, regional and sectoral equity, poverty reduction and efficient use of natural resources.

Develop mechanisms for favorable policy and regulatory environment aimed at promoting agriculture by forging effective partnerships between public and private sectors, synergy between research and outreach activities, and integration between processing and marketing activities: It is expected that as a result of changing food habits and preferences, increasing urbanization and higher per capita income, the demand for fruits, vegetables, edible oils, livestock products and other processed and ready to serve products will grow rapidly. In recent years, corporate investment in the farming sector has increased substantially resulting in the creation of quality retail chains which needs to be further strengthened through an enabling policy environment.

Develop suitable extension models for effective management to harness knowledge and information from various sources for better farming and improved livelihood and to achieve synergy among farmers, agricultural scientists, extensionists and policy makers: The emerging agricultural scenario would be knowledge intensive requiring greater congruence among productivity, sustainability, profitability and equity for sustainable agricultural development. The modern communication and information technologies have to be effectively utilized for revitalizing extension systems and knowledge management in India. Effective models in the form of village knowledge centres, expert systems for different crops, e-learning, and weather forecasting and resource databank need to be developed.

Stimulation and support of micro-enterprises with greater focus on rural entrepreneurship development through agribusiness extension system with sound farmer-advisory services based on demand driven technologies: Inter-sectoral micro-level planning with the help of *Panchayati Raj* institutions for rural development involving different sectors like forestry, environment, irrigation, agro-industry, health and education will become a necessity for synergising their collective output. Women empowerment through capacity building programmes will also have be developed to ensure livelihood security.

Human Resource Development

Provision of need-based basic and advanced courses and rigorous hands-on practical experience aimed to produce updated skilled scientific workforce for the new millennium: The forward looking academic environment at the Institute attracts the most talented students available for agricultural sciences in the country. Thus, an IARI alumnus is already groomed to be a competent teacher, researcher, extension officer or manager bearing a hallmark of excellence. A vibrant academic atmosphere will be maintained through activities such as prestigious lecture series including Shri Lal Bahadur Shastri Memorial Lecture, and other conferences, faculty seminars, presentations of significant researches, debates, etc. Sports, yoga, cultural and other extra-curricular activities will also be encouraged for overall personality development. The presence of students from all parts of India and abroad, secular culture, as well as faculty with vast national and international exposure will broaden the outlook of IARI students in a national spirit and perspective. The academic system encourages continuous updating of the post-graduate syllabi to maintain their high standards. New courses and training programmes for developing the needed trained manpower will be launched for not only research teaching and extension programmes of the public funded organisations, but also for meeting the requirements of the fast expanding private industry, international trade, and entrepreneurship.

New breed of trained manpower: The new breed of trained manpower will be prepared for meeting the toughest challenges ahead, including those related to research management in the fast changing national and international arena. For this, IARI will focus on developing a highly trained band of scientists in the area of hard-core biotechnology, nanosciences, information technologies, space science and related fields. The country will also need highly trained personnel in large numbers for areas like crop improvement, protection, production, resource management and social sciences. The Institute proposes to develop a band of scientists trained in international agriculture who must also be familiar with IPR/PBR/SPS/PVP regimes, various international conventions and their implications so that they become a major resource for international agricultural development through M.Sc. and Ph.D. programmes, and through post-doctoral programmes.

Developing the Post Graduate School as an important international centre for human resource development: The development of Post Graduate School as an important international centre for human resource development is visualized by providing highly trained faculty, well equipped and functional laboratories and efficiently managed field experimentation facilities of international standard. Exporting higher education in fundamental and applied agricultural sciences to other parts of the world will be one of the goals of IARI.

Development of centres of advanced studies: The scope of training at dynamic levels of interaction among faculty and students on one hand, and encouraged mechanism of building a network of training human resource in specialty areas of a discipline on the other, is enabled by the concept of centres of advanced studies of the ICAR. By upgrading the disciplines with advanced academic features, the Institute proposes to facilitate the transformation of all its teaching disciplines into centres of advanced studies.

8. ISSUES

The main issues of agricultural growth and development in India which seek scientific research and technological redressal, for which IARI must be sensitive and responsive, are:

- Food self-sufficiency versus food self-reliance
- Low productivity and declining rate of growth of factor productivity
- Farmers' distress
- Fatigue in the rice-wheat system
- Low and unstable yields in rainfed areas
- Drying up of basic research
- Widening and increasing ecological and environmental insecurity
- Shift in poverty mix and food basket due to increasing urbanization
- Inadequate and poor human resource
- Rapid loss of agro-biodiversity
- Decline in access to technologies
- Poor linkages
- Dwindling investment in agricultural research and technology development

In India, agriculture will continue to be the backbone of economic, employment and food securities and for the overall national progress. Sustainable agricultural growth in turn is dependent on the availability and use of modern technologies, and research would continue to be the engine of science-led growth. The Green Revolution witnessed in the past four decades had granted the much needed food security and overall agricultural and national development in the country, albeit causing certain environmentally and ecologically adverse effects. As during the Green Revolution era, the path of technology-led growth is the only way open for India, but the future path of growth must be different to ensure the congruence among enhanced productivity, sustainability, profitability and equity. The widespread hunger and malnutrition in the country is rooted in the widespread poverty. Research and technology development must focus on alleviating poverty and unsustainability to ensure comprehensive food security. Such a path can lead to Ever Green Revolution which must be equally effective, if not more, in terms of increasing productivity but would differ from the past one in being environmentally benign (doubly green) and socio-economically equitable. In other words, the future agricultural growth should be spatially and economically dispersed so that the rainfed drylands, marginal lands, resource poor farmers and the other unreached could be reached. An agriculture-based development strategy relying on increase in the productivity of small holders, the availability of more and possibly less expensive food and the provision of employment opportunities in the farm and rural non-farm sector is intrinsically poverty reducing and food security promoting. The strategy, however, should not be confused with a "food first" or a food self-sufficiency strategy that quests to increase food production at all costs and at the exclusion of other promising options. Such a strategy is not necessarily desirable or helpful in alleviating food insecurity and may furthermore be unsustainable in agroecological and/ or economic terms as it may result in serious resource degradation and/or misallocation of resources.

In the articulation of the points raised in the above sections and in the preceding chapter on the perspectives, IARI's strategy would be to mobilize its human resources, infrastructure, scientific base and knowledge to ensure enhanced and sustainable growth of agriculture in India by increasing yield potential and efficiency; diversification of agricultural economy, increasing income growth for promoting food self-reliance; strengthening basic research, technology-led promotion of equity; system approach for synergy; differentiating natural resources, agricultural potentials and technological opportunities; integrated management of biotic and abiotic stresses; integrated management of natural resources; managing rice-wheat system; post-harvest handling and value addition; socio-economic and policy research; participatory technology assessment and transfer; and human resource development.

9. PROGRAMMES AND PROJECTS ON A TIME SCALE AND FUND REQUIREMENTS

IARI has a century long track record of outstanding research and technology development. It has also been a pioneer in post-graduate education as well as in extension education and technology transfer for the last nearly four decades. The Institute had all along kept its research, education and, extension programmes in a dynamic phase to be able to respond to the needs of the country. As mentioned earlier, while generally, the research and technology outputs have been quite effective, there are, at times, cases of inefficiency and under-exploitation of the Institute's resources.

Indian agriculture, as the world agriculture, is currently experiencing several unprecedented pressures and prospects. At this critical juncture, it is absolutely necessary to prioritize and programme the activities of the Institute in such a way that they meet the challenges and harness the opportunities most ably and efficiently. Some organizational adjustments would be needed to improve the efficiency of the Institute in achieving its mission. While several of the core programmes and activities of the past will continue, quite a few must be dropped and several new programmes must be added in a synergistic manner.

The following current trends and developments at the national and international levels are taken as the basis for identifying research:

- Prevalence of malnutrition, low and unstable yields of most commodities, and wide gaps in technology transfer and adoption.
- Deceleration in the rate of growth of crop productivity, shrinkage of land and water resources, and increasing demand for more and better quality food.
- Fast degradation of natural resources, particularly soil, water and biodiversity, leading to unsustainability.
- Globalisation of markets, increasing significance of private sector, emphasis on intellectual property rights and increasing competition in trade.
- Increasing economic inequality and sociological drifts, including gender issues.

There exists an unholy alliance among poverty, food insecurity and environmental degradation. IARI's priority and strategy should be to break this alliance by initiating appropriate research, education, and extension programmes. Genetic amelioration and conservation for the development of high yielding and superior quality varieties resistant/tolerant to biotic and abiotic stresses, generation of techniques for increasing the efficiency of the use of inputs and natural resources, especially IPM and lPNS, creation of technologies for preventing post-harvest losses and adding value to agricultural products, and formulation of appropriate policies for food self-sufficiency, sustainability, trade, and equity through policy research will be the main weapons for breaking this unholy alliance.

Keeping in mind the national development priorities, international research and technology development trends, recommendations of the Research Advisory Committee of IARI, the report of the IARI Quinquennial Review Team (1990-2000), and consultations with the scientific staff and peers, the following programmes and sub-programme areas covering research, extension and education have been identified:

School of Crop Improvement

Heterosis breeding and development of hybrid seed production machinery

Justification

The public-bred hybrids have reached the farmers of India only in sorghum, maize and pearl millet. The varieties of Green Revolution seem to have reached their maximum potential and stagnating production in these crops is resulting in reduced buffer stocks. The only means to realize this vision is on a public-private partnership mode. The vegetable seed sector has been dominated by the private seed producers with the technologies from Europe. While the hybrids may not be the best for Indian conditions, these are the only available materials for farmers to adopt. This is where is the scope for targeting with area specific hybrids in vegetables by IARI with strong linkage for product development with the private sector for commercialization of the hybrids. With the awareness level and demand from farmers on the rise, it is time IARI took to this potential technology on top priority so that the fatigue of Green Revolution is overcome, pulse and oilseed productivity is increased and seed replacement which is abysmally low with less than 10% in major crops like wheat and rice can be revved up to more than 50% with the involvement of marketing and production of hybrids by private sector.

Objectives

- Breeding hybrid rice, wheat, *bajra*, maize, cotton, rapeseed & mustard, pigeonpea, vegetables, fruits and flowers
- Identification of the apomixes among crops and their exploitation for commercial viability
- Diversification of CMS and fertility restoration lines/genes
- Development of heterotic pools through genetic and molecular approaches (Crop-wise)
- Standardization of hybrid seed production technology of each crop

Prebreeding activities and development of basic strategies for genetic reconstruction

Justification

Indian crop breeding programmes in major cereals like wheat, rice and maize drew from the CGIAR system-provided genetic materials or nurseries to select for genes expressing best under Indian agroecologies. With increasing levels of IPR regime and restricted material transfer and even exhausted resource from these centres to an extent, IARI needs to take up the leadership in providing advanced, initial and fixed genetic materials to the Indian crop breeding programmes. This can be achieved through targeted prebreeding activities by incorporating diverse species and genotypes including underexploited local land races to mobilize genes of interest by adopting distant hybridization with cytogenetic and molecular cytogenetic tool usage to enable precise transfer to required regions in the suitable genetic background stocks.

Objectives

- To introgress through inter-specific and intrageneric hybridization for desirable traits in good agronomic backgrounds
- To genetically enhance *basmati* rice with resistance to BPH and blights
- To improve plant architecture design with new plant type for increased productivity
- To standardize, through modern molecular cytogenetic tools, the introgression of specific genomic segments from related/wild species

Maintenance breeding of parental lines of hybrids, inbreds and varieties of crops, vegetables, fruits and flowers

Justification

In the coming years of PVPFRA and IPR, it is the Institute's responsibility to have a dedicated unit in Seed Science and Technology to have an exclusive maintenance breeding programme in collaboration with concerned breeders of the varieties with documentation of the DUS traits. The maintenance breeding of such transgenic varieties or parental lines would be of very high significance, which will require determination of isolation distances, border rows, effective population size, etc., for varietal/parental line purity. It is envisaged that an effective combination of diagnostic morphological characteristics and system specific molecular marker based testing procedures needs to be developed for each crop. This will assume more priority and essentiality in crop improvement school over the phase following the first five years of the next Plan.

Objectives

- To standardize protocols for purity maintenance during seed production
- To develop DUS characteristics documentation for each crop as applicable under PPVFRA regulations

Conventional breeding for improvement of mandate cereals, pulses, oilseeds, cotton, vegetables, flowers and fruits

Justification

The importance of conventional breeding is all the more relevant in view of the stagnating productivity potential of current varieties. The conventional breeding will provide the base material for generation of new varieties per se, and these will also serve as base for transgenic development or marker assisted back cross breeding procedure.

Objectives

- Breeding crops, vegetables, fruits and flowers for favourable input conditions targeting higher productivity
- Breeding crops, vegetables, fruits and flowers for less favourable input conditions with better productivity

Molecular breeding for improvement of specific traits with precision in mandate crops

Justification

Molecular breeding is the advanced plant breeding methodology with high degree of precision and selectability for desirable traits without having to make the selection for the phenotype. This approach is now gaining importance in view of the quantitative trait loci which need to be accumulated for increased performance value of the trait and is likely to pave way for the quantitative increment in yield which seems to have stagnated by and large.

Objectives

- To identify markers, map and their validation and MAS for known genes/QTLs for productivity and other traits
- To develop standard mapping populations like RILs, NILs for national use
- To develop molecular maps of mandate crops for traits of importance to India and whole genome maps in crops relevant to India and developing countries
- To adopt transformation tools for genetically engineering plants for productivity and quality traits

Breeding for biofortification and nutrition use efficiency of both macro and micro nutrients

Justification

Breeding for biofortification and nutrition use efficiency needs to be adopted with the advent of precision breeding tools so that varieties are available for direct nutritive quality enhancement e.g., β-carotene enrichment in rice, and mustard oil or specialty starch enrichment in maize for industrial application. This is expected to enable farming to become 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.

Objectives

- To genetically enhance the nutrition value through biofortification of provitaminA, iron, and zinc through transgenic route based and molecular marker based backcross breeding (MABB) in rice, maize and wheat
- To improve the NUE of nutrients like N, P, K, Zn, Fe, B, etc., in rice, wheat, maize, *bajra*, pulses, *Brassica*, soybean, brinjal, tomato, onion, etc.
- To develop IPNM, tissue nutrient guide in fruit crops, physiological and molecular bases of plant microbe interaction

Breeding for quality improvement

Justification

Having achieved production levels in food grains to meet the need of the nation, it is now important to focus on the quality of the produce so that it gets higher value and higher acceptability internationally in trade. This will also help industry-food crop production to be linked for specific quality based products for most of which Indian industry has been importing raw material.

Objectives

- Breeding for specialty traits in varieties suitable for diabetics, industrial product use, grain and fruit quality for domestic and export quality
- To improve grain quality traits of bread and durum wheat, and *basmati* rice
- To improve protein quality and quantity in cereals, pulses and vegetables
- To develop canola quality in rapeseed and mustard
- To improve quality to meet industrial and export market requirements in crops, vegetables, flowers and fruits
- To enhance phyto-extracts like oils and alkalies as required for the industry from flowers, herbs and medicinal plants

Breeding for biotic stress resistance

Justification

Insect pests, diseases and nematodes have been causing about 25 per cent loss, in general, to annual production from crops and horticultural products. Development of resistance to specific diseases is a major contribution that is farmer-friendly and low input requiring technology that has to be worked in continuous dynamic scale with the disease causing organisms and pests. The strategy required would be to develop an integrated pest management strategy with more and more genes, particularly of plant origin.

Objectives

- To incorporate specific and multiple disease and pest resistance in good agronomic backgrounds
- To evolve strategies/procedures for achieving durable resistance

Breeding for abiotic stress tolerance

Justification

Drought, salinity, and high or low temperatures are the major abiotic stresses affecting crop productivity. A large proportion of the nation's cultivated area is subjected to drought and other abiotic stresses. The development of cultivars resistant or tolerant to these abiotic stresses through conventional plant breeding has not met with a major success on its own strength. Therefore, an integrated approach involving molecular technologies needs to be put together for achieving the objectives.

Objectives

- To develop varieties for resistance to abiotic stress resistance in rice, wheat, *bajra*, maize, cotton, rapeseed & mustard, pulses, vegetables, flowers and fruits
- To understand the genetics of abiotic stress tolerance and resistance to specific abiotic stresses keeping in view the targeted environment

Seed quality enhancement and production of quality seed or planting material

Justification

Success of crop production depends primarily on the availability of high quality seeds of improved varieties. In addition to carrying the genetic potential of the improved varieties, seeds also provide means for effective disease, pest and nutrient management. The high quality seeds of IARI bred varieties, popular as "Pusa seed", have earned the trust of the farmers which was achieved through a systematic mechanism of seed production and quality control. Sustained efforts are, therefore, needed to develop appropriate production technology for the seeds and other planting materials of new hybrids of field and horticultural crops being developed by IARI and popularize them through participatory approaches.

To keep pace with the rapid technological advancements taking place globally, and aggressive crop improvement programmes initiated by the private sector, there is a need to upgrade and standardize more precise techniques for seed quality evaluation, maintenance and enhancement. This will provide maximum quality assurance and planting value to the consumer and also enhance India's potential in international seed market. For an effective implementation of the newly introduced PPV&FR Act, there is a need to intensify research efforts on various issues pertaining to the characterization and protection of new, extant and derived varieties, using morphological and molecular characteristics/markers.

Objectives

- To develop a sound seed supply system from breeders to farmers in participatory mode
- To develop a comprehensive seed quality assurance system, refined and precise technologies
- To make available seeds of highest planting value by enhancing seed quality through appropriate treatments
- To provide technological back up for effective implementation of PPV&FR Act and thus support the growth of the seed industry

DUS testing of plant varieties

Justification

Plant variety protection is one of the means for commercialization of plant varieties and further investment in variety improvement research. Testing of plant varieties for distinctness, uniformity and stability (DUS) parameters is a pre-requisite for protection. With the advent of genetic engineering techniques in variety development, the application of bio-chemical and molecular techniques would be needed for testing the essentially derived varieties (EDVs) and new varieties. Development of appropriate norms and procedures of DUS testing of EDV, new and extant varieties including farmers' varieties of field, vegetable and horticultural plants including tree species will be the future needs.

Objectives

- To develop crop-wise DUS testing parameters and standards for uniform assessment across locations
- To develop and standardize biochemical and molecular techniques for EDVs and new IVs

Germplasm collection, conservation and evaluation

Justification

Genetic resources are building blocks of crop improvement strategies. The available and acquired genetic resources are to be used for creating new variability or expanding the existing levels for their evaluation and exploitation in breeding. Those which can be used as ready material will be used as genetic stock in the breeding material and the others with potential will be submitted for long term or medium term conservation modules at NBPGR.

Objectives

- Evaluation of genetic resources and their documentation
- Systematic use of genetic resources in creating new and novel combinations for breeders's use
- Maintenance of working collections and evolution of new strategies for the conservation and utilization of the genetic stocks

Genetic/molecular and structural bases for regulation/facilitation of germination, dormancy and vigour in seed of mandate crops

Justification

Germination results from a combination of many cellular and metabolic events, coordinated by a complex regulatory network that includes seed dormancy, an intrinsic ability to temporarily block radicle elongation in order to optimize the timing of germination. The availability of the complete genome sequence of the model plant *Arabidopsis thaliana*, together with the development of procedures for global analyses of gene function, has launched the 'post-genomic' era of plant biology. Systematic analysis of RNA and protein expression patterns, and of post-translational modifications, are now feasible for a large set of genes. These can provide important clues about protein-protein interactions and gene functions in relation to dormancy germination, longevity and vigour. There is a need to develop strong partnership in functional genomic studies on seed quality traits. Dormancy and germination are complex traits that are controlled by large number of genes and environmental factors. Molecular analyses involving germination specific gene expressions, transcriptomics and proteomic studies will be undertaken to identify the target genes and regulate their expression under given set of conditions, particularly under moisture and temperature stress conditions. This will have potential application in regulation of germination and need-based induction and release of seed dormancy.

Objectives

- Genetics of seed dormancy and vigour under different environmental conditions with reference to G × E interactions
- Generation of experimental evidence for pre- and post-translational regulation of seed vigour, germinability and dormancy with molecular and functional genomics

Value addition for post-harvest processing through genetic and organic means and standardization and improvement of crops, vegetables, fruits and flowers suited to protected cultivation technologies

Justification

Huge post-harvest losses occur in agricultural crops in India. Considering the rapid urbanization, changing consumer preferences and demand for diversity of food and other agricultural products, appropriate post-harvest management techniques would be required not only to prevent the huge losses, but also to develop various high quality value added products to compete at domestic and international markets. This sector has largely remained neglected in the past, but now we need to give it top priority**.** Post-harvest life of horticultural crops is influenced by many pre-harvest factors. Research is required to be undertaken to develop protocols for various crops for proper harvesting to obtain good quality processed products. Horticultural crops being highly perishable in nature require proper packaging and storage conditions. New packaging and storage techniques are required to be developed to maintain the quality characteristics during marketing and storage. Pathogens, insects, and pests play a major role in spoilage of horticultural and arable crops; hence, their association and management is an important aspect in post-harvest technology. Development of new value added products through primary and secondary processing of perishable and non-perishable crops is the need of the hour to provide variety and convenience to the consumers.

Objectives

- To integrate production, post-harvest handling, packaging, transportation, storage, processing and marketing through multidisciplinary research so as to reduce post-harvest losses, enhance the profitability and to meet the new demands of consumers
- To study pre- and post-harvest factors associated with post-harvest physiology of horticultural crops
- To study the effect of packaging and storage environments on processing
- To develop value added products from horticultural and arable crops
- To study the microbiological, pathological and entomological aspects related to post-harvest
- To study the milling characteristics of different cereals and pulses
- To develop protocol for modified atmosphere packaging of cereal crops
- Product diversification

Post-harvest management of arable crops

Justification

The major arable crops such as aromatic rice, other cereals, pulses and oilseeds suffer from quality deterioration or poor utlity value upon storage and due to inherent genetic constitution. Therefore, PH management becomes important in these cases in consolidation of the production with proper value and purpose behind the production. This is also important in trade and providing proper economic value to the products.

Objectives

- Post-harvest management of *basmati* rice varieties and their by-products
- Development of convenience products from cereals, pulses and oilseeds

Enhancement in quality and productivity of horticultural crops under protected conditions

Justification

The crop productivity is greatly influenced by the growing environment and management practices. Protected cultivation provides a favourable environment for the sustained growth of crops so as to realize their maximum potential even in adverse climatic conditions, thus using the land and other resources more efficiently and accruing higher returns even on small land holdings. This kind of production system has great potential for enhancing incomes and generating employment through quality and all-season production of high quality horticultural produces for exports as well as domestic markets. The technology package, however, needs intensive R&D and extension strategies to make it more profitable to the growers.

Objectives

- To standardize production technologies of high value vegetable and flower crops under different protected conditions
- To develop planting material development technology for grafted seedling for selected crops
- To develop soil-less culture technology for high value horticultural crops
- To design location-specific, economically viable greenhouses
- To facilitate collection, adaptation and acclimatization of indigenous unexplored ornamentals

Genetic improvement of crops, vegetables, fruits and flowers suited to protected cultivation technologies

Justification

Greenhouse crop production represents the most intensive of agricultural production systems. The genetic material that is grown for commercial production should be so bred as to meet the cost of the generally capital intensive, high energy requiring technology to be fully compatible with the artificial growth conditions inside the structures. The materials currently are those which are bred and selected for nomal cultivation and, therefore, may not be the best suited for maximized productivity. This production system requires location-specific designs and adaptation of structures, and use of information technology tools for better management and higher returns.

Objective

- Development of genotypes specifically suited for protected cultivation in moderately controlled greenhouses under precision controlled greenhouses

Breeding organic crops, vegetables and flowers

Justification

Organic agriculture integrated with resource conservation technologies (RCTs) seems to have come to stay with increasing demand from food importing countries and domestic consumers having high purchase capacity. The currently used varieties are those which are exclusively suited for either low-medium or high fertility conditions which are never met by organic fertilizers. The whole gamut of activities of growing breeding materials for selection has to be managed under organic agriculture in lands which are maintained at internationally approved standards of organic agriculture conditions. The germplasm has to be first grown under such conditions to identify those genotypes that are responsive to slow release of nutrients through varied sources of organic-biologic means. This would be one of the components of "prebreeding programmes" so that yield levels comparable to the yield levels under high inorganic fertilizer conditions are achieved. This may mean identifying nutrient-genotype combinations in different crops characterized with maximized and yet synchronized source-sink supply-demand levels from very early flowered semi-indeterminate habit for generating photosynthates accompanied by efficient translocation. Varieties developed for organic agriculture need to be supported with a seed production system also with the same situation which may mean restricted use of off-season seed production options. This will be a challenging proposition for development of organic varieties under RCTs and organic seed production. Considering the changing consumer demand, IARI would be focusing on this activity.

Objectives

- To identify and develop suitable selection strategies for plant types with maximized nutrient uptake from slow release or low density nutrients in the soil and standardize the optimum plant-type best suited to organic cultivation
- To standardize seed production packages and organic maintenance of quality seed
- To develop production technologies for organic cultivation, and to assess soil residue for nutrients and their fortification for optimal nutrient supply under continuous cultivation
- To evaluate and assess the profitability and productivity potential of the genotypes bred through organic means for organic cultivation.

School of Resource Management

Transgenic microorganisms for enhanced agricultural productivity

Justification

More than 99% of bacteria in the environment cannot be cultured using conventional methods. To study and use the genomes of such uncultured microbes, metagenomics has been in the spotlight since the 1990s. Metagenomic approach to search for novel biocatalysts or molecules for biotechnological and pharmaceutical applications and transgenics shall pave the way for better living. Isolation of novel genes controlling various useful traits like antibiotic production, enzymes for degradation, organic acid production, etc., is an important activity for producing transgenic microbes with better efficiency of the desired trait. Studies are lacking on using DNA directly from soil which is a rich source for novel genes and metabolites. Under this programme, genetic diversity and genomic analysis of microbial communities would make it possible to capture operons or genes encoding pathways that may direct the synthesis of complex molecules such as antibiotics.

Objectives

- To isolate and characterize culturable and non-culturable microbial DNA for novel genes of agronomic importance

- To identify superior strains of blue green algae and develop genetically modified organisms for exploitation in the area of natural colours and herbicide resistance
- To develop transgenic microbes with enhanced efficiency of the selected trait

Microbial bio-control agents

Justification

With the regular use of chemical agents, soil health is degraded with the concomitant result that many pathogens do not respond to chemicals' use. Many plant diseases also have no chemical control. The use of biological agents in plant pathogen protection is the need of the hour and future research efforts need to focus on it. The use of biological agents as protectants will not only enrich the soil and improve its fertility and health but also will prevent pollution caused by nondegradable chemicals. This approach would be most economical to farming community. Cyanobacteria comprise a unique assemblage of photosynthetic prokaryotes, which produce a wide range of bioactive molecules, especially cyanotoxins. Such molecules have been gaining importance in the last two decades. However, the fungicidal/nematicidal/bactericidal activity of these compounds is less explored.

Objectives

- To isolate and screen different microbes for antagonistic effects on pathogens under *in vitro* assays
- To conduct *in vivo* tripartite studies with plant, pathogen and biocontrol agents to evaluate the efficacy of biocontrol agent
- To isolate the antimetabolite /gene responsible for biocontrol trait and sequence it
- To identify potential cyanobacterial strain(s)/their products and develop biocontrol formulation(s)

Integrated plant nutrient management (IPNM) system

Justification

Almost half of the total increase in foodgrain production has been credited to fertilizers. However, indiscriminate use of chemical fertilizers has led to nutritional imbalances and emergence of multiple nutrient deficiencies even in the most fertile areas. Integrated nutrient management involving complementary use of organic manures, biofertilizers and chemical fertilizers not only meets the nutrient requirements of plants but also maintains the physical and biological properties of the soils. Since different crops grown in succession require different amounts of nutrients, it is necessary to develop an integrated nutrient management options for different cropping systems.

Soil health is very important for a good healthy crop growth and its productivity. Microbes play an integral role in nutrient use efficiency or in increasing the nutrient availability, fixing biological nitrogen and producing organic acids and enzymes for degrading recalcitrant and bound compounds in the soil. Since soil is a conglomerate of microbes, it is obvious that microbial consortia would play a better role than a single strain of bacterium. In the past, artificial inoculation experiments have not always been successful; one reason could be the delivery system itself. There is a need to have alternate inoculation methods, and liquid formulations may be the answer. Problem soils have specific needs and microbial population surviving in these soils is endowed with certain traits. A strategy to exploit these would help in improving soils for crop productivity and bringing more land into cultivation.

Cyanobacterial biofertilizers are recognized for their potential to aid in the efficient use of water and nutrients by the crop. A major problem in the successful utilization of cyanobacterial biofertilizers in rice-wheat cropping system is their poor establishment in soils of diverse ecologies. Therefore, research efforts need to be made to understand the factors/molecules involved in the interactions between cyanobacterial strains possessing the ability to enter/interact with plant tissues, especially in the phyllosphere and rhizosphere for developing tight linkages that are not affected by soil type/ agro-climatic diversity.

Objectives

- To develop environmentally sound and economically viable practices of balanced usage of chemical fertilizers, organic manures and biofertilizers for sustainable high productivity of cropping systems involving cereals, pulses, oilseeds, fodder and vegetable crops
- To evaluate the effects of chemical fertilizers, organic manures and biofertilizers on soil properties, nutrient transformation and transport in soils and their availability to plants, and crop yields
- To determine the nutrient status and their interactions in soils and plants influencing crop yield
- To develop, test and validate models for nutrient availability in soil
- To evaluate organic and inorganic sources of nutrients along with other productivity factors for enhancing the yield and quality of crops
- To screen germplasm and cultivars for their efficacies in the utilization of nutrients from soil and applied sources
- To understand the molecular and biochemical bases of interactions between cyanobacterial strains and rice and wheat crop
- To develop microbial consortia for recycling of agricultural waste
- To develop alternate carrier for microbial inoculants
- To study biochemical and molecular bases for stress tolerance in microbes

Soil resource management

Justification

Of late, crop productivity in the IGP has been stagnant, presumably due to resource degradation and inefficient input use. There is no perceptible change in soil organic matter in most areas, rather a decrease has been observed in some areas with increased fertilizer use in intensive cropping systems. A complete inventory of soil resources is needed for planning their optimal utilization in which modern techniques of remote sensing, GIS and other tools need to be extensively used. The information so gathered can be used for the effective utilization of soil resources and arresting the declining productivity of land. Identification of suitable resource conserving techniques (RCTs) is the need of the hour to arrest resource degradation and yield decline. The short-term and long-term consequences of RCTs are thus required to be investigated on soil physical environment. There is a need to improve soil organic matter levels through recycling of at least a part of the harvested crop residues into the soil.

Objectives

- To collect and collate existing soil data
- To strengthen fundamental and applied research on pedogenesis, soil mineralogy, soil classification, soil chemistry, soil fertility and soil biology
- To develop suitable criteria for soil health monitoring under different land uses
- To evolve technological options for restoring and maintaining soil productivity

Geo-informatics applications in agriculture

Justification

The rapid development of information and communication technologies is going to play a vital role in the process of agricultural development. Since agricultural production system is a complex system, it requires an innovative approach to develop an extensive dataset spatially and temporarily, analyze the information and provide the solution in a dynamic mode. Geoinformatics is a rapidly developing service which encompasses all modern tools and techniques like remote sensing, GIS, GPS, simulation modeling, etc., and can play a very substantial role in enhancing the agricultural production without any adverse impact on natural resources.

Objectives

- To characterize diverse agro-ecologies and production environments in the country
- To refine and develop remote sensing applications for crops' discrimination, condition assessment and production forecast
- To develop appropriate land use options on watershed, command area on administrative boundary basis
- To develop a methodology of linking the bio-physical and socio-economic databases with the remote sensing and simulation models for land use planning, and agri-production estimates

Agro-advisory services

Justification

Weather is the critical phenomenon impacting agricultural production, and timeliness of agricultural activities is linked with it. There is, therefore, a need to link short-, medium- and long-range weather forecast coupled with decision support system for agro-advisory services to the farmers.

Objectives

- To understand the inter-annual and intra-seasonal climatic variability in various agro-ecologies
- To evaluate the probability of occurrence of the extreme climate events and their association with resource use planning and estimates
- To develop a national network for medium range linked agro-advisory

- To evaluate the insect-pest changing scenario over different agro-ecologies and link with the crop-weather interaction models for yield loss assessment

Water and land resources management

Justification

The per capita availability of water is declining rapidly and is expected to reach the critical scarcity level within the next two decades. The share of water for agriculture is also going to decrease due to fierce competition from other water user sectors. Fresh water bodies are being polluted due to disposal of untreated industrial and domestic effluents. Since the land available for cultivation is fixed, its proper management becomes absolutely essential for sustainable agricultural production. There are evidences of deterioration of the quality of agricultural land due to waterlogging, salinization, pollution from industrial, domestic and even agricultural effluents and operations. Some of these polluting sources have adverse impact on the surface and groundwater quality as well. Usurping of agricultural land, particularly due to urbanization is also evident besides land fragmentation, making agriculture non-remunerative for the large population of small and marginal farmers. To ensure a sustainable agriculture vis-à-vis the demands of increasing population on the limited and degradable land and water resources, there is an urgent need to increase the use efficiency of the vital inputs of land and water, besides optimizing the use of other essential inputs such as seed, fertilizer, ago-chemicals and energy to meet the ever increasing demands for food, fuel, fodder and fibre.

Objectives

- To conduct basic and applied research on different aspects of water management of crops leading to more efficient use of water and land resources for optimum crop production in irrigated and rainfed areas
- To develop efficient water allocation, conveyance and utilization systems for irrigated and rainfed areas for enhanced crop productivity and to avoid wastage of water and land degradation
- To study the water requirement and the moisture extraction pattern of different crops, the relative efficiency of different methods of irrigation and the interactions of irrigation with other agro-techniques
- To develop *in situ* water conservation, harvesting and utilization technologies
- To improve groundwater management for conjunctive use and drainage problems
- To quantify interactive effect of water and nutrient application and other management inputs on crop growth and soil properties
- To inculcate the concept of precision farming, which is aimed at optimizing the input application and use with better crop productivity but without undue stress on land and water resources.

Recycling of waste waters in agriculture

Justification

Because of rapidly increasing industrialization and urbanization, the share of water for irrigation sector is bound to decrease from 80 to 70 per cent or less in the next 10 to 15 years. The use of different types of waste waters for irrigation of field crops without adversely affecting the productivity and quality, would be a necessity in future. It will mitigate the pollution problem caused by the waste waters including industrial effluent and sewage water. Since majority of these waste waters are good source of organic carbon, their use in agriculture will reduce the requirement of inorganic fertilizers.

Objectives

- To study the nutritional enrichment of waste waters with respect to both essential and toxic elements
- To quantify the impact of waste water irrigation on crop growth and soil health
- To develop a technology for safer use of waste waters in agriculture

Water and nutrient synergy for enhancing crop productivity

Justification

Sustainable crop production in an irrigated agriculture involves critical use of resources. Agricultural productivity depends on the efficient use of both water and fertilizers. For sustaining production at a higher level, in addition to the above inputs, management of soil through tillage and use of organic sources to meet the nutrient requirement, either wholly or partly, are all very important. Studies have been carried out to evaluate the effect of each of these inputs independently or in combination with one more factor on the productivity of rice-wheat and maize-wheat cropping systems. However, the effect of these critical inputs has never been studied in an integrated manner. Quantification of the effect of all these inputs on crops and their interaction is another aspect that has been generally ignored. It is planned to have an integrated approach to monitor the effect of two critical resources, namely, water and fertilizer, coupled with management options on long term basis. Exerimental findings on irrigation and fertilizer interactions would help in answering the questions related to nutrient movement and uptake arising from irrigation water supply, uptake pattern and application methods to be adopted. Thus, proper fertilizer application rates and technology may be developed for optimum use of the most previous resources, viz., irrigation and nutrients.

Objectives

- To study the effect of integrated resource management practices on sustainability of different cropping systems
- To optimize water and nutrient combinations for higher productivity and profitability in different crops and cropping systems
- To quantify the short and long term impacts of resource management practices on plant-soil-atmospheric environment, soil quality and crop productivity parameters
- To develop and standardize diagnostic tools for estimation/quantification of various stresses on crop growth and sustainability parameters

Enhancing productivity of rainfed areas

Justification

About half of the arable lands in the country is likely to remain rainfed, even if all the available potential for irrigation water is realized to the maximum. The rainfed areas need attention for rainwater management *in situ* as well as *ex situ* to achieve reasonably good yields on a sustainable basis. Further, contingent plans for mid-season corrections under aberrant conditions are required against total crop failures.

Objectives

- To develop an economically viable method for moisture conservation *in situ*
- To develop rain water harvesting and agro-techniques for efficient utilization of conserved soil moisture for increasing crop production in rainfed/dryland conditions
- To evolve contingent crop plans as well as mid-season correction techniques in crops and cropping system to increase the crop yield under rainfed/dryland areas

Crop diversification

Justification

Enhanced productivity from the conventional cropping systems has not necessarily yielded higher profits in most areas. This is due to increasing prices of inputs, not commensurate with the prices of farm produce over the years. Therefore, there is a need to diversify and suggest alternative cropping systems, which are more productive as well as profitable and sustainable in the long run. The cultivation of high-value crops including horticultural crops such as vegetales, flowers and also spices needs to be taken in specific situations. Such endeavours should necessarily take into account marketing and export opportunities.

Objectives

- To evaluate the potential of different high-value crops in diversification, productivity, nutrient economy and soil health in major cropping systems
- To identify and develop sustainable production technology for different crops and their economics vis-à-vis conventional cropping systems

Resource conserving technologies

Justification

Major research and development efforts in the Green Revolution era focused on enhancing productivity of selected foodgrains and a few other crops. In the post-Green Revolution era, the issues of conservation have assumed greater importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Resource degradation problems are manifesting in several ways. Declining water tables in many agriculturally important regions imply increasing pumping costs, replacement of shallow gravity tube wells with submersible pumps at huge cost, and adverse effects on water quality and overall ecology of the region. Declining soil carbon and fertility are reflecting in declining soil biodiversity, multiple nutrient deficiencies, need for increasing inputs use to maintain yields, and implications for quality of produce and environment. Inefficient input use and management practices are leading to widespread contamination of surface and groundwater with connected health hazards.

Therefore, there is an urgent need for developing and promoting technologies that can reverse the processes leading to resource degradation.

Adoption of resource conserving systems is the need of the hour as a method of 'low-input agriculture' to reduce costs and achieve sustainability in Indian agriculture. Accordingly, there is a need to evaluate and analyse the effects of resource conserving techniques on carbon sequestration and improving productivity in intensive cropping systems with a multi-disciplinary, multi-locational approach.

Objectives

- To study the influence of various tillage practices including conservation tillage and modified crop establishment techniques on productivity and soil health
- To improve resource use-efficiency, particularly nutrients and water, through optimization of tillage and crop establishment techniques
- To study the dynamics of weed-flora and to develop integrated weed management practices in cropped and non-cropped lands for enhancing productivity

Organic farming

Justification

Organic farming has drawn the attention of agricultural scientists in the past few years due to overflowing food stocks and residue hazards in the conventionally-grown foods with liberal doses of chemical fertilizers and agro-chemicals. Therefore, organic farming is being emphasized in high value crops and essentially for export purposes. There are, however, not adequate quantities of organic materials available for realizing the yield potential of crops. Accordingly, there is a need to evaluate different available sources in terms of their nutrient release and availability to the crops to satisfy a greater part of the crop nutritional requirement. Further, other related issues on quality of the produce and soil health are required to be investigated.

Objectives

- To determine the optimum combination of organic manures, crop residues and biofertilizers for meeting the nutritional requirement of organically grown high value crops
- To study the effect of organic farming practices on physical, chemical and biological properties of soil
- To study the effect of organic farming practices on quality of produce
- To develop organic farming models involving nutritional and plant protection requirements for *basmati* rice and vegetables
- To isolate and screen microbes for degrading lignin, cellulose, starch and other agricultural wastes.
- To develop microbial consortia for efficient use of vermicompost and crop residues
- To develop technology for compost production at low temperatures
- To develop a package of practices for organic culivation of *basmati* rice using blue green algae and *Azolla* with other organic amendments

Farm mechanization and development of equipment

Justification

Problem areas of the country like dry land, hilly areas and coastal areas and a large group of small farmers would require specific machines to work under specific situation for specific purpose. To meet out this requirement, automation has emerged as an important area for R&D. R&D on Aqua Fertilizer Seed Drills and Planters for dry land areas and small powered multi purpose equipment for farmers of hilly areas with small land holding is a necessity. To achieve reasonable level of precision in tractor-based field operations, a tractor operator has to guide accurately, monitor and control both the tractor and the attached implement. Ergonomic evaluation of agricultural machine with interventions is also needed to reduce injuries and health hazards. To encourage the inter changeability of the machines, design and development of dies, jigs and fixtures is required for process optimization of small scale agro machinery manufacturers. In addition, technologies for conversion of bio-mass into efficient solid and liquid fuel, including bio-diesel from tree based oils, are also needed to avoid dependence on fossil fuels and to fulfill the energy requirements. Timeliness and precision of farm operations right from the land preparation to the crop threshing contribute greatly in boosting the agricultural production. With the accent on higher cropping intensity, the limited turn around time between two crops must be managed effectively to ensure timely operations. The dearth of labour for seasonal operations is yet another problem in post-harvest operations with increasing emphasis on post-harvest operations and value addition. All these trends call for a judicious intervention of farm machines and implements.

Objectives

- To design and develop equipment for dry land agriculture and hilly areas
- To bring automation in agricultural engineering machines
- To develop implements and machines for preparation, handling, and application of organic manures and agriculturally important microorganism
- To develop processes for manufacturing of agro-machinery
- To evaluate and indigenise suitable precision farm equipment
- To study farm machinery use and management, status, constraints and use of farm power sources
- To reduce farm worker’s drudgery and occupational heath hazards through appropriate tools and equipment
- To develop and utilize non-conventional sources of energy for agriculture

Precision farming and surface covered cultivation

Justification

For increasing the agricultural production with decreasing land resources the greenhouse cultivation is considered as one of the feasible solutions because it utilizes the vertical space and is helpful in controlling plant diseases resulting in quality production. It is labour intensive, hence proper tools and equipment have to be developed to reduce human drudgery. India has diverse climatic conditions ranging from the hot deserts to the cold hilly regions; therefore, region specific environmental control systems need to be designed. Hence, instead of developing various designs for various climatic conditions, a single composite model with removal modular attachments will be helpful for adopting greenhouse cultivation. With vast areas expected to be brought under greenhouse production, efficient environment control systems will be necessary to make the cultivation economically remunerative.

Objectives

- To design and develop tools and equipment for greenhouse automation
- To develop suitable environmental control systems for greenhouse for different climatic zones of India
- To design and develop composite greenhouse easily adaptable to various agro-climatic zones of India
- To develop good agricultural practices (GAP) for greenhouse crops
- To develop decision support systems (DSS) for greenhouse management

Post-harvesting engineering

Justification

The two major goals of post-harvest processing of agriculture produce are loss prevention and value addition. The harvested raw food biomass is processed to improve its palatability, nutritional value and shelf life. Appropriate post-harvest technology would be needed to prevent the losses, add value to products, increase competitiveness of the products in national and international markets, and to increase the overall profitability. At every stage of agriculture, from production to consumption, value is added to the produce and by-products. The lowest and the highest monetary values of agricultural commodities are, respectively, when it is in raw and fresh form and when it is in processed and ready-to-use form. Processing technology is commodity and location specific. Estimated value additions to the raw food materials through primary processing, and secondary/tertiary processing in India are 75% and 25%, respectively. It, therefore, shows that primary processing has a greater role to play in improving the economic benefits to the farmers.

Objectives

- To design and develop oil extractors with improved efficiency of oil milling
- To design and develop milling equipment and storage structures for pulses, oilseeds and cereals
- To design and develop equipment for processing of by-products of cereals, pulses, oilseeds, fruits and vegetables
- To study the drying of spices & condiments and the development of low cost transportation and storage system for perishable and semi-perishables
- To integrate production, post-harvest handling, packaging, transportation, and storage, processing and marketing through multidisciplinary research so as to enhance the profitability and to meet the new demand of consumers

Climate change and agriculture

Justification

Anthropogenic emissions of GHGs are projected to increase atmospheric temperature (1.4 to 5.8°C), shift precipitation patterns, and lead to increased occurrence of extreme climatic events. Such a changing climate will have consequences on the agricultural productivity, quality, resources, pest dynamics, biodiversity and land use patterns affecting our food security. We need to understand the impact of these variables on agricultural systems through studies on controlled environment facilities, field experiments, and simulation modeling approaches. There is also a need to provide enhanced policy support on global warming through backup research.

Objectives

- To assess the impact of disturbed climate including elevated carbon dioxide, temperature, rainfall, and ozone on agricultural production systems
- To identify and develop adaptation strategies including alternative land use pattern for sustaining production in changing climate
- To develop and identify tools and bioindicators for rapid identification of climate change signals
- To develop agriculture based approaches that can mitigate greenhouse gases in atmosphere

Environmental impact of agriculture

Justification

Demand for new/quality food products is increasing global trade in food items. This together with increasing urbanization and industrialization could lead to increased pollutant load in agricultural resources such as soil, water, and air, which may ultimately get into the whole food chain. Some evidence of this has already started appearing. There is a need for its long-term monitoring and for developing analytical tools for rapid detection of probable toxicants/contaminants in soil, water, air, agricultural products as well as by-products.

Objectives

- To analyze the long-term impact of changing land use, land cover pattern on agricultural production and sustainability of natural resources
- To assess the long term impact of natural resource degradation on food security
- To characterize the critical load of various pollutants on different components of agricultural production system
- To characterize the spatial variabilities of probable pollutants load in soil, water, air, agricultural products and by-products as a consequence of different farming practices and associated environmental pollution
- To identify agri-environmental hotspots with reference to probable toxicants/contaminants load in selected agro-ecological regions
- To develop and test various analytical tools for rapid detection of different pollutants in food chain at different levels of production and consumption

- To develop a framework for setting and reviewing of environmental objectives and targets for good agricultural practices (GAP)

Biofuels

Justification

The demand for energy is growing exponentially in all sectors including agriculture. The intensive mechanization of Indian agriculture shall further aggravate the dependence on conventional fuels, which are limited and are becoming more expensive. There is a need to explore agriculture-based new renewable energy sources such as biological fuel cells, new energy crops, alcohol from biomass, and thermophillic microbial community. Energy-rich crops and trees are being thought of as possible alternatives to develop indigenous fuels without harming the environment. The crops/trees like castor, jatropha, sugarcane, sweet sorghum and other non-edible oilseeds are being investigated as possible energy crops for the future. There is, therefore, a need to evaluate these trees/crops and develop suitable agro-techniques for higher yields and better quality.

Objectives

- To develop biological fuel cells for producing hydrogen or hydrogen from potential agricultural wastes
- To identify new plants and to improve plant types for increased biofuel production
- To evaluate different energy rich crops for higher productivity
- To develop agro-forestry-based systems involving biofuel yielding trees with field crops
- To develop technology for mass multiplication of thermophillic microbial community suited for anaerobic degradation of agricultural wastes

Agri-informatics

Justification

In view of the multi-dimensional activities and the relevance of ICT in agricultural sciences it is imperative to strengthen the area of agri-informatics at the Institute. Major emphasis will be on crop informatics, pest/disease informatics, soil informatics, hydroinformatics, socioeconomic informatics, and geoinformatics. Updates on all these aspects are essential for knowledge information and dissemination to all concerned (like policy makers, researchers, students, extension specialists, farmers, etc.) and, in turn, for achieving the oft-repeated ‘Evergreen Revolution’.

Objectives

- To create comprehensive data bases in respect of all crops from sowing to final destination (consumer)
- To develop decision support systems in soil informatics, hydroinformatics, crop informatics, pest/disease informatics, socioeconomic informatics and geoinformatics in the light of available literature and existing scenarios
- To facilitate in-silico studies on various aspects of informatics for researchers in agricultural sciences

- To upgrade the existing Bioinformatics Centre as a Centre of Excellence in Bioinformatics
- To organize HRD activities on the applications of computer tools in agriculture for the benefit of researchers and students from time to time
- To enhance the internet related facilities for the entire Institute and facilitate on–line R & D activities in frontier areas of agricultural research

Sub-sub-programmes

Transgenic microorganisms for enhanced agricultural productivity

- Bioprospecting of culturable and non-culturable microorganisms for using them as vectors of gene delivering systems for potential attributes
- Development of genetically modified organisms (GMOs) and new strains of blue green algae for exploitation in agriculture and industry

Microbial bio-control agents

- Bacterial, fungal and algal bio-control agents for important crop diseases

Integrated plant nutrient management systems

- Sustaining soil health for increasing productivity and quality of crops through integrated plant nutrient supply and management strategies
- Nutrient availability through microorganisms and recycling of agricultural residues through microbial consortia
- Development of alternate carrier for microbial inoculants
- Development of new formulations for blue green algae biofertilizer and understanding plant cyanobacterial associations for enhancing crop yields
- Evaluation of biochemical and molecular bases of stress tolerance, in specific for their possible exploitation as successful bioinoculants for problem soils

Soil resource management

- Development of soil quality index by integrating physical, chemical and biological aspects for different land use systems
- To identify resource conservation technologies for various cropping systems in the IGP, its assessment on soil physical environment(short-term and long-term consequences) and crop growth and yield
- To develop pedo-transfer functions for soil moisture and soil fertility evaluation
- To develop simulation procedures for tillage induced properties changes for their linkage with the crop growth models
- Regional level planning for improving soil physical conditions and sustaining crops' yields
- Carbon sequestration through residue recycling for sustaining productivity and improving soil quality

Geoinformatics applications in agriculture

- To evaluate the spectral signatures of various crops and cropping systems under various production environments

- Characterizing biophysical and socioeconomic aspects related to agricultural activities through remote sensing and conventional methods
- To devise methodology for linking remote sensing signatures with relational database layers through decision support system (such as simulation models and technical coefficients for agri-production estimates and land use planning)
- Operationalization of remote sensing based technique for monitoring of the crop production and drought monitoring in various agro-ecologies of the country (rural knowledge centres and dissemination procedures)
- Creating geo-visualisation tools for effective knowledge dissemination in the north-western region of the country
- Development of plan for optimal use of land and water resources in agriculture
- Development of simulation models and use of GIS for crop diversification indices

Agro-advisory services

- Development of decision support system for effective agro-advisory based on weather forecast (short-, medium- and long-term based)
- Insect-pest forecast on the basis of weather conditions
- Probability of occurrence of extreme climatic events (drought, aerosol, haze, heat and cold waves) and relate it with agricultural management

Water and land resources management

- Determination of crop water demand for different cropping systems
- Development of techniques to bridge the gap between available water supply and crop water demand
- Development of efficient water control and conveyance structures
- Assessment and performance evaluation of available instruments for on-farm water management
- Development of low-cost instruments for on- farm water management
- Assessment of utilizable ground water resources for agriculture
- Development of technologies for groundwater recharge

Recycling of waste waters in agriculture

- Development of technologies for use of poor quality and waste waters for agriculture
- Monitoring the accumulation of nitrates and heavy metals in soils and ground waters
- Development of bioremediation technology for waste and polluted waters using blue green algae and *Azolla*

Water and nutrient synergy for enhancing crop productivity

- Crop planning for efficient water and nutrient management under deficit water availability
- Quantification of water-nutrient interactions in various cropping systems

Enhancing productivity of rainfed areas

- Assessment of harvestable rain water
- Development of technologies for rain water recharge and direct use
- Assessment and planning for efficient utilization of natural resources on watershed basis

- Assessment and performance evaluation of available instruments for watershed management
- Development of low cost instruments for watershed management
- Conservation of rain water through *in situ* or *ex situ* conservation practices
- Perfection of technology using aqua-ferti-seed drill
- Integrated rain water, ground water, river water, sewage water and waste water management

Crop diversification

- Introduction and evaluation of high-value specialty crops for increasing system productivity and sustainability
- Introduction of oilseeds in non-traditional areas, i.e., late-sown mustard in rice fallows
- Need-based nutrients application including use of secondary and micronutrients in deficient areas grown to oilseeds
- Improved technology and incentive for promoting spring sunflower cultivation
- Integrated farming systems research for small and marginal farmers

Resource conserving technologies

- Nutrient budgeting by monitoring long-term changes in soil fertility for arresting decline in factor productivity
- Development and field testing of value-added new fertilizer materials to increase productivity and soil health
- Research on contributions and management of soil biodiversity for improved soil health and productivity
- Conservation tillage and modified crop establishment techniques for improving resource use efficiency
- Herbicide resistant crops and their evaluation under varied soil and climatic conditions, weed dynamics, development of resistance in weeds to herbicides, residual toxicity and their mitigation strategies

Organic farming

- Development of technology for efficient use of farmyard manure, compost, vermicompost, green manure, biofertilizers and crop residues involving microbes, etc., for success of organic farming
- Organic farming of bold-seeded groundnut, and bold- and white-seeded sesame for export purpose
- Assessment of impact of organic farming on soil health
- Development of low cost organic cultivation of *basmati* rice and sustaining soil productivity using blue green algae and *Azolla*

Farm mechanization and development of equipment

- Design and development of equipment for farmers of hilly areas with small land holding
- Automation in agricultural engineering machines
- Design and development of equipment for dry land agriculture
- Development of implements and machines for preparation, handling and application of organic manures and agriculturally important microorganism

- Development of process for manufacturing of agro-machinery
- Evaluation and indigenisation of suitable precision farm equipment
- Machines for vegetable cultivation
- Studies on status, constraints and use of farm power sources
- Studies on farm machinery use and management

Precision farming

- Precision farming at different scales by using remote sensing and conventional tools

Post-harvesting engineering

- Design and development of processes, products and processing equipment

Climate change and agriculture

- To assess the impact of disturbed climate including elevated carbon dioxide, temperature and ozone on agricultural production systems
- To identify and develop adaptation strategies including alternative land use pattern for sustaining production in disturbed climate
- To develop and identify tools and bioindicators for rapid identification of climate change signals
- To develop agriculture based approaches that can mitigate greenhouse gases in atmosphere
- Investigation of climate change on water availability and quality and its consequence on crop production

Environmental impact assessment of agriculture

- To analyze the long-term impact of changing land use, land cover pattern on agricultural production and sustainability of natural resources
- To assess the long-term impact of natural resource degradation on food security
- To characterize the critical load of various pollutants on different components of agricultural production system

Biofuels

- To develop biological fuel cells for producing hydrogen from potential agricultural wastes
- To identify and develop new plants for biofuels production
- To develop technology for mass multiplication of thermophillic microbial community suited for anaerobic degradation of agricultural wastes
- Field evaluation of energy crops for increased productivity of biofuels

Agri-informatics

- Collection and collation of available information related to climate, soil, water, crop and socioeconomics for planning and their optimal utilization and in strengthening/ sustaining agricultural production and productivity
- ICT applications in agriculture such as GIS, remote sensing, DSS, web-based application and development of software in agricultural research and education

- Research activities on agricultural ontology
- Research application of system simulation, modeling, virtual and digital farming
- Structure and function prediction of hypothetical protein using different bioinformatics tools
- Applications of bioinformatics tools for studies on biotic and abiotic stresses on genes in different crops
- Plausible identification of missing genes and noble genes for biotechnological applications
- Genome analysis of *Dictyostelium discoideum*, a soil amoeba and its characteristics

Linkages with Other Schools

Physiological and molecular basis of drought and high temperature tolerance (linked to sub-programme on abiotic stress under basic sciences)

- Understanding the basis of abiotic stress tolerance at the level of processes and traits
- Identification of novel genes contributing towards abiotic stress tolerance
- Identifying molecular markers linked with traits and processes through marker assisted selection

Studies related to physical and physiological bases of growth and yield of crops (Bio-Physics Section of the Division) to be linked to basic sciences programme of the Institute

- Bio-physical research for protein structure, genomics, gene simulation and markers aided selection
- To develop bio-informatics tools for bio-molecular level studies
- Nanotechnology application in physical and physiological basis of crop growth

School of Basic Sciences

The extent and quality of research and teaching in hard-core basic sciences in the IARI is very much inadequate. A clear understanding and insight into the basic processes and mechanisms governing molecular, biochemical and physiological bases of yield, resistance and quality of crops, inputs use efficiency and dynamics of soil-water-plant interaction are essential for building on the available technologies. Development of simple diagnostic tools to unravel the intricacies of these processes at molecular level is a challenge worth pursuing. Scope exists to reorient and consolidate the emphasis and activities of the Divisions, from the existing compartmentalized disciplinary mode, commodity based research to problem-solving inter-disciplinary eco-regional approaches, realizing the significance of close inter-linkages with physical sciences and biological sciences. Physical methods only can give a direct insight into the crop productivity linked ultimate detailing of various processes and parameters, improving quality traits in crops for export, developing new methods and techniques for creating such traits and rapid screening techniques for desirable quality traits. The knowledge generated from basic research and captured in modern technologies to fructify intensification will be the substitute for the future challenges. IARI, being the premier Agricultural Research Institute in the country, must continue to play its flagship role in basic sciences as well, with national and international linkages.

The School envisages to generate increasing knowledge on physiology, molecular biology, biotechnology, biophysics and nanosciences that can be helpful to develop modern technologies and strategies in enhancing crop productivity, and in identifying parameters for conferring greater tolerance to biotic and abiotic stresses, etc. High attention will be given to develop technologies for post-harvest preservation and value addition to improve the post-harvest quality through proper storage and packaging. Research will be strengthened to help generate knowledge to develop designer crops and identify unique attributes of agricultural pests, pathogens, etc., for commercial exploitation. The necessary infrastructure and human resources will be strengthened in the XIth Plan and beyond to realize this goal.

Keeping in mind the national development priorities, international research and technology development trends, recommendations of the SRCs, RACs and QRTs of the IARI, and consultations with the scientific staff and peers, the following programmes and sub-programmes covering research and education have been identified:

Programmes on basic sciences

- Productivity Enhancement
- Biotic Stress Tolerance
- Abiotic Stress Tolerance
- Post-harvest Physiology and Preservation
- Nutritional Quality Improvement and Nutrient Dynamics
- Biological Nitrogen Fixation and Biocontrol
- Impacts of Climate Change and Vulnerability Assessment
- Genomics
- Molecular Breeding
- Isolation of Genes and Promoters

Proposed new programmes

- Development of a Central Facility with Modern Instrumentation
- Application of Nanosciences in Agriculture

Productivity enhancement

Justification

For enhancing the productivity of a crop, it is desirable to identify the key factors and interacting reactions and processes that occur during the ontogeny of the crop, limiting yield. One of the major approaches of increasing economic yield is to enhance the sink capacity, which would require efficient source capacity. In wheat, enzymes AGPase and soluble starch synthase are important determinants in the pathway leading to starch synthesis, deposition, improved grain size and yield. While, due to end products inhibition of photosynthesis through regulation of Rubisco, it is often viewed as a potential target for genetic manipulation to improve photosynthesis by decreasing photorespiration, by increasing the affinity of Rubisco for CO_2, and thereby decreasing its oxygenase activity, or by concentrating CO_2 in the vicinity of Rubisco through the introduction of C_4 pathway, certain plant species do not show end product inhibition of photosynthesis because they accumulate excess starch (and not sugars) in the leaves. Obviously, one approach could be to convert sugar accumulator to starch accumulator. Furthermore, inhibition of photosynthesis by heat stress is one of the important factors that adversely affects productivity. An effort to improve the performance of these enzymes is, therefore, important for greater productivity.

Hybrid technology for raising productivity could not be exploited yet in oilseed crop *Brassica*. It is very desirable to generate basic knowledge for exploiting heterosis, to improve the productivity, aiming at development of new male sterility lines and their fertility restoring genotypes, molecular characterization and stabilization. Genes encoding enzymes responsible for biosynthesis of membrane lipids are of importance to study their structure and function. It is necessary to isolate/analyse the promoters of the important genes in the biosynthetic pathway of plant lipids, and for expression of *DGAT* in *E.coli* to study the substrate specificity of the protein expressed from the cloned gene. Emphasis will be on generating organelle 'protein maps' of mitochondrial and chloroplast proteins from different developmental stages of plant growth, to study the diversity among the germplasm and identify the agronomic traits useful for the selection of desired cultivars.

Objectives

- To isolate promoters of genes in lipid biosynthesis and study the structure and function of membrane lipids
- To enhance the performance of Rubisco and the level of ammonia-assimilating enzymes for greater productivity in wheat
- To exploit AGPase and soluble starch synthase for improved grain growth and yield of wheat
- To develop genetic stocks for hybrids in *Brassica* and high yielding mustard varieties
- To study the diversity of germplasm for the selection of desired cultivars

Sub-programme

- Genetic manipulation of flowering time to enhance grain-filling period
- Efforts to change the existing non-determinate and input non-responsive behaviour to achieve higher yield in pulses
- Development of growth and yield enhancing formulation comprising different nutrients and growth regulating substances
- Isolation of promoters for important genes involved in lipid biosynthesis in plants
- Isolation of genes encoding enzymes responsible for biosynthesis of membrane lipids like galactolipids and sulfolipids in plants
- Biochemistry of plant organelles, and 'Protein maps' of mitochondrial and chloroplast protein
- Exploitation of enzymes involved in ammonia assimilation
- Development and molecular characterization of male sterility & fertility restorer in *Brassica*
- Evaluation and diversification of production, field evaluation and coordination of mustard hybrids for higher productivity

Sub-sub-programme

- Over expression of starch accumulating enzymes for better assimilate partitioning towards grain growth in wheat and rice
- Maintaining higher expression levels and activity of Rubisco and engineering for higher carboxylation efficiency

Biotic stress tolerance

Justification

Insects-pests and fungal diseases are the most important factor contributing to yield losses in major cereals, pulses and oilseed crops. Our knowledge of molecular events, occurring during plant pathogen interactions, has expanded significantly in the recent past. Based on this knowledge, several strategies have emerged for developing insects & pathogen-resistant crop varieties: (a) over expression of genes for antifungal compounds in transgenic plants, and (b) isolation of R (resistance) genes and transferring them to susceptible varieties. However, desirable level of resistance has not been obtained, and only a few durable R genes have been isolated, and yet, these too have limitations for their applications across taxonomical barriers. The use of regulatory defense genes involved in pathogen signal transduction also deserves attention.

Objectives

- To study the communication between plants and various micro-organisms in the phyllosphers

Sub-programme

- Transgenic mustard for the development of aphid repellent, using fernesene synthase gene
- Construction of construct in binary vector and production of transgenic mustard
- Construction of novel Bt gene, vectors, genetic transformation of brinjal, molecular analysis and plant breeding for gene stacking
- Isolation and characterization of defense genes and promoters from *Brassica juncea* and development of fungus-resistant transgenic plant
- Biological control of plant diseases

Abiotic stress tolerance

Justification

Unfavourable temperatures and salinity both at germination/seedling and grain filling/maturity stages affect crop productivity, cause considerable yield losses and reduce the opportunities of multiple cropping. The development of cultivars resistant or tolerant to these stresses through conventional plant breeding methods has met with limited success due to crossing barriers, as the genes are mostly available outside the primary gene pool. Understanding the molecular level mechanisms of tolerance or resistance to identify the genes or molecular markers associated with stress tolerance will be helpful to develop tolerant cultivars through molecular aided selection. The genetic engineering approaches offer hope to develop abiotic stress resistant crops by cloning and delivering such genes into varieties.

Drought affects the growth and development of plants through alterations in cellular and subcellular metabolism and functional and regulatory genes expression. Synthesis of HSPs (heat shock proteins) has been correlated with the acquisition of thermotolerance in a number of organisms. Analysis of the functional role of LEA (late embryogenesis abundant) and HSPs and the biochemical basis of their expression, and the effect of regulatory genes on expression of these proteins may be helpful. Study of the respiratory pathway in wheat genotypes for tolerance, expression of HSPs and enzymes related to ammonia assimilation and carbohydrate synthesis during grain development may be useful. Microorganisms - plants interaction in the rhizophere is less well understood in the aerial region of a plant. It would be interesting to study the communication between the bacterial strains and the compartment below the cuticle (apoplast) to understand how the nutrients are exported without causing damage to the cuticle. The molecular mechanisms involved in signal transduction pathways involved in hormonal, developmental and environmental expressions and their regulations are not well understood. Elucidation of the role of these pathways and their regulation of various physiological and biochemical processes in plants is likely to provide more insight.

Objectives

- To understand the molecular mechanisms of tolerance or resistance at cellular and biochemical levels and identify the genes or molecular markers associated with them
- To elucidate the molecular mechanisms involved in signal transduction pathways for hormonal, developmental and environmental expressions
- To standardize the techniques for screening large breeding populations/germplasm lines and develop heat tolerant wheat cultivars through molecular aided selection
- To investigate the microorganisms - plants interactions in the rhizophere
- To study various morphological parameters contributing towards stress tolerance and the role of growth regulators in amelioration of stress

Sub-programme

- Clone and characterize stress inducible genes and promoters
- To develop transgenic crops (mustard & wheat) for enhanced tolerance to drought, heat and salinity
- Identification of genotype and simple traits for screening and development of plant types tolerant to various abiotic stresses
- Elucidating the mechanisms of water, high/low temperature, waterlogging and salinity stress tolerance, including antioxidant defence mechanism and membrane characteristics
- Biochemical basis of drought and heat tolerance in germinating seeds
- Proteomics and protein - protein interactions
- Elucidation of signal transduction pathways in plants
- Isolation of novel genes & promoters
- Construction of constrict in binary vector
- Generation of design crops

Sub-sub-programme

- Identification of stress induced proteins acting as chaperons to functional/enzyme proteins
- To elucidate the role of endogenous phytohormones in relation to nutrient uptake and productivity under stress environment

Post-harvest physiology and preservation

Justification

Post-harvest losses due to physical, physiological and pathological factors account for 20-35%

of the agricultural produce. The series of processes operating right from the time of harvest till it is used for consumption, export, and reuse in crop production needs greater attention from the point of view of value addition, increase in shelf life, etc., without much reduction in the quality of the produce. Fruits ripen rapidly and often over-ripen during shipment, transportation and storage causing enormous losses. Years of breeding efforts to increase the shelf life of such fruits had little success. It is known that a plant hormonal gas, ethylene, induces fruit ripening. By reducing the synthesis of ethylene through antisense RNA technology, it is possible to delay fruit ripening and extend the shelf life of such fruits as tomato, banana, mango, peach, plum, etc. Alternative methods to remove hard seededness also need to be investigated. Seeds of many species in a number of families exhibit hard seededness and are impermeable to water which results in non-uniform crop stand. Various approaches involving physical energies, such as radiations, radiofrequency, microwave and magnetic fields have potential to reduce/prevent post-harvest losses by controlling insect-pest infestation damage. Magnetic and RF field treatment can also improve vigor of the seed.

Objectives

- To understand the mechanism of ethylene sensitivity and exploit this trait to delay the flower senescence in gladiolus by biochemical and molecular approaches
- To understand the mechanism of ripening and its regulation in climatic fruits and enhance the nutritional quality in fruits and vegetables
- To overcome the dormancy in hard seeded crops and to enhance the germination characters and storability in seeds using microwave, RF, and magnetic fields
- To establish a relation between the biochemical and biophysical parameters associated with germination process of the seeds treated with RF, MW and magnetic field, and quality studies in processed agri-products

Sub-programme

- Investigate the mechanisms of fruit ripening and flower senescence, including anatomical modifications
- Integrated treatment of different energy (gamma, microwave, RF, and magnetic fields, etc.) for biostimulation and post-harvest preservation of seeds, and agri-products (cereals, pulses and oilseeds)
- Evaluate the efficacy of MW and RF energies in controlling microflora and storage pests in seeds and grains, for minimal processing of fresh fruits and vegetables, and stability studies of rice bran

Sub-sub-programme

- Identification of novel compounds (non-toxic) for post-harvest enhancement of shelf life of fruits, vegetables and flowers
- Identification, isolation and characterization of senescence/ripening associated genes and their functional analysis by over-expression/silencing, using genetic transformation techniques
- Enhancement of banana nutritional quality by manipulating carotenoids biosynthetic pathway genes

- Development and standardization of radiofrequency and microwave generators for effective control of infestation in stored grain products and to enhance the field performance of seeds of problematic crops
- Basic studies on changes at cellular level and changes in nutritional qualities of agri-products exposed to different energies

Nutritional quality improvement and nutrient dynamics

Justification

Incorporation of quality traits such as good *chapati*, baking and pasta qualities in wheat, and aroma and flavour in rice is an important breeding objective. In addition, protein of wheat is deficient in lysine and tryptophan while that of chickpea is deficient in sulphur containing amino acids. Thus, the improvement of protein quality in terms of balanced amino acids is also important. To supplement the breeding efforts, it is now possible to employ genetic engineering tools for quality improvement to adjust the chemical compositions according to the need. Basic studies on the regulation of quality traits need to be strengthened or undertaken to enhance the efficacy of the biotechnological tools. It is desirable to study the microbiological, physical and chemical pathways, mechanisms and processes that regulate the NUE.

Objectives

- To enhance nutritional quality of wheat grains
- Identification of iron-dense and low phytic acid wheat cultivars
- Development of wheat cultivars with enhanced iron bioavailability potential using molecular tools
- Improvement of the availability of phosphorous to the animals
- To understand the accumulation of vitamins, minerals and antioxidants in crop plants
- To study the basic processes of nutrient dynamics in soils, retention-release and use efficiency

Sub-programme

- Biochemical and molecular bases for the regulation of starch biosynthesis in wheat grains
- Biochemical and molecular studies on the mechanisms controlling the level and bioavailability of iron in wheat grains
- Recombinant phytase expression in soybean seeds
- Understanding the basic mechanism involved in synthesis and accumulation of vitamins, minerals and antioxidants in crop plants
- Plant rhizosphere effects on mineral acquisition in sub-optimal nutrient environment and their manipulation for biofortification
- Soil organic matter dynamics and nutrients recycling under cropping systems

Biological nitrogen fixation and biocontrol

Justification

High input production technology has brought in several problems in farming system such as nitrate toxicity of soil and fixed nitrogen to crop plants. Biological nitrogen fixation is likely to minimize exogenous use of nitrogenous fertilizers and provide a strong base for sustainable systems

Objective

- To have an insight into the physiological and molecular mechanisms controlling NUE for selecting efficient genotypes

Sub-programme

- Development of novel genotype of *Rhizobia* for improved nitrogen fixation and *Bacillus* for biocontrol

Impact of climate change and vulnerability assessment

Justification

In the recent past, all over the world, even the best-managed agro-ecosystems are facing the uncertain climate variability emphasizing the need for their documentation, studying their possible impact and devising suitable adaptation strategies to match with the future climate scenarios. Basic processes and adaptation strategies relevant to specific crops and agro-ecosystems under Indian agriculture should be worth pursuing. By the yardstick of irrigation efficiency, much of the agriculture is dependent upon the natural availability of groundwater resources. Changes in the water availability as a result of climatic impacts are generally most detrimental for the effective management of water resources, as climate change increases the level of competition between potential users for water. There is a need to assess these linkages and influences to evaluate the options for managing water more productively for the benefit of all users.

Objectives

- To elucidate the effect of CO_2 enrichment on photosynthesis, growth, WUE and nutritional quality in crop plants and suggest adaptation strategies
- To study the interactive effects of elevated CO_2 and temperature on gaseous exchange, biomass accumulation and partitioning
- To assess groundwater vulnerability and suggest management performance in an integrated irrigation water management framework

Sub-programme

- To study the interactive effect of elevated CO_2 and temperature on gaseous exchange, carbohydrate metabolism and nutritional quality in crop plants
- Identification of various adaptation strategies in crop plants to respond to elevated CO_2 and temperature
- Groundwater vulnerability and adaptability assessment at regional scale, suggest protection and management strategies on quality and availability using physical methods and conceptual modeling

Genomics

Justification

Whole genome mapping and sequencing in the case of rice, *Arabidopsis* and poplar has provided a deep insight into the structure and evolution of these genomes. The sequence information is also greatly facilitating functional analysis of plant genes. DNA chips have been designed and being used to identify genes involved in different developmental, physiological and biochemical pathways. Functional validation of specific genes, however, requires the use of mutants and functional knock-out, by using gene silencing technology. There is an urgent need to design experimental strategies in genomics to develop resources and use them to address specific agricultural problems.

Objectives

- To identify plant genes involved in various developmental, physiological and biochemical pathways
- Functional analysis and validation of genes to identify useful alleles

Sub-programme

- Large-scale EST sequencing in dry land crops and use the sequence information and gene-based SNP markers
- Expression profiling using gene chips/whole genome tiling arrays to identify novel genes
- Development of knock-outs using gene silencing technology for functional validation of genes
- Development of mutants and their use in functional analysis of genes & identification of useful alleles

Molecular breeding

Justification

Molecular breeding has emerged as sub-specialization in biology with considerable development in the area of gene tagging and markers and their application. Molecular markers represent differences at DNA sequence level and are very useful in genome mapping assisted selection. Key to the success of molecular breeding is the availability of sequence based robust markers, amenable to automation. Isolation of target genes and development of allele specific markers such as STMS and SNP would be highly desirable. Besides, to take advantage of the huge germplasm resources, there is a need to undertake association genetic studies and identify new alleles of high agricultural value.

Objectives

- To isolate target genes and develop allele specific markers such as STMS and SNP
- To identify new alleles in germplasm of high agricultural value

Sub-programme

- Development of sequence based robust molecular markers
- Cloning genes of agricultural importance based on their map position and designing allele specific markers

- Carrying out association genetic analysis to identify new alleles in germplasm
- Validation of markers and their use in various molecular breeding applications

Isolation of genes and promoters

Justification

The pre-harvest losses due to insect pests, despite the use of various chemical insecticides and pesticides, are 15% of the total production. Therefore, for the future, it is necessary to develop more environment friendly agriculture, which will have decreased inputs in energy and chemicals and will not generate harmful output such as pesticide residues. A few genetically modified crops using *Bacillus thuringiensis* (Bt) gene for insect pest resistance has a problem of public acceptance as Bt toxin is of non-plant origin. Therefore, it is important to engineer the crops using resistance genes of plant origin. With this view, the genes of plant origin were used for genetic modification of crops plants. Such genes include protease inhibitors, lectins and alpha amylase inhibitor genes. In addition, metabolic engineering of crop plants to produce insect repellent compounds is also a better strategy to slow down the evolution of resistance in insect species such that the engineered plants would not kill the insects. Rapid progress in genomics and unraveling of several metabolic pathways leads to identification of such semi chemical and their biosynthetic genes. To find out the efficacy of such insect repelling compounds and utilization of their biosynthetic genes would be a new direction in genetic engineering for insect resistance. Finally, an integration of both, conditioning the resistance and development of repellence to insect-pests to save crop losses would be the best strategy of crop improvement.

Objectives

- To evaluate the efficacy of insect repelling compounds and use their biosynthetic genes for insect resistance
- Integrated pest management by combining resistance conditioning technology with other technologies

Sub-programme

- Isolation and characterization of agronomically important genes and promoters
- Construction of plant transformation vectors using the isolated genes and promoters
- Genetic engineering of mustard, pigeonpea and other priority crops
- Development of integrated pest management by combining this technology with other technologies

Development of a central facility with modern instrumentation

Justification

In recent years, at international level, spectacular advancements in the frontier areas of research in plant biochemistry and plant biology have been made by the use of modern tools of biochemistry, molecular biology and physical sciences. These have provided a basis for addressing the major challenges in the field of agriculture at the cellular and ultra- structural level worldwide. Physical methods only can give a direct insight into the crop productivity linked ultimate detailing of various processes and parameters, and enable us to peep into the micro world of plants and connect it to the macro phenomenon, with the aim of improving quality traits in crops for export.

Objectives

- To develop an excellent centralized facility with sophisticated state of the art physical instruments
- To promote inter-institutional cooperation and collaboration, for application of physical methods in agricultural research

Sub-programme

- Development of a multidisciplinary centre of excellence with modern instrumentation and foster system research, updating instrumental facilities
- To promote, expand and strengthen education, research and training facilities and develop trained manpower for the application of physical methods in agricultural research

Application of nanosciences in agriculture

Justification

Biomolecules often assemble in cells to yield dynamic complexes with highly ordered structures on the nanometer scale. Thus, nanoscience of cell biology provides an opportunity into the study and manipulation of nanometer-sized objects in agricultural research. Physical microscopy techniques developed to probe materials at the nanometer scale have revolutionalised the characterisation of nanostructures, and are already producing new molecular information and mechanisms in a number of areas in food science. Biosensors can help in identifying pathogens for biotic stress management. Genetic engineering provides a tool for manipulating structure and deducing structure-function relationships in these complex systems. Nanoscience may permit other related analysis methods, such as gel electrophoresis, to be miniaturised through development of nanofabricated artificial gel systems.

Objectives

- To study detailed functioning and response of cells and biomolecules to wide-ranging stimuli and analytic processes
- To produce patterned structures or controlled arrays of molecules for investigating and controlling structural features/function and interaction between specific molecular components and processes in biological complexes

Sub-programme

- Self-assembly in biology
- Biomineralization
- Single molecule crystallography
- Soft condensed matter physics (membranes, proteins, nucleic acids, liquid crystals, colloids)