Report of the

# Quinquennial Review Team

(2009-2016)

of

# Indian Agricultural Research Institute
New Delhi

Indian Council of Agricultural Research
New Delhi-110012

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# Preface

Indian Agricultural Research Institute provides leadership in multiple fronts of agricultural research, education and extension in the country. It has been the premier Institute in the country for propelling agricultural growth through development of new varieties, technologies and their dissemination to the farming community. Hence, the Committee was happy to review its progress of research, teaching and extension education during 2009-16.

The Committee reviewed the progress of the Institute and noted the developments in various spheres of agricultural research which included excellent infrastructure for research in new and emerging areas, and generation of skilled human resource through its post-graduate programme. Inspite of the outstanding achievements, the Institute suffers from several constraints which need to be addressed. The Committee has made recommendations, which if implemented, would help the Institute to maintain and carry forward its legacy in the field of agricultural research, education and extension.

The Chairman and members of the QRT would like to express their gratitude to Dr. S. Ayyappan, the then Secretary, DARE and Director General, ICAR for giving the Committee an opportunity for reviewing the work and to Dr. Trilochan Mohapatra, for his inputs and guidance initially as Director, IARI, and later as Secretary DARE and DG, ICAR. The Committee would like to thank Dr. A.K. Singh, Director, IARI for providing all facilities and logistics during the review process and in preparing the final report. Special thanks are due to Dr. K.V. Prabhu, Ex-Joint Director (R) and Ex-Member Secretary, QRT who shouldered major responsibility of organizing meetings and planning the visits of the Committee to regional stations. The assistance provided by the PME Cell in preparation of the background information for the report is sincerely acknowledged.

(Anupam Verma)
Member

(S. A. Patil)
Member

(P.K. Joshi)
Member

(D.P. Ray)
Member

(J.P. Sharma)
Member Secretary

(Panjab Singh)
Chairman

18/5/18

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# Executive Summary

The Indian Council of Agricultural Research (ICAR) constituted a Quinquennial Review Team (QRT) consisting of Prof. Panjab Singh, President, National Academy of Agricultural Sciences (NAAS) as Chairman and Dr. D.P. Ray, Ex-VC, OUAT, Bhubaneswar, Dr. S.A. Patil, Ex-Director, IARI, Dr. Anupam Varma, Former Dean, IARI, INSA Honorary Scientist and IARI Adjunct Professor, Dr. P.K. Joshi, Ex-Director, NCAP and NAARM and Director, South Asia, IFPRI, South Asia Regional Office, New Delhi as members and Dr. K. V. Prabhu, Joint Director Research, IARI, as member secretary to review the progress of research achievements made by the Indian Agricultural Research Institute during 2009-2016.

Foruteen meetings of the Quinquennial Review Team (QRT) were held to conduct review work. At present, the Institute functions through a network of 19 discipline-based divisions, 2 multidisciplinary centres, and 7 service units in Delhi; 8 regional stations situated at Amartara Cottage, Shimla (HP); Indore (MP); Kalimpong (WB); Karnal (Haryana); Katrain (HP); Pune (Maharashtra); Pusa (Bihar); and Wellington, the Nilgiris (TN); two off-season nurseries situated at Dharwar (Karnataka); and Aduthurai (TN); and a Krishi Vigyan Kendra at Shikohpur, Gurgaon (Haryana). These divisions, centres and regional stations are working in the school mode under six schools namely, School of Crop Improvement, School of Horticulture, School of Basic Sciences, School of Crop Protection, School of Natural Resources Management, and School of Social Sciences.

In the first meeting held in 2015 the QRT finalized the programme of visits. There were seven meetings held at IARI during 2016. In the first two meetings the presentations were given by the then Director and the respective divisional heads on the salient achievement and the future programmes. In subsequent three meetings the team visited all the divisions of IARI and took direct stock of the prevailing research work, the condition of the laboratory and equipments, and the constraints faced by scientists were discussed. The activities of Post Graduate School and those of Finance & Administration of the Institute were also reviewed and discussions held with the representatives of P.G. School Students Union, Master of Halls and Associate Wardens of students' hostels among others. The team also visited IARI Regional Stations at Indore, Karnal, Wellington, Kalimpong, Pusa Bihar and Katrain.

During this period (2009-16), IARI employed cutting-edge science and technologies to develop several crop varieties with improved yield, quality and adaptability, resource management technologies, and pest and disease management methods, farm machineries, protected cultivation methods and food processing techniques for enhancing the input use efficiency, farm profit and environmental sustainability. During this period, IARI has released 27 varieties in cereals, pulses and oil seed crops.

In the school of crop improvement the achievements are as follows:

- In wheat, IARI has released 18 varieties during the reported period, of which 15 were released by Central Sub-Committee on the Crop Standards, Notification and Release of the Varieties for Agricultural Crops, Government of India and four by SVRC. These varieties represented all the six wheat growing zones [i e., NHZ (2), NWPZ (6) NEPZ (3) CZ(3), PZ (2) and SHZ(4)], all three types of cultivated wheat [bread (14), durum (3) and *dicoccum* (1) wheat] and all production conditions (irrigated timely and late sown, rainfed and restricted irrigation and conservation agriculture) of wheat cultivation. The bread wheat variety, HD3086 (Pusa Gautami), resistant to yellow rust and brown rust and superior bread making qualities is the first variety that has been able to significantly yield better than the long standing rust susceptible PBW 343. Subsequently it was released for timely sown irrigated conditions of NEPZ as well. The variety top the list of breeder seed demand and annual production of breeder seed touching the unprecedented mark of 4050 q. IARI has licensed this variety to more than 200 seed companies, including 57 start-ups, and made the seeds available to large number of farmers of the country. Conservation agriculture (CA) has emerged as a technology for environmental and farm output sustainability. For the first time in the world, IARI has bred and released a high yielding bread wheat variety HDCSW 18 specifically bred for CA. HD2967 and other wheat varieties of IARI currently occupy nearly 10 million ha and contribute approximately 50 million tons of wheat to the nation's granary.

- IARI has released seven basmati rice varieties viz. Pusa Basmati 1728, Pusa Basmati 1637, Pusa 1592, Pusa Basmati 1609, Pusa 1612, Pusa Basmati 1509 and Pusa 1612 during this period. Pusa Basmati 1509 and Basmati rice varieties earlier developed by the Institute (Pusa Basmati1, Pusa Basmati 1121) contribute approximately Rs. 20,000 crores annually to forex earning and bring prosperity to Basmati farmers.

- Eight high yielding and biotic and abiotic stress tolerant desi and kabuli chickpea varieties (two by CVRC and 6 by SVRC) viz., Pusa 3043, Pusa 3022, Pusa 2085, Pusa Green 112, Pusa 103, Pusa 1105, Pusa 5023 and Pusa 5028 have been released for commercial cultivation in different agro-ecological regions of India

- For enhancing oil seed production and bringing down the import cost on oil seeds, IARI has released eight varieties *viz.,* Pusa Mustard-24, Pusa Mustard-25, Pusa Mustard-26, Pusa Mustard-27, Pusa Mustard-28, Pusa Mustard-29, Pusa Mustard-30 and Pusa Mustard 31 for various agro-climatic regions of the country. This is the outcome of 89 entries contributed to the AICRP on Rapeseed and Mustard trials during 2009-10 to 2016-17. Twenty nine of which were promoted upto AVT-I and nine to AVT-II. The Pusa Mustard 30 with less than 2% erucic acid and balanced oil quality is one of very essential component under 'Make in India' initiative of Government of India, and has been licensed to M/s Arpan Seeds Private, Ltd., Rajasthan under the Public Private Partnership mode.

In horticultural crops about 40 varieties in important vegetables, fruits and flower been identified/ released.

- The carrot variety carrot "*Pusa Rudhira*", triggered entrepreneurship and profitability to several farmers. The pro-vitamin A rich cauliflower variety Pusa Kesari VitA-1 is suitable for reducing pro-vitamin A deficiency among children. The first indigenous cherry tomato variety Pusa Cherry Tomato 1, suitable for greenhouse cultivation was released.

- Among fruit crops, in citrus, “Pusa Abhinav” acid lime and “Pusa Round” sweet orange were released by the Delhi State Variety Release Committee. In mango, Pusa Pratibha, Pusa Shreshth and Pusa Peetamber were released during 2012, two promising hybrids (H-11-2 &H-11-5) with high pulp content and intense peel colour have been identified. In grape, five early maturing hybrids have been identified which ripen by the last week of May and have high TSS (20-24ºBrix). In flower crops, varieties in gladiolus (Pusa Srijana, Pusa Unnati, Pusa Sindhuri), chrysanthemum (Pusa Kesari, Pusa Adity, Pusa Guldasta, Pusa Chitraksha, Pusa Sona) and marigold (Pusa Bahar) were identified/ released.

The Natural resource management research at the Institute made significant contribution in the area of restoration and improvement of soil health, safe use of wastewater, integrated crop resource management and diversification, precision agriculture for enhanced water and nutrient input use efficiency, crop yield forecasting, drought monitoring and risk assessment, greenhouse gas and air pollution impact assessment and management, agri-residue and biomass and scale neutral farm mechanization.

- IARI has developed Pusa Soil Test Fertilizer Recommendation (STFR) Meter during 2012 which has now been licensed to 12 companies. This STFR was improved during this period to analyze about 12 different soil parameters.

- Toward achieving *more crop per drop*, the Institute has developed and commercialized Pusa Hydrogel. Results revealed that it is useful for enhancing water use efficiency in several crops like groundnut, potato, soybean, mustard, wheat, onion, tomato, cauliflower, carrot, strawberry, opium, maize, sugarcane, paddy, turmeric, chrysanthemum, cotton, etc. The technology has been licensed to several private companies.

- Direct sown rice with mungbean residue followed by rice residue (RR) retention in ZTW followed by ZT summer mungbean with wheat residue system was found to yield significantly higher system productivity, water productivity, net returns and could also reduce global warming potential as compared to the conventional Rice-Wheat system.

- Developed and successfully tested the performance efficiency of novel nano delivery systems for restoration of soil N, P, Zn and B.

- Keeping in view of the importance of water and energy security under changing climatic conditions, to utilize the large quantities of wastewaters for agricultural purpose, a zero energy eco-friendly waste-water treatment technology and a facility (with capacity to treat 2.2 million litres per day of wastewater) based on this technology were developed. It was out scaled to Mathura, UP for treating 75000 litres of sewage water per day. This first ecofriendly waste water treatment plant is under construction at Pandit Deen Dayal Upadhyay Dham at Farah, UP.

- Varied soil moisture measuring techniques (such as relative water content, gypsum block, tensiometer, infrared thermometer, TDR, and FDR and Drone based techniques) were standardized and cross compared for development of precision irrigation method. Efficient surface irrigation operating guidelines were developed for sandy loam soil type.

- A number of indices and suit of technologies for real time crop condition monitoring were developed and tested across regions and seasons. Techniques for near real time meteorological, hydrologic and agricultural drought monitoring were developed and validated.
- A near real time crop yield forecasting technique for forecasting wheat yield across Punjab and Haryana was developed and validated.
- A number of pest and disease forecasting tools were also developed and validated.
- Global Warming Potential (GWP) of Rice-Wheat System in Indo-Gangetic Plains (IGP) was quantified. Estimates confirmed that Rice-Rice system has higher GWP than rice-wheat system and that emission per ton of production is highest in the Lower IGP compared to the Upper IGP.
- Diversified uses of Azolla biomass in relation to nutritional quality for its efficient utilization as feed supplement and value added products were explored. Investigations revealed that levels of important nutritional indicators remained more or less the same round the year despite differences in biomass production and frond color changes.
- Microbial consortium for ex-situ rapid composting of diverse agri-residues at low temperature were also isolated and tested.
- For precision irrigation management, a DSS integrated with soil moisture sensor for real time irrigation scheduling either on time basis or soil moisture sensor basis has also been developed and tested in six vegetable crops viz. okra**,** tomato, brinjal, broccoli, potato, and knol-khol. Water savings of 39 to 49 % was achieved using automated drip irrigation over manually controlled check basin irrigation for all the six vegetable crops.
- A number of machines such as Gladiolus planter, Seed cum fertilizer plot drill, precision paddy planter for direct seeding, Compost making/ turning machines and a machine for growing wheat under System of Wheat Intensification were developed and successfully validated.

The crop protection research at the Institute during this period focused on diversity analysis, diagnostics and integrated management of nationally important pests and pathogens, and agrochemicals design and discovery.

- A microarray chip with 1572 probe sets was developed for detection of all the known plant viruses and viroids. The chip has been validated for detection of viruses and viroids in cowpea, mungbean, urdbean, chilli, tomato and grapevine. This will be very useful in plant quarantine. Similarly molecular diagnostic methods were developed for fungal (*Puccinia striiformis tritici*, *Tilletia indica*, *Fusarium fujikuroi* and *Magnaporthe oryzae*), bacterial (*Ralstonia solanacearum*, *Bacillus* spp.) and viral pathogens (Potato virus X and S; begomoviruses species, namely, ToLCNDV, ToLCBV, ToLCPalV, ToLCGV and ToLCJoV infecting tomato; Garlic Leek yellow stripe virus and common latent virus; Grapevine leaf roll-associated virus; Large cardamom chirke virus) for early diagnosis.

- RNAi technology has been successfully utilized for management of root knot nematode *Meloidogyne incognita* in brinjal. Transgenic brinjal events expressing flp18, flp14, msp1, msp18, msp20 and msp40 are in various stages of development. An international patent covering 148 countries has been filed for the nematode resistant transgenics developed using this technology.

- RNAi technology was also developed for control of insect pests viz., tobacco caterpillar *S. litura*, cotton bollworm *Helicoverpa armigera* and green peach aphid *Myzus persicae*.

- Formulations such as novel chalcone and thiadiazole derivatives having antifungal activity, Hydrogel based combo formulations of *Trichoderma harzianum* for management *Rhizoctonia solani*, controlled release nano-formulations of thiamethoxam for better control of white fly in soybean and a novel schiff base GS 21 to induce systemic acquired resistance (SAR) against rice sheath blight control were developed.

- Entomopathogenic nematodes like *Heterorhabditis indica* infecting *Galleria mellonella* were found to be effective for biocontrol of white grubs in sugarcane and apple. This is now widely adapted by farmers.

The School of Basic Sciences has made significant progress in identification of donors and understanding the mechanisms of abiotic stress tolerance in rice and wheat, and the nutritional quality improvement in soybean.

- For effective use of the genomics for crop improvement, phenotyping remains a rate limiting step. To bridge the phenotype-genotype gap, IARI has established a state-of-art automated high throughput plant phenomics facility for non-destructive and accurate characterization of a large number of germplasm under defined environmental conditions and for developing abiotic stress tolerant genotypes.

- Hyperspectral reflectance based non-destructive, high throughput method was developed to phenotype drought tolerance (RWC) in rice and wheat.

- An imaging system was developed for rapid and non-destructive field phenotyping of biomass by capturing side view image profiles between crop rows in wheat and rice.

- Phenotyping of large number of rice and wheat germplasm for drought and heat tolerance and nutrient use efficiency led to the identification of several donors. Nerica L 44 was identified as better donor parent as compared with Nagina 22 for both day and night high temperature stress tolerance in rice.

- Transcriptome analysis and genome-wide bioinformatic analyses were carried out to identify genes and gene networks associated with stress tolerance in wheat and rice. A heat stress regulated Rubisco activase (RCA) gene, which is necessary for maintaining photosynthesis under heat stress, has also been cloned from wheat.

- Large-scale gene function validation using transgenic and genome editing is in progress to identify genes for "*more crop per drop*" and drought tolerance in rice. Molecular and physiological analysis of T2 transgenic rice lines over-expressing plant stress hormone receptor (ABA receptor 6) gene and *ICE1 transcription factor* gene showed the potential of these genes in improving drought tolerance through enhanced stomatal closure, reduced water requirement and enhanced cellular tolerance to low tissue water content.

- Every year India produces about 6 million tonnes of soymeal which is a very good source of supplemental protein for humans, livestock and poultry. However, soymeal contains an anti-nutrient called phytate which reduces bioavailability of P and micronutrients. Metabolic pathway engineering approaches are being used to reduce phytate in soybean. Soybean transgenic RNAi silencing lines of *MIPS* gene and over-expression lines of *PHYTASE* showed significantly low seed phytate content and enhanced bioavailability of minerals viz, Fe, Zn & calcium.

- The work on CRISPR/Cas9 based genome editing for enhancing abiotic stress tolerance of rice and nutritional quality of soybean has been initiated.

The School of Social Sciences made significant contribution in studies on policy reforms and development of agricultural markets analyzed the variation in progress of agricultural marketing reforms in different states, development of innovative extension models, transfer of IARI technologies through collaboration with various extension agencies, and training of extension officials and farmers.

- The IARI Post Office Linkage Extension Model was designed and validated for effective outreach mechanism for frontline extension system. An innovative IARI Post Office Linkage Extension Model was validated in five locations including Sitapur (UP), Buxar (Bihar), Sheopur (MP), Sirohi (Rajasthan) and Jammu (Jammu & Kashmir) for effective dissemination of farm information to the remotely located farmers. This model has connected 130 post offices in 56 districts of 13 states. The model has been found as an effective and successful means for making improved agricultural technologies available in the rural areas in relatively lesser time and cost. With Branch Post Masters serving as para extension workers KVKs offering technological back-up led to enhanced availability of good quality seeds to the farmers at their doorstep at right time and affordable price in various parts of the Country.

- Climatic risk analysis of selected villages in West Bengal revealed risk to the climate led hazard specially flood was very high in terms of its probability (30%), exposure (24.67%) and consequences (31.33%) in the area. Developed content for paddy varieties for voice bases SMS. Voice based SMS was sent to the farmers of Vaishali district of Bihar.

- An analysis of the pluralistic extension models of India covering ATMA, KVK, ICT – based, community-based, livelihood-based, Public-Private-Partnership based extension models and *Krishi Mahotsav* revealed the convergence, skill development, instant and high fidelity of information and acceleration of extension service delivery.

- Six Capacity building Modules identified through training need analysis were designed, developed and are being subjected to content validation by self Help Group Members. The designed modules include Motivation, Leadership, Financial management and use of ICT. Self rating scale was developed for assessment of new learning taken place, utility, appropriateness and overall satisfaction with the module. Knowledge tests were finalized for selected components of the modules.

- A study of entrepreneurship development revealed best practices: opportunity recognition in reference to abundance of available resources, capitalizing on one's own prior knowledge or skills, hygiene and strict adherence to quality standards; facilitative factors: seeking adequate technical knowledge through interaction with experts, entrepreneurial competencies of farmers, available opportunities, optimum utilization of available resources; and inhibitive factors: lack of entrepreneurial competencies, timely non availability of critical inputs, non availability of critical technical guidance at the opportune time.
- Agricultural Technology Information Centre (ATIC) is effectively providing products, services, technologies and information services to the different stakeholders through a '*Single Window Delivery System*'. Each year about 40,000 farmers and other stakeholders receive farm advice through *Kisan Call Centre* and the *Pusa Agricom* facility of the Institute.
- Every year, the Institute has organized Krishi mela (Agricultural Fair) with over one lakh visitors. IARI has directly sold large quantity of quality seeds of improved varieties to large number of farmers.

The Indian Agricultural Research Institute has a glorious record of being a centre of excellence in higher education and training in Agricultural Sciences.

During the review period, 1152 M.Sc., 57 M.Tech. and 1373 Ph.D. students including 155 foreign students were admitted to Post Graduate School. The Institute awarded M.Sc., M.Tech. degrees and Ph.D. degrees to 878, 110 and 739 students, respectively, which include 49 foreign students for M.Sc. degree, 2 M.Tech. and 53 for Ph.D. degree. IARI has a student Placement Cell, and need based Institute-Industry meets have been arranged for career counselling and placing outgoing students in the jobs of their choice. Most of IARI students because of their skills got selected in ARS or went overseas for higher studies. Several national and international short-term training courses (regular, *adhoc* and individual) and refresher courses were conducted in specialized areas for the scientists of NAREES. As a tribute to Prof. M.S. Swaminathan and his dedicated global services to agricultural sciences & the eminent scientist & father of Green Revolution of India, name of IARI Library was renamed as "Prof. M.S. Swaminathan Library on 29$^{th}$ April 2016. Library is one of the 10 best agro-biological libraries of the world. Library provided the services as lead centre to all ICAR institutes/SAU & International institutes. During 2014-15 initiated the IARI Ph.D. outreach programme at Indian Institute of Horticultural Research, Bengaluru in four disciplines namely, Floriculture & Landscape Architecture, Fruit Science, Vegetable Science and PHT and at Central Institute of Agricultural Engineering, Bhopal in the sub-disciplines of Agricultural Processing & Structure and Farm Power & Equipment. During 2015-16 onwards admitted M.Sc. students for IARI, Jharkhand and Assam in five disciplines, namely Agronomy, Genetics and Plant Breeding, Soil Science and Agricultural Chemistry, Vegetable Science & Water Science & Technology. PG School, IARI is actively involved in establishing: i) Afghan National University of Agricultural Sciences and Technology (ANASTU), Afghanistan; ii) Advanced Centre for Agricultural Research and Education. Yezin Agricultural University, Myanmar; and iii) Institute of Life and Earth Sciences, Pan Africa University, in Ibadan, Nigeria. During 2009-2016, forty faculty members were awarded the Best Teacher Awards for their untiring efforts in improving the teaching in different subjects. Several awards like Rao Bahadur Dr. B.Viswanath award, Dr. A.B.Joshi award, Hooker Award, Dr. B.P. Pal Memorial Award, Hari Kishan Shastri Memorial Award, Sukumar Basu Memorial Award are given by the Institute to promote excellence in agricultural research in the country. Also the faculty members of the Institute have been honoured with various awards like Om Prakash Bhasin Award, VASVIK Award, Rafi Ahmed Kidwai Award and Hari Om Ashram Award.

Apart from this the Institute has obtained NIRF ranking, and won the Agriculture Leadership Award 2009 instituted by the publishers of "Agriculture Today". Outstanding ICAR Institution Award for the year 2010, Environment Leadership Award of Agriculture Today, 2011, Best Agribusiness Incubator Award at the "2nd Global Agribusiness Incubation Conference – NITBI, 2012, Gold Flame Award, 2015, mBillionth Award Sou th Asia 2016, Gold Flame Award Asia, 2016.

Based on the review of research, technology development, education and extension activities carried out during the period April 2009 to March 2016, and keeping in view the goals of the institute and needs of the farming community, the following **recommendations** are made:

- Strengthen public-public and public-private partnership, strategies to manage biotic and abiotic stresses on crops through interdisciplinary research.
- Create an Accelerated Breeding Centre, a large scale seed storage facility, strengthen and effective use of Plant Phenomics facility.
- Upgrade the pesticide testing laboratory (NABL accredited), and applications of drones, remote sensing and artificial intelligence (AI) in agriculture.
- Develop technologies and designs for different types and capacities of storage systems at farm-gate or local community level along with low-cost cold-storage transport systems employing solar/wind energy.
- Strengthen research on pre-breeding for biotic and abiotic stress tolerance for fruits, vegetables and flowers.
- Thrust on development of technologies/options for Integrated farming system specifically for rainfed and low-water situations of North-western, Central and North Eastern sectors and up scaling of precision agronomy research and conservation agriculture research for different ecologies and cropping systems.
- Waste water and agricultural residue management should get emphasis in R &D.
- Development of alternative extension and agri-business models through Startups / Farmer Producer Organization (FPO)/ Woman or Farmer enterprises/ cooperatives etc.

- A proper transfer policy needs to be evolved for scientists between Delhi and its 10 outstations. There has to be term transfer at all approved cadres with a ready replacement.
- Training of technicians for high end equipments, one time catch up grant, maintaining a healthy ratio between scientists and technical staff.
- Establish tele-conferencing facility with the HoDs and the Regional Station Heads.
- Rename Centre for Environment Science and Climlate Resilient Agriculture (CESCRA) as Division of Environmental Sciences and Division of Fruits and Horticulture Technologies as Division of Fruit Science.
- Regarding regional stations, (i) Pusa Bihar station needs to be upgraded in view of the importance of the region as well as its location being in the priority region for agricultural development and (ii)Amartara and Tutikandi at Shimla needs to be made independent.
- Initiate Post-Doctoral research and sandwich Ph.D. programme; promotion of faculty improvement programmes and establishing a few Chairs of eminence like those in Central Universities.
- Focus on scientific data management across divisions and regional stations.

# Introduction

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. The post-graduate school of IARI was established in 1958 when UGC granted it the status of "Deemed to be University". The post-graduate school of IARI even today is one of the centre's of excellence in agricultural studies. Over a century, the Institute had accepted challenges and provided solutions to various agricultural issues faced by the country by moulding its mandate, plans and programmes. The Institute has played an unparalleled role in changing the face of agricultural research, education and extension in the country.

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 forum. The Institute has geared up with research progrmames to address some of these issues with the available manpower and resources. With the growth of Science and availability of voluminous data the Institute is growing vertically with an increased thrust on strategic and basic researches to generate neo scientific knowledge, technology and product development and is able to withstand every kind of competition in its field. Along with crop Improvement and breeding, the Institute is focussing on Basic, strategic and anticipatory research in field and horticultural crops for enhanced productivity and quality. A lot of is being done on research in frontier areas to develop resource use efficient integrated crop management technologies for sustainable agricultural production system, besides serving as centre for academic excellence in the areas of post-graduate and human resource development in agricultural science, and provide national leadership in agricultural research, education, extension and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards. To address these mandates, the Institute has categorized its research programmes in four groups. A) Flagship programmes, B) Mandated programmes, C) Outreach programmes, D) Strengthening and Modernizing Research Facilities, and E) Programmes for NEH and TSP. Besides these programmes, other topical research issues will be addressed through F) ICAR Research Consortia Platform. The human resource development will be addressed by G) PG School, IARI.

Currently the institute's scientist's strength is 510 against the sanctioned strength of 578. Category wise details with regard to the Head Quarters are depicted in Table 1.

**Table 1: CONSOLIDATED STATEMENT OF IARI/DIVISIONS/CENTRES/PROJECTS/ REGIONAL STATIONS**

| NAME OF THE DIVISIONS/ PROJECTS AND STATIONS ETC. | *SANCTIONED STRENGTH* | | | | *SCIENTIST IN POSITITON* | | | | *VACANT POSITION* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCI. | SR. SCI. | PS | TOTAL | SCI | SR. SCI | PS | TOTAL | SCI | SR. SCI | PS | TOTAL |
| | 1 | 2 | 3 | 4 | 6 (ABCDE) | | 8 | 9 (6+7+8) | 10(6-1) | 11(7-2) | 12(8-3) | 10+11 +12 |
| ***A- HEADQUARTER*** | | | | | | | | | | | | |
| IARI, DIVISIONS | 278 | 132 | 51 | 461 | 290 | 106 | 30 | 426 | 12 | -26 | -21 | -34 |
| IARI, CENTRES | 18 | 7 | 5 | 30 | 18 | 5 | 0 | 23 | 0 | -2 | -5 | -7 |
| IARI, PROJECTS | 3 | 2 | 2 | 7 | 2 | 0 | 1 | 3 | -1 | -2 | -1 | -4 |
| ***TOTAL*** | ***299*** | ***141*** | ***58*** | ***498*** | ***310*** | ***111*** | ***31*** | ***452*** | ***11*** | ***-30*** | ***-27*** | ***-45*** |
| ***B- REGIONAL STATION*** | | | | | | | | | | | | |
| IARI,R.S. STATIONS | 38 | 29 | 7 | 74 | 36 | 16 | 3 | 55 | -2 | -13 | -4 | -19 |
| ***SUB-TOTAL(A+B)*** | ***337*** | ***170*** | ***65*** | ***572*** | ***346*** | ***127*** | ***34*** | ***507*** | ***9*** | ***-43*** | ***-31*** | ***-65*** |
| ***(+) EXCESS (-) VACANT*** | | | | | | | | | | | | |
| ***R.M.P POSTS*** | ***SANCTIONED -*** | | | ***6*** | | | | ***3*** | ***VACANT - 3*** | | | |
| ***GRAND TOTAL*** | | | | ***578*** | | | | ***510*** | | | | ***-68*** |

A division wise statement of the scientific manpower at IARI is given in Table 2, which is depicting the sanctioned, in position and vacant numbers.

**Table 2: SCIENTIFIC MANPOWER AT IARI**

| *DIVISION-WISE STATEMENT* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sanctioned posts** | | | | **Scientist in Position** | | | | **Vacant Posts** | | | |
| **Names of the Divisions/ Units Etc.** | **SCI** | ***SR. SCI*** | **PS** | **TOTAL** | **SCI** | **SR. SCI** | **PR. SCI** | **TOTAL** | **SCI** | **SR. SCI** | **PR. SCI** | **TOTAL** |
| | *1* | *2* | *3* | *4* | *6 (ABCDE)* | | *8* | *9 (6+7+8)* | *10 (6-1)* | *11 (7-2)* | *12 (8-3)* | *10+11+12* |
| AGRONOMY | 16 | 6 | 3 | 25 | 16 | 9 | 3 | 28 | 0 | 3 | 0 | 3 |
| GENETICS | 33 | 28 | 8 | 69 | 34 | 20 | 4 | 58 | 1 | -8 | -4 | -11 |
| PLANT PHYSIOLOGY | 12 | 3 | 1 | 16 | 12 | 2 | 1 | 15 | 0 | -1 | 0 | -1 |
| SEED SCI. & TECH.* | 10 | 5 | 3 | 18 | 8 | 6 | 1 | 15 | -2 | 1 | -2 | -3 |
| NEMATOLOGY | 13 | 4 | 2 | 19 | 14 | 4 | 1 | 19 | 1 | 0 | -1 | 0 |
| BIOCHEMISTRY | 09 | 3 | 2 | 14 | 9 | 1 | 1 | 11 | 0 | -2 | -1 | -3 |
| ENTOMOLOGY | 18 | 6 | 2 | 26 | 15 | 4 | 1 | 20 | -3 | -2 | -1 | -6 |
| FRUIT & HORT.TECH. | 09 | 5 | 2 | 16 | 11 | 5 | 1 | 17 | 2 | 0 | -1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEGETABLE SCIENCES | 12 | 5 | 2 | 19 | 13 | 6 | 3 | 22 | 1 | 1 | 1 | 3 |
| FLORI.& LAND SCAPP. | 11 | 4 | 2 | 17 | 12 | 3 | 0 | 15 | 1 | -1 | -2 | -2 |
| F.S. & PHT | 04 | 2 | 1 | 7 | 8 | 3 | 0 | 11 | 3 | 1 | -1 | 4 |
| **(A)** MICROBIOLOGY | 10 | 6 | 2 | 18 | 11 | 4 | 1 | 16 | 1 | -2 | -1 | -2 |
| **(B)** B.G.ALGAL | 05 | 2 | 1 | 8 | 3 | 2 | 0 | 5 | -2 | 0 | -1 | -3 |
| AGRIL. EXTENSION | 10 | 8 | 2 | 20 | 11 | 5 | 1 | 17 | 1 | -3 | -1 | -3 |
| AGRIL. ECONOMICS | 11 | 5 | 3 | 19 | 12 | 4 | 3 | 19 | 1 | -1 | 0 | 0 |
| PLANT PATHOLOGY | 18 | 8 | 4 | 30 | 18 | 11 | 3 | 32 | 0 | 3 | -1 | 2 |
| AGRIL ENGINERING | 16 | 9 | 3 | 28 | 16 | 3 | 1 | 20 | 0 | -6 | -2 | -8 |
| SOIL/SCI/AG/CHEM. | 18 | 6 | 2 | 26 | 20 | 2 | 1 | 23 | 2 | -4 | -1 | -3 |
| AGRIL. CHEMICALS | 14 | 3 | 2 | 19 | 15 | 4 | 1 | 20 | 1 | 1 | -1 | 1 |
| CESCRA (ENV. SCI.) | 12 | 5 | 1 | 18 | 15 | 2 | 1 | 18 | 3 | -3 | 0 | 0 |
| SPU | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| AGRI. PHYSICS | 10 | 5 | 1 | 16 | 9 | 3 | 1 | 13 | -1 | -2 | 0 | -3 |
| CPCT | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | -1 | 0 | -1 |
| **OUT REACH EXT** | | | | | | | | | | | | |
| (A) CATAT | 4 | 0 | 0 | 4 | 4 | 2 | 0 | 6 | 0 | 2 | 0 | 2 |
| (B) ATIC | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 3 | 1 | 1 | 0 | 2 |
| NAT. PHYTOTRON FACILITY | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | -1 |
| DIRECTORS OFFICE | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| FLEXI DISCIPLINE | 0 | 3 | 2 | 5 | 0 | 0 | 1 | 1 | 0 | -3 | -1 | -4 |
| TOTAL | **278** | **132** | **51** | **461** | **290** | **106** | **30** | **426** | **12** | **-26** | **-21** | **-34** |

**(+) EXCESS (-) VACANT**

**Note: *Including (6 post of CSTF(PS-1,SR.SCI.-2, SCI.-3)**

Category wise statement of scientific staff at the regional stations is given in Table 3. Total sanctioned is 74, filled up post is 55 and 19 posts are vacant.

**Table 3: STATEMENT OF SCIENTIFIC STAFF IN IARI REGIONAL STATIONS/CENTRES**

| REGIONAL STATIONS | SCI. | SR. SCI. | PS | TOTAL | SCI | SR. SCI | PS | TOTAL | SCI | SR. SCI | PS | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *6 (ABCDE)* | | *8* | *9 (6+7+8)* | *10 (6-1)* | *11 (7-2)* | *12 (8-3)* | *10+11+12* |
| R.S.INDORE | 5 | 3 | 1 | 9 | 4 | 3 | 0 | 7 | -1 | 0 | -1 | -2 |
| R.S.KATRAIN | 6 | 3 | 1 | 10 | 7 | 0 | 0 | 7 | 1 | -3 | -1 | -3 |
| R.S.KARNAL | 8 | 6 | 1 | 15 | 9 | 1 | 1 | 11 | 1 | -5 | 0 | -4 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R.S.PUNE | 2 | 3 | 1 | 6 | 2 | 4 | 0 | 6 | 0 | 1 | -1 | 0 |
| R.S.PUSA BIHAR | 4 | 6 | 1 | 11 | 3 | 0 | 0 | 3 | -1 | -6 | -1 | -8 |
| R.S.KALIMPONG | 3 | 1 | 0 | 4 | 2 | 1 | 0 | 3 | -1 | 0 | 0 | -1 |
| R.S.ADUTHURAI | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 3 | 0 | 0 | 1 | 1 |
| R.R.C., DHARAWAD | 1 | 1 | 0 | **2** | **0** | 2 | 0 | **2** | -1 | 1 | 0 | **0** |
| R.S.WELLINGTON | 4 | 2 | 1 | **7** | **6** | 2 | 0 | **8** | 2 | 0 | -1 | **1** |
| R.S.AMARTARA & | 4 | 3 | 1 | **8** | **2** | 2 | 1 | **5** | -2 | -1 | 0 | **-3** |
| TUTIKANDI, SHMILA | | | | | | | | | | | | |
| ***TOTAL*** | ***38*** | ***29*** | ***7*** | ***74*** | ***36*** | ***16*** | ***3*** | ***55*** | ***-2*** | ***-13*** | ***-4*** | ***-19*** |
| **(+) EXCESS (-) VACANT** | | | | | | | | | | | | |

The technical and administrative staff includes 458 technical and 329 administrative positions as shown in Table 4 and Table 5 respectively.

**Table 4: Position of Technical Personnel**

| Sr. no. | Category/Grade | Sanctioned Strengths | PIP | Vacant Posts |
|---|---|---|---|---|
| 1 | Cat.III/T-6 | 19 | 11 | **8**<br>*All the 5 posts reported to ASRB<br>* 3 posts vacated during the year 2016-17 |
| 2 | Cat. II/T-3 | 290 | 175 | **115**<br>*71 posts under<br>Recruitment Process<br>*11 posts deemed abolished (2006-07/07-08 & 09-10)<br>*27 post reported to ASRB<br>*06 post vacated between 01.04.2017 to 31.08.2017 |
| 3 | Cat.-1/T-1 | 360 | 272 | **88**<br>*39 posts under Recruitment Process<br>*5 post reported to ASRB<br>*18 posts deemed abolished (2006-07/07-08 &09-10)<br>*5 posts offered issued under Deptt. Quota (conditional Acceptance)<br>*4 posts ST backlog under 33.3% Deptt. Quota<br>*3 posts under process 33.3% Deptt. Quota<br>*14 post vacated between 28.03.2017to 30.09.2017 |
| | **Total** | **669** | **458** | **211** |

**Table 5: Administrative Staff strength**

| POST | GRP | SANC. | FILLED | TOTAL VACANT | SC | ST | Male | Female |
|---|---|---|---|---|---|---|---|---|
| **JD(A)/ Registrar** | A | 1 | 0 | 0 | | | 0 | 1 |
| **C.Ad.O.** | A | 2 | 2 | | | | 2 | 0 |
| **Comptroller** | A | 1 | 1 | | | | 1 | |
| **CF&AO** | A | | | | | | | |
| **SAO** | A | 2 | 1 | | 0 | 0 | 1 | 0 |
| **AO** | A | 6 | 6 | | 1 | | 5 | 1 |
| **F&AO** | A | 3 | 3 | | 1 | 1 | 1 | 2 |
| **Sr. FAO** | A | 1 | 0 | 1 | 0 | | 0 | |
| **Dy. Dir. (OL)** | A | 1 | 1 | | 1 | | 1 | |
| **Asstt.Dir (OL)** | A | 1 | 1 | | 1 | | 0 | 1 |
| ***Sub Total*** | ***A*** | ***18*** | ***15*** | | | | | |
| **AAO** | B | 42 | 40 | 1 | 10 | 8 | 34 | 6 |
| **AF&AO** | B | 5 | 1 | 4 | | | | 1 |
| **Asstt.** | B | 144 | 130 | 17 | 21 | 10 | 76 | 54 |
| **PS** | B | 37 | 35 | 2 | 5 | 1 | 14 | 21 |
| **PA** | B | 16 | 0 | 16 | | | | |
| **ALA** | B | 1 | 1 | 0 | 0 | | 1 | |
| ***Sub Total*** | ***B*** | ***245*** | ***207*** | **41** | | | | |
| **St. Gd. III** | C | 11 | 8 | **3** | 1 | | 3 | 5 |
| **UDC** | C | 91 | 66 | **24** | 6 | 0 | 50 | 16 |
| **LDC** | C | 61 | 33 | **27** | 7 | 3 | 26 | 7 |
| ***Sub total*** | ***C*** | ***163*** | ***107*** | **54** | | | | |
| **Total** | | **426** | **329** | **95** | | | | |

**Including one post of St. Grade III at KVK in the total sanctioned post of St.Grade III**
**Excluding one post of asstt at KVK in the total sanctioned post of asstt**
**9 posts to be filled in feeder cadre i.e. LDC under GFR 254**

**Quinquennial Review Team (QRT)**

In consonance with the policy of the Indian Council of Agricultural Research of quinquennial review of its institutes, the QRT was constituted under the Chairmanship of Prof. Panjab Singh, Ex-DG, ICAR & President, FAARD dated 3rd November 2015 and even number dated December 27th November 2015.

**Composition of QRT**

Two members of the QRT team namely, Dr. R.P. Sharma, Ex-PD, NRCPB and Dr. S.R. Singh, Ex-VC, RAU, Bihar could not be part of the team due to prior commitments. Hence their names were excluded from the list. In place of Dr. T. Mohapatra, Director, IARI, Dr. K.V. Prabhu was nominated as Member Secretary.

The final composition of the QRT is given below:

1. Prof. Panjab Singh, Ex-DG, ICAR and President FAARD - Chairman
2. Dr. D.P. Ray, Ex-VC, OUAT, Bhubaneshwar - Member
3. Dr. S.A. Patil, Ex-Director, IARI and Former Chairman, KK Mission, Govt. of Karnataka - Member
4. Dr. Anupam Varma, Ex-National Professor, IARI, INSA Honorary Scientist and IARI Adjunt Professor – Member
5. Dr. P.K. Joshi, Ex-Director, NCAP and NAARM and Director, South Asia, IFPRI, South Asia Regional Office, -Member
6. Dr. K. V. Prabhu, Joint Director Research, IARI-Member Secretary

**Visits of QRT**

In all thirteen meetings of the Quinquennial Review Team (QRT) were held during 2009-2018 to review the work of IARI. The first meeting was held on 4.12.2015 in the Chamber of the Director, IARI. During the discussions, the QRT members obtained first hand information from the various project directors/heads of divisions of IARI and apprised them as to how the QRT will proceed with the review of the work of various divisions, etc. In the subsequent meetings, the QRT visited at different periods of time, Fruits & Horticultural Technology; Vegetable Science; Floriculture & Landscaping; Microbiology; Centre for Protected Cultivation Technology (CPCT); Divisions of Biochemistry; Plant Physiology; Genetics; Seed Science and Technology; Seed Production Unit; Agricultural Economics; Agricultural Extension; Centre for Agricultural Technology Assessment and Transfer (CATAT); Agricultural Technology Information Centre (ATIC); Zonal Technology Management (ZTM); Plant Pathology/Virology; Nematology; Agricultural Chemicals; CESCRA; Agricultural Physics; Farm Operation & Service Unit/OHLU; Agricultural Engineering; Agronomy; Soil Science & Agricultural Chemistry; Water Technology Centre; Entomology;

The activities of Post Graduate School and those of Finance & Administration were also reviewed and discussions held with the representatives of P.G. School Students Union, Master of Halls and Associate Wardens of students' hostels among others. In the eighth meeting held on 7-9 November 2016 the information received from various divisions/units/stations was handed over to the QRT members. Details of schedule of QRT meetings and visits are given in Annexure III.

**Fig. 1: Glimpses of QRT monitoring at IARI Regional Station, Katrain**

## Fig. 2: Glimpses of QRT monitoring at Pusa Bihar

# History of the Institute

## Establishment and Development

IARI, popularly known as Pusa Institute, has a history of more than 100 years and development of organized agricultural research and education in India is the culmination of some historical events. The Institute was initially established at Pusa in Bihar on the bank of river Gandak in 1905, largely financed from a generous donation of £30,000 received by Lord Curzon from his American Philanthropist friend, Mr. Henry Phipps of Chicago (USA). The Institute started with five sections, viz., Agriculture and Cattle Breeding, Chemistry, Economic Botany, Entomology, and Mycology. In 1907, a section of Bacteriology was created. The Institute was renamed as Imperial Institute of Agricultural Research in 1911 and as Imperial Agricultural Research Institute in 1919.

The institute shifted to Delhi during 1934 due a devastating earthquake at Bihar. With the dawn of India's Independence, the Institute was renamed Indian Agricultural Research Institute (IARI). The Institute was conferred the Deemed-to-be University status in 1958 under the UGC Act 1956 and its administrative control was shifted to ICAR from April 1966.

## The IARI campus

The present campus of IARI is a self-contained aesthetically laid out sylvan complex spread over an area of about 500 ha. The beautiful clock-towered building of the Central Library of the Institute constitutes the focal point of the campus around which stand the laboratory buildings of various Divisions, staff quarters, students' hostels, guest houses, a medical dispensary and schools for boys and girls. The experimental fields, which form an integral part of the IARI campus, cover an area of about 340 ha, of which about 300 ha is irrigated by an interlinked chain of tubewells, water storage tanks, while the remainder is used for dryland farming research experiments.

## Growth of Regional Stations

In 1939, the concept of Regional Stations emerged to tackle regional problems. The Institute established Regional Stations at Pusa (Bihar), Sirsa and Karnal (Haryana), Shimla and Katrain (Himachal Pradesh), Bhowali (Uttaranchal), Wellington (Tamil Nadu), Indore (Madhya Pradesh), Kalimpong (West Bengal) and Pune (Maharashtra). Initially, the centres at Kanpur and Hyderabad were PIRRCOM stations which were subsequently given the status of Regional Stations. These stations conducted basic and strategic research on a wide range of subjects including horticultural technology, wheat and barley breeding, virus research, seed technology, pulse research, etc. The mandate of Regional Stations is to provide the much needed support in the form of materials, technology or off-season nurseries to scientists all over the country. Two stations located at Aduthurai (Tamil Nadu) and Dharwad (Karnataka) serve as off-season nurseries. The Regional Station at Flowerdale, Shimla of IARI, which was created as a national facility to support wheat breeding programme against rusts, was transferred to the Directorate of Wheat Research at Karnal. Similarly, the IARI Regional Stations at Kanpur, Sirsa and Bhowali were handed over to Indian Institute of Pulses Research, Central Institute of Cotton Research and Vivekananda Parvatiya Krishi Anusandhanshala, respectively, for research on pulses, cotton and wheat.

**Growth of Divisions**

The original five sections established during the British era later developed into Divisions in the year 1945. A more extensive growth of IARI and its Divisions started following the Independence. Now, the research activities are carried out through 19 Divisions. Thus, it is the growth of Divisions which has made IARI one of the largest institutions of its kind not only in India but also in the world.

**Growth of specialized laboratories**

Along with the general Divisional Laboratory facilities, the Institute takes pride in having developed sophisticated specialized laboratories in all the fields of agricultural sciences. Realizing the need for interdisciplinary and advanced research, the Institute expanded its infrastructure by creating the following facilities:

**The Nuclear Research Laboratory**, a multi-disciplinary unit was established in 1969, **Water Technology Centre** was established in 1970 for research and training on integrated management of water, soil and crop, including engineering for water management, **National Plant Biotechnology Centre** in the country was established in 1985. It is equipped with highly sophisticated equipment for working in the areas of molecular biology, recombinant DNA, cloning and sequencing of genes and genomes, tissue culture, plant transformation and somatic hybridization. In 1988, the Institute created an **Advanced Centre for Plant Virology** in the Division of Plant Pathology for generating basic knowledge on economically important plant viruses and virus like pathogens. The Centre has well equipped laboratories for work on electron microscopy, production of monoclonal and polyclonal antibodies, cloning of viral genomics, sequencing, disease diagnosis and plant transformations. The institute has also acquired Scanning Electron microscopes.

The Institute realized the importance of diversity of biological forms and their importance in maintaining the ecological balance right from the inception of the Institute when it established **Herbarium Cryptogamae Indiae Orientalis** (HCIO) and a **National Pusa Insect Collection** in 1905. Later on, an Indian Type Culture Collection of Fungi (1936), a **National Collection of Nematodes** and **a National Rhizobial Collection (1986)** were also established. These collections are National wealth and show windows of the Institute. The Institute has also developed a **National Facility for Conservation and Utilization of Blue Green Algae and Azolla**. In addition to these collections, IARI has also a **large germplasm** collection of food, fodder, vegetable and fruit crops. The Institute established a **National Phytotron Facility** in 1997. This is the first facility of its kind in the country to study the live responses of plants under controlled conditions and the possible impact of climate change and greenhouse gases. The **Seed Testing Laboratory** of the Institute has got the status of CSTL under the Ministry of Agriculture and serves as a Referral Laboratory for all the 96 seed testing labs located in different parts of the country. Regular training programs for the personnel of the State Seed Testing Labs are being organized. The Institute also developed a big complex providing state of the art facility for **protected horticulture** under Indo-Israeli collaboration in the year 1998. This facility is extremely useful for students and scientists of horticulture and provides a model for efficient agriculture. A centre was established for research on climate resilient agriculture (CESCRA) with objectives of addressing the current concerns of climate change in agriculture taking into account the changes in Environmental Sciences components relevant to agriculture.

**Extension**

Although the Institute did not have a formal programme of extension education activity after its inception at Pusa (Bihar) in 1905, the pioneering research work done at this Institute in those days did serve indirectly to educate the farmers of the region. This is evident from the fact that famous Pusa Wheat (NP series) varieties developed by the Institute became very popular with the farmers. This state of affairs continued even after the shifting of IARI to its present location in New Delhi in 1936. The IARI started its extension activities in a formal and modest way through its Intensive Cultivation Scheme in Delhi territory in 1949-50. Since then, a number of innovative extension approaches and methodologies were experimented and developed which in due course became the basis and forerunner for many extension programmes and activities in the country. The concepts of seed village production unit and national demonstration took shape in 1965. Krishi Vigyan Mela and mini-kit demonstration (1972), Integrated Area Development Programmes, Operational Research Projects (1975-76), Lab-to-Land Programme (1979), Integrated Whole Village Agricultural Development Programme (1985), Single Window System, and Farmer-to-Farmer Quality Seed Programme (1986), etc. were initiated by the Institute for effective linkage between the research Institute and development departments to transfer technologies generated by scientists. The Division of Agricultural Extension has placed greater emphasis on training in package of practices, credit, storage and marketing aspects. The Division, through its Centre for Agriculture Technology Assessment and Transfer (CATAT) and Agricultural Technology Information Centre (ATIC) units, gives advice and technical information to a large number of extension workers and farmers and prepares folders, pamphlets and other extension literature. The Publication Unit of IARI also caters to the needs of technical and extension publications.

**Education**

The Institute has a long and distinguished record as a centre for higher education and training in the major disciplines of agricultural sciences. Right from its establishment in 1905, it has played an important role in imparting the best training in research in agricultural subjects to post-graduate students and the senior officers of State Departments of Agriculture hailing from all parts of the country.

In 1958, IARI received the status of a Deemed-to-be-University under the UGC Act of 1956 and was empowered to award its own M.Sc. and Ph.D. degrees, which at present is awarded in 23 disciplines of agriculture. The Post-graduate School was established under an

Indo-US programme to impart teaching in agricultural sciences. The Institute has produced trained human resource in all major disciplines of agricultural sciences and this has heralded the growth of Sate Agricultural Universities in India. The recognition it received in the form of NIRF ranking by the Ministry of Human Rsources Development stands testimony to this accomplishment.

**Library services and information networking**

The IARI library is one of the oldest and possibly the best in South Asia. Prior to India's Independence, the library was dedicated to Lord Linlithgow and was known as "Linlithgow Library". During the last 100 years, the Library has expanded and strived to meet the ever growing needs of the scientific and student community of the Institute and of the country as a whole. It has the status of National Agricultural Library of India, and is regarded as one of the 10 best agro-biological libraries of the world.

The library today houses specialized research publications on agriculture and related sciences consisting of books, monographs, reference materials, journals, annual reviews, abstracting and indexing journals, translated periodicals, statistical and data publications, bulletins, reports, pamphlets, reprints, news clippings, post-graduate theses of IARI and ICAR research fellowship theses. The library also provides reference service, bibliographical services, documentation services, CD-Rom database searches, reprography services, etc. In the year 2009 under the NAIP project eGranth was established and an catalogue called Agricat was shared. **AgriCat"** is a Union Catalogue of the holdings of 12 major libraries (IARI, IVRI, UAS, GBPUAT, CCSHAU, ANGRAU, NDRI, CIFE, CSKHPKV, MPKV, TanuVAS, ICAR HQ-DKMA) of the ICAR Institutes and SAUs combined together. Now eGranth is continued as KRISHI KOSH wherein the thesis and other publications of the IARI are available. CeRA programme run jointly by the library caters to many agricultural universities and other instititutions with e Resources.

**Training programmes**

In addition to the regular post-graduate courses leading to the award of M.Sc. and Ph.D. degrees, the Institute organizes a large number of refresher courses and short-term and long-term training courses in specific areas of agricultural sciences for the benefit of teachers, research and extension scientists of agricultural departments, SAUs, research and educational institutions and officials from autonomous organizations. Since 1976, the Institute has organized several training programmes in which a large number of scientists have been trained in new and emerging areas for skill development and upgradation of knowledge. Besides these, thematic courses are also organized for farmers. CAFT supported by the ICAR is being run in many of the Divsions/ Units on advanced aspects in the selected disciplines and it serves the faculty / teachers and research scientists. Under HRD grants of ICAR, a number of in servise training courses are conducted.

**Present set-up**

At present, the Institute functions through a network of 19 discipline-based divisions, 2 multidisciplinary centres, and 7 service units situated in Delhi; 8 regional stations situated at Amartara Cottage, Shimla (HP); Indore (MP); Kalimpong (WB); Karnal (Haryana); Katrain (HP); Pune (Maharashtra); Pusa (Bihar); and Wellington, the Nilgiris (TN); two off-season nurseries situated at Dharwad (Karnataka); and Aduthurai (TN); and a Krishi Vigyan Kendra situated at Shikohpur, Gurgaon (Haryana). These various divisions, centres and regional stations are working in the school mode under six schools namely 1) School of Crop Improvement, 2) School of Horticulture, 3) School of Basic Sciences, 4) School of Crop protection, 5) School of Natural resources Management and 6) School of Social Sciences.

The administrative head of IARI is its Director. The Board of Management, with the Director as its Chairman, provides the overall management direction, and is served by four Councils, namely Research Advisory Council, Academic Council, Extension Council and Executive Council.

**Mandates and Objectives**

**Mandates**

The mandates of the Institute are 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 lead 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 and serve as a national agricultural library and database.

**Objectives**

Under the above mentioned four mandates, the major thrust given is as follows:

**A. Mandated Programmes**

A total of 47 mandated research programmes was being implemented in the Institute in the last plan. The school-wise mandated research programmes along with human resource development are presented below.

**1. School of Crop Improvement**

1. Genetic enhancement of wheat and barley for productivity, disease resistance, resilience, quality and cropping systems
2. Improving resilience, productivity and quality in rice through genetic and genomic approaches

3. Genetic improvement of productivity, stress tolerance and nutritional quality of early- to full-season maize hybrids
4. Development of varietal and hybrid technologies of pearl millet [*Pennisetum glaucum* (L).R.Br.] for higher yield and nutritional improvement
5. Genetic improvement of chickpea (*Cicer arietinum* L.) for higher productivity under marginal and dry land situations
6. Genetic improvement of pigeonpea for yield and disease resistance
7. Enhancement of genetic potential of mungbean and lentil in multi-season and different cropping system adaptations
8. Breeding climate resilient high yielding rapeseed mustard varieties and hybrids with enhanced quality
9. Genetic enhancement of soybean for yield, tolerance to abiotic stress, biotic stress and seed quality
10. Understanding gene functions through genetic and molecular analysis in *Drosophila melanogaster*
11. Development of technologies/ methodologies for quality seed production, maintenance of seed purity and varietal identification
12. Seed quality enhancement by processing, packaging and storage options in high volume seed crops
13. Seed quality enhancement by processing, packaging and storage options in low volume seed crops
14. Development of protocols, validation and execution for quality seed production through farmers for sustainable truthfully labelled seed production system.

**2. School of Horticulture**

1. Pre-breeding for biotic and abiotic stress resistance and quality in selected vegetable and flower crops.
2. Genetic improvement of selected annual open field vegetable & flower crops
3. Genetic improvement of selected perennial fruit and ornamental crops
4. Development of improved technologies for higher yield and quality in selected fruit crops
5. Development of technologies for higher yield in important flower crops and turf grass management
6. Development of technologies for realizing production potential of new varieties and hybrids of vegetable crops

7. Integrated approaches for pre- & post-harvest loss reduction and quality enhancement in fruits and vegetables
8. Development of nutraceutical & functional food from horticultural produce and cereal & pulse based convenience food products
9. Development of Hi-tech cost effective technologies for protected horticulture

**3. School of Crop Protection**

1. Biosystematics of insects, fungi, bacteria and nematodes of economic importance
2. Studies on population dynamics / epidemiology, host-plant relationship, tritrophic interactions, and development of pest management strategies in relation to climate change and contemporary cropping systems
3. Studies on biochemistry, physiology and molecular biology of insects and nematodes of economic importance
4. Development of novel chemicals, toxicological evaluation, structure-activity relationships and formulations for crop protection
5. Assessment and management of contaminants in agricultural produce and in the environment
6. Identification of important plant viruses and virus like pathogens, their characterization, diagnostics and application of emerging technologies for management and host virus interaction
7. Virulence, variability, pathogenomics and diagnostics of major fungal and bacterial plant pathogens
8. Interactions of parasitic and beneficial nematodes with rhizosphere, microbes and insect pests

**4. School of Natural Resource Management**

1. Restoration and improvement of soil health
2. Safe use of wastewater in agriculture
3. Integrated crop and resource management for enhanced productivity and profitability
4. Risk assessment and management of hydro-climatic hazards on natural resource degradation and agricultural sustainability
5. Assessment and mitigation of green house gas emission and air pollution in agriculture under current and future climatic conditions
6. Agri-residue and bio mass management

7. Development of technologies and strategies for scale neutral farm mechanization

**V. School of Basic Sciences**

1. Deciphering physiological, biochemical and molecular mechanisms of abiotic stress tolerance and nutrient use efficiency of crop plants
2. Genetic modification of soybean for improved nutritional / flavour quality

**VI. School of Social Sciences**

1. Enhancing smallholder's productivity and agricultural growth through technology, sustainable intensification and ecosystem services
2. Inclusiveness and effectiveness of agricultural markets and trade reforms and development of agro-industries
3. Commercialization and impact of improved agricultural technology
4. Development of innovative agricultural extension models
5. Enhancing nutritional security and gender empowerment
6. Maximizing farm profitability through entrepreneurship development and farmer led innovations
7. Out scaling agricultural innovations for enhancing farm income and employment

**B. Out-reach Programmes**

1. Strengthening of Wheat Programme in Eastern India (IARI Regional Station, Pusa, Bihar)
2. Strengthening of Wheat Programme in Central India (IARI Regional Station, Indore)
3. Strengthening extension education programme of developing innovative models and techniques for higher productivity and profitability in agriculture.

**C. Strengthening and Modernizing Research Facilities**

1. Diagnosis and management strategies of virus and virus like diseases of crops
2. Strengthening of Protected Horticultural research
3. Modernization of the IARI Research Farm using Solar Energy and Micro-irrigation
4. National Facility for Insect Rearing and Xenobiotic-cum-Transgenic Bioassays

**D. Establishment of Two Out-Station Research Centres in Public Private Partnership Mode**

**E. Programmes for N.E.H Region and TSP**

***i. Programmes for NEH***

- Transfer of technology for appropriate farm mechanization, improving soil health and livestock management
- Quality seed production including hybrids and new varieties in priority crops like maize, rice, pearl millets, mustard and vegetables
- Develop seed processing, drying and storage facilities along with facilities for value addition
- Develop soil and water testing facility, protected cultivation with drip irrigation for off season vegetable cultivation and seed production
- Develop strategies to increase overall agricultural production in north east

***ii. Tribal Support Programme (T.S.P)***

- Integrated programme promoting IARI technologies and other relevant agricultural technologies for economic development of tribal areas

**F. ICAR Research Consortia Platform**

The institute is involved in number of ICAR Consortia research platforms. There are two platforms in which IARI is lead centre and coordinating the two platforms. They are (i) Molecular breeding for improvement of tolerance to biotic and abiotic stress, yield and quality traits in crops, and (ii) Hybrid technology for higher productivity in selected field and horticultural crops. They will be implemented by the Division of Genetics at IARI with the collaboration of many centres across the country.

In addition to the above research programmes, to maintain academic excellence in agricultural education, the institute will channelize research for human resource development as well

**G. Human Resource Development – PG School, IARI**

- Post Graduate Education and Research
- Centres of Advanced Studies and Training in Frontier Knowledge
- Faculty Upgradation
- Central Library and Bio-Informatics
- Strengthening Post Graduate Education through National and International Collaboration
- Teaching Aids: Text books, Laboratory Manuals and Audio-Visual Aids
- IARI type institutions in Jharkhand
- Myanmar and Afghanistan

**Organization**

The highest policy making body of the Institute is its Board of Management. The Staff Research Council is responsible for the formulation of research projects and monitoring of their progress. The Academic Council takes decision in all matters related to post-graduate education. The Director is the executive and academic head of the Institute, which is also a Deemed-to-be-University and is the ex-officio Chairman of the Board of Management, Executive Council, Academic Council and Extension Council. The Board of Management and the Academic Council are the apex bodies of the Institute, which take decisions on administrative, financial and academic matters. Academic Council, Executive Council, Staff Research Council, Extension Council and various Standing Committees provide the necessary recommendations/ suggestions to facilitate the Board of Management to take appropriate decisions.

The research activities are monitored by the Joint Director (Research). The Dean and the Joint Director (Education) co-ordinates the academic activities of the Institute. Matters pertaining to extension education of the Institute are executed through the Joint Director (Extension). The Joint Director (Administration) of the Institute provides the necessary support to the Director in taking decisions regarding service matters of both faculty and staff. Matters pertaining to financial and budgetary aspects are channelled through the Chief Finance and Accounts Officer.

# Indian Agricultural Research Institute

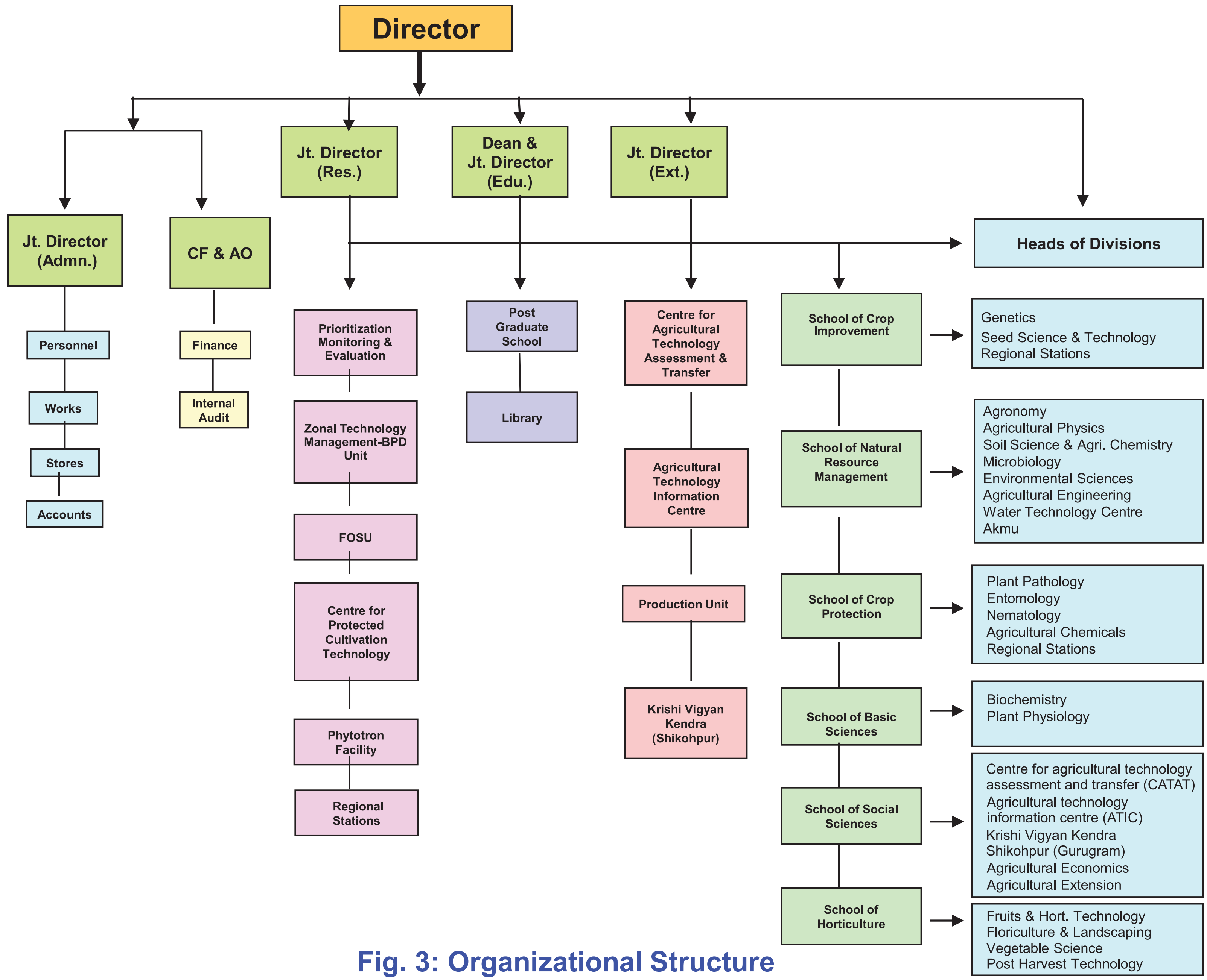


**Fig. 3: Organizational Structure**

# Management

The smooth functioning of the Institute activities is ensured by the Institute's Management Committee with the Director as the administrative head. Three Joint Directors, viz., Joint Director (Research), Dean and Joint Director (Education), and Joint Director (Extension) dealing with research, teaching and extension provide complete support to the Director. T he Joint Director (Administration) and the Comptroller/ Chief Finance and Account Officer provide support in administration and finance of the Institute. The Board of Management, Research Advisory Committee, Executive Council, Academic Council, Extension Council and Staff Research Council facilitate in the smooth functioning of the Institute with their support in various ways. The two other important statutory bodies for the smooth functioning of the Institute are the Joint Staff Council and Institute Grievance Cell.

**Board of Management**

A total of 13 meetings were conducted during this period under Chairmanship of the Directors of IARI during that period. In 2009 it was under the chairmanship of Dr. S.A. Patil. From 2010 to 2014 these meetings were chaired by Dr. H.S. Gupta. Dr. Ravinder Kaur was the Chairman of the meetings held in 2015 and 2016. Some of the important decisions related to annual budget and allocation of funds to various divisions were taken. Policy issues related to the affairs of the institute including the rights of the staff were addressed. Some of the recommendations made by the Grievance Cell and Institute Joint council were approved.

**Research Advisory Committee (RAC)**

The function of RAC is to give directions and suggestions on the research programmes of the Institute and review the research achievements of the Institute and to see that these are consistent with the mandate of the Institute.

**Chairman and members for 2008 to 2011**

Dr. R.S. Paroda, Chairman Trust for Advancement of Agricultural Sciences ,members were Dr. H.S. Dhaliwal, Professor, Department of Biotechnology, IIT Roorkee (Uttarakhand) Prof. S.L. Mehta, Former Vice Chancellor (MPUAT), Prof. A.N. Mukhopadhyay, Dr. R.K. Pathak, Vice Chairman, Manas Rural Development Institute , Dr. J. C. Katyal, Former VC, CCSHAU, Hissar, Dr. S.K. Datta, DDG (CS), Shri Subhash Bapurao Patil, Post PALSA , Distt. Nanded, Shri Bipin Shankar Rao Kolhe, Chairman, Sanjivani Sahakari Sakhar Karkhana, Sahajanandnagar, Post Kopargaon, (non official members of Board of Management)

**Chairman and members for 2012 to 2014**

Dr. R.S. Paroda, Chairman, Trust for Advancement of Agricultural Sciences, Dr. Mruthanjay, Former Director, NCAP , Prof. S.L. Mehta, Former Vice Chancellor (MPUAT), Prof. A.N. Mukhopadhyay, Dr. G.L. Kaul, Former Vice Chancellor, AAU, Jorhat, Dr. M. Velayutham, Former DDG (NRM), ICAR, Dr. S.K. Datta, DDG (CS,) Shri R. S. Patel and Shri M.J. Umman (non official members of Board of Management)

**Chairman and members w.e.f. 2015**

Dr. P.L. Gautam, Former DDG (Crop Science) & Former Chairperson, PPV&FRA Chaired the RAC meetings from 2015. Dr. J.S. Sandhu, Deputy Director General (Crop Science), Division of Crop Science, Dr. S.P. Ghosh Former DDG (Hort.), ICAR , Dr. B. Mishra Former VC, Sher-e- Kashmir University of Agril. Sciences and Technology, Jammu, Dr. C.L. Acharya Former Director, Indian Institute of Soil Science (ICAR), Bhopal, Dr. Koundal Former Joint Director (Res.), IARI, Dr. P.K. Joshi, Former Director, NCAP & NAARM and Director, South Asia, IFPRI, Dr. R. Khetrapal Regional Director (South Asia) CABI, Dr. I.S. Solanki, ADG (Food and Fodder Crops), Dr. T. Mohapatra, Director IARI, were the members and Dr. K.V. Prabhu member secretary. In 2016 Dr. C.L. Acharya, Dr. Koundal, Dr. P.K. Joshi Former Director, NCAP & NAARM and Director, South Asia, IFPRI, Dr. Ravinder Kaur Director (Acting) IARI , Dr. R.K. Jain Dean and Joint Director Education, IARI, Dr. J.P. Sharma Joint Director Extension, Mrs. Razdan, Joint Director Administration were members and Dr. K.V. Prabhu, Joint Director Research was member secretary.

**Institute Research Committee (IRC)**

The Institute Research Council plays a major role in monitoring the research activities of the Institute. During the period under report sixteen meetings were held under the Chairmanship of the Director and a crucial role is played by the Joint Director Research in assessing and evaluating the current research programmes including the externally funded projects of the institute. The prioritization, monitoring and evaluation cell of the institute is responsible for coordinating these meetings. Individual scientists of each division present their work in IRC I which is evaluated by expert members and the JD (R)/ Director. The in house and externally funded project are reviewed for their objectives and achievements in these meetings and mid term corrections undertaken. In IRC II the Project Directors present their work, and is evaluated by the expert members and the JD (R)/Director . These meetings provide a forum for interdisciplinary research and review of such accomplishments.

**Extension Council**

Extension Council of the Institute monitors the extension activities of the institute and helps to promote participation with outside agencies and institutions. In all fifteen meetings were conducted during the reported period. Outcome of these meetings include-updating and improving the website of IARI, to get the feedback not only about the varietal performance but also of other technologies/ packages of practices developed by the Institute. This also enables developing strong linkages between IARI and Development Department of Delhi Government towards implementation of extension programmes of the Institute, to plan and implement a comprehensive plan for extension/TOT activities. These activities focus on aspects of collaborative mode between the two organizations; to publicize the importance of ATIC (Single Window System); to identify various parameters for monitoring and evaluation of developing “Model Village”; also ensure holistic and integrated development of the village which may really reflect the showcase window for other villages to follow up. It also provides a platform to present research activities of CATAT and Division of Agricultural Extension. The policy matters regarding extension activities of the Institute are dealt with in Extension Council and this also develops plans to re-organize the Extension Council to (a) decide the relevant technologies for extension activities and (b) to deal with issues, policies, models and mechanisms of technology transfer and approval of recommendations of Standing Committees. The MGMG- *Mera Gaon Mera Gaurav* program initiated by the Ministry of Agriculture and Farmers' Welfare is monitored and implemented by the Extension council.

**Academic Council**

The Academic Council is supreme in the matter of academic activities of the Institute at the Post Graduate School. All the matters relating to post graduate education and training are decided by the Academic Council which is supported by the Board of Studies in each discipline and four Standing Committees, namely, i) Courses, Curricula and Academic Affairs, ii)Faculty and Discipline, ii) Scholarships, Financial Assistance and Academic Progress, and iv) Students' Problems and Discipline, Welfare Board and Residences. The Dean and Joint Director (Education) takes decisions regarding the constitution of the Board of Studies. At the Divisional level, the Board of Studies takes decisions and/or makes recommendations to the Academic Council. The Academic Council is also empowered to take decisions on all academic matters and translate them into action. Some of the important decisions taken by the Academic Council during 2009-2016 are:

i. Introduction of M.Sc. and Ph.D. degree programme in Bioinformatics and Ph.D. in Computer application

ii. Revision of the faculty and research induction guidelines and also the selection criteria of Professor

iii. re-nomenclature of the M.Sc. degree in Agricultural Engineering and Post Harvest Technology as M. Tech.

iv. Institution of an award in the name of Dr. A.B.Joshi and divisional award in the name of Dr. P.N. Bahl and Dr. E.A. Siddique, initiated adjunct faculty scheme at IARI, adopted split Ph.D. relief provision.

v. Revision in mode of admission and eligibility to master and doctoral programme and creation of three new disciplines from the disciplines of Horticulture namely Floriculture & landscape Architecture, Fruit Science and vegetable Science

vi. Revision of the entire course curriculum relating to all teaching disciplines for strengthening the P G education at IARI.

**Institute Joint Staff Council (IJSC)**

The Institutes Joint Staff Council is elected by the administrative, technical and skilled supporting staff of the institute. Every year four members are elected –one Secretary, and 3 members of the Joint Staff Council.

During the period under report the following matters were taken up by the IJSC

- The institute's administrative staffs were demanding equal grade pay at par with their counter parts in head quarters. To press their demands the administrative staff went on relay fast for 46 days. IJSC took up the matter with Council and to court and now its awaiting decision.
- Pay upgradation of the technical staff was taken up and efforts were made by IJSC to constitute a committee under the Chairmanship of Dr. Alagasundaram. The issues relating to various categories of the technical staff were taken up and all these matters are at the decision making stage at the council.
- A committee was constituted for considering the issues related to cadre review of the Skilled supporting staff and the administrative staff. The committee has given its recommendations which are under consideration at the Council.
- Issues related to different categories of staff w.r.t. $6^{th}$ pay commission in relating to discrepancy in pay and promotion were sorted through correspondence with the concerned authorities.
- Implementation of the $7^{th}$ Pay commission to the staff was taken up with the Agriculture ministry and finance ministry and finally it got implemented.
- Issues with respect to staff of other regional stations were taken up and the Director/ Officers were informed of their issues and also sort out various matters.

**Institute Grievance Committee**

This committee proved as an apparatus to facilitate individuals for ventilating their own personal grievances, ensure speedy consideration of grievance and decision thereon. The committee helped to establish good communication between the office of the unit and the employee. Joint Director Extension is the Chairman of the Committee and there are a few official members and some members elected by the staff. Meetings are held at regular intervals and matters are taken up for discussion and decisions are recorded.

Chapter 4

# Policies, Priorities, Strategies and Programmes

With a vision to provide leadership for "*Science-led sustainable and globally competitive agriculture for food, nutrition and livelihood security*", IARI proposes to continue its research, education and extension during the EFC period of 2017-2020 with the following mandates: 1) Basic, strategic and anticipatory research in field and horticultural crops for enhanced productivity and quality, 2) Research in frontier areas to develop resource use efficient integrated crop management technologies for sustainable agricultural production system, 3) Serve as centre for academic excellence in the areas of post-graduate and human resources development in agricultural science, and provide national leadership in agricultural research, education, extension and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards. To address these mandates, the Institute has categorized its research programmes in four groups. A) Flagship programmes, B) Mandated programmes, C) Outreach programmes, D) Strengthening and Modernizing Research Facilities, and E) Programmes for NEH and TSP. Besides these programmes, other topical research issues will be addressed through E) ICAR Research Consortia Platform. The human resource development will be addressed by F) PG School, IARI.

**A. Flagship Programmes**

1. Improving basmati rice varieties for domestic and export market
2. Breeding vegetables and flowers for protected environment
3. Diversification of rice-wheat cropping system for enhanced sustainability and profitability
4. Precision farming for enhanced input use efficiency

**B. Mandated programmes**

**a. School of Crop Improvement**

| Projects | Objectives |
|---|---|
| 1. Genetic enhancement of wheat and barley for productivity, disease resistance, resilience, quality and cropping systems | 1. Development of wheat varieties with higher productivity and disease resistance under irrigated environment<br>2. Breeding climate resilient wheat varieties<br>3. Introgression and pre-breeding for transfer of important traits and exploitation of heterosis for wheat improvement<br>4. Genetic enhancement for quality traits, and value-addition of Indian wheat<br>5. Wheat based cropping system breeding for sustainable intensification under CA<br>6. Genetic enhancement of productivity of barley with special reference to northern hills |

| Projects | Objectives |
|---|---|
| 2. Improving resilience, productivity and quality in rice through genetic and genomic approaches | 1. Breeding high yielding rice varieties/hybrids with resilience to biotic and abiotic stresses<br>2. Creation of hybrid oriented source germplasm for enhancing heterosis and development of rice hybrids<br>3. Development of semi-dwarf high yielding short grain aromatic rice varieties<br>4. Genetic enhancement and molecular mapping of agronomic and quality traits<br>5. Understanding genetic bases of nutrient use efficiency and development of improved genetic stocks<br>6. Genetic improvement for grain, cooking and nutritional quality |
| 3. Genetic improvement of productivity, stress tolerance and nutritional quality of early- to full-season maize hybrids | 1. To understand the genes responsible for abiotic stresses through genetic and genomic approaches.<br>2. To breed inbreds and hybrids in early- to full-season maturity groups for favorable and marginal environments.<br>3. To breed inbreds and hybrids in early- to full-season maturity groups for disease resistance.<br>4. To understand the genetics and to breed inbreds and hybrids in early- to full-season maturity groups for nutritional quality and specialty traits. |
| 4. Development of varietal and hybrid technologies of pearl millet [*Pennisetum glaucum* (L).R.Br.] for higher yield and nutritional improvement. | 1. To breed early and medium maturing, downy mildew and blast resistant dual purpose hybrids and populations for adoption in moisture stress areas<br>2. Development of parental lines with high level of resistance/ tolerance to biotic stresses (downy mildew, blast) and abiotic stresses (drought and heat).<br>3. Development of breeding material with higher micro nutrient content, essential amino acids, improved shelf life and suitable for alternative food uses.<br>4. Understanding/ deciphering genetics of economically and nutritionally important traits – earliness, spike thickness, spike length, seed weight, phytic acid and popping. |
| 5. Genetic improvement of chickpea (*Cicer arietinum* L.) for higher productivity under marginal and dry land situations | 1. Genetic improvement of chickpea for grain yield, quality and wide adaptability<br>2. Genetic improvement of chickpea for increased yield and resilience to abiotic stresses<br>3. Restructuring plant type for high yield and suitability to mechanical harvesting with resistance to biotic stresses<br>4. Genetic improvement for higher grain yield, tolerance to rust and terminal moisture stress condition of southern zone environment |

| Projects | Objectives |
|---|---|
| 6. Genetic improvement of pigeonpea for yield and disease resistance | 1. Development of pigeonpea varieties and hybrids for plant type, early maturity and high grain yield suitable for pigeonpea – wheat rotation.<br>2. Development of pigeonpea high yielding medium duration varieties.<br>3. Development of disease resistant pigeonpea varieties.<br>4. Development of pigeonpea high yielding varieties suitable for mid and post rainy seasons |
| 7. Enhancement of genetic potential of mungbean and lentil in multi-season and different cropping system adaptations | 1. Breeding mungbean and lentil varieties for different cropping systems.<br>2. Breeding for resistance to abiotic stresses (mungbean: drought, salinity and lentil: drought, heat, aluminium, salinity/alkalinity).<br>3. Breeding for resistance to biotic stresses (mungbean: MYMV, PM and lentil: Wilt and rust).<br>4. Enhancement of nutritional quality of mungbean and lentil. |
| 8. Breeding climate resilient high yielding rapeseed mustard varieties and hybrids with enhanced quality | 1. Breeding for tolerance to abiotic stresses<br>2. Breeding for resistance/tolerance to biotic stresses<br>3. Pre-breeding for resistance/tolerance to biotic & abiotic stresses and yield improvement<br>4. Breeding for quality improvement<br>5. Enhancement of seed quality<br>6. Management in quality seed production |
| 9. Genetic enhancement of soybean for yield, tolerance to abiotic stress, biotic stress and seed quality | 1. Breeding soybean varieties suitable for different cropping systems with inbuilt tolerance to biotic and abiotic stresses<br>2. To create genetic variability and analyze QTL for improvement of yield and seed quality traits.<br>3. Breeding for rust resistance and earliness |
| 10. Understanding gene functions through genetic and molecular analysis in *Drosophila melanogaster* | 1. Understanding gene interaction between *DWnt6, DWnt10, DWnt4* and *wg* with their influence on canonical and non canonical cell signaling pathways.<br>2. To study role of *DWnt4* in development.<br>3. To study regulation of d*Ino80* expression.<br>4. To study chitin deacetylase gene family in *Drosophila melanogaster* |
| 11. Development of technologies/ methodologies for quality seed production, maintenance of seed purity and varietal identification | 1. To undertake basic studies and to develop hybrid seed production technology of rice, maize, pearl millet, Indian mustard, pigeon pea and cauliflower.<br>2. To understand effect of high temperature on seed yield and quality in parental lines of wheat hybrid |

| Projects | Objectives |
|---|---|
| 12. Seed quality enhancement by processing, packaging and storage options in high volume seed crops | 1. Evaluation of seed vigour and dormancy traits in rice<br>2. To study the basis of differential response of seed quality traits in conventional and quality Indian mustard genotypes<br>3. To understand the relation of seed composition with seed vigour and storability in speciality maize<br>4. To understand the physiological and molecular mechanisms of seed priming in pigeonpea and soybean under various abiotic stresses<br>5. To evaluate morphological, physiological and molecular traits associated with seed vigour and longevity in mini-core collections of soybean<br>6. To standardize the machine and crop variables for multi-stage mechanical seed processing<br>7. To develop seed quality enhancement technology for direct seeded rice, summer mungbean, chickpea and pigeon pea |
| 13. Seed quality enhancement by processing, packaging and storage options in low volume seed crops | 1. To access seed quality changes during seed development and maturation under changing climatic conditions<br>2. Improving planting value of seed through priming, coating and pelleting technologies and evaluation of their effect on seed longevity in selected vegetable crops<br>3. Effect of seed moisture content and packaging material on seed storage and vigour assessment<br>4. Optimization of mechanical processing parameters for upgradation of seed quality |
| 14. Development of protocols, validation and execution for quality seed production through farmers for sustainable truthfully labeled seed production system | 1. Development of efficient quality seed production programme of cereal crops<br>2. Development of efficient quality seed production programme of pulses and oilseed crops<br>3. Development of efficient quality seed production programme of vegetable crops<br>4. Standardization of postharvest handling of seeds |

**b. School of Horticulture**

| Project | Objectives |
|---|---|
| 1. Pre-breeding for biotic and abiotic stress resistance and quality in selected vegetable and flower crops. | Development of elite genetic stocks for resistance/tolerance to major biotic & abiotic stresses and quality through inter-intra specific hybridization to transfer traits in advance breeding lines. |
| 2. Genetic improvement of selected annual open field vegetable & flower crops | Development of varieties/ hybrids for high yield, resistance/ tolerance to major biotic & abiotic stresses, high nutraceuticals & nutrients, flavouring compounds and exploration of oil quality of selected crops. |

| Project | Objectives |
|---|---|
| 3. Genetic improvement of selected perennial fruit and ornamental crops | 1. Development of mango variety(ies) with improved yield and quality for domestic and overseas markets.<br>2. Development of desired trait-specific rootstock(s) and scion variety (ies) in citrus.<br>3. To develop seedless and early maturing variants in Kinnow mandarin and sweet orange with improved quality through mutation and polyploidy breeding.<br>4. To evolve early maturing grape genotypes with improved berry quality, and to develop abiotic stress tolerant rootstock(s).<br>5. Development of guava varieties for desirable horticultural traits (yield, quality and processing traits)<br>6. Breeding papaya for desirable horticultural traits.<br>7. Improvement of temperate fruit crops for yield, quality, biotic & abiotic stress resistance.<br>8. Collection and characterization of Darjeeling mandarin, large cardamom and chilli genotypes and development of superior clones / lines.<br>9. Development of varieties/ hybrids for desirable horticultural traits in rose, gladiolus, chrysanthemum, liliums and iris. |
| 4. Development of improved technologies for higher yield and quality in selected fruit crops | 1. Rootstock Research and Canopy Management in Fruit Crops.<br>2. Evolving Technologies in Fruit Crops for Improving Yield and Fruit Quality through INM, use of Bio-regulators and Bio-agents.<br>3. Development of Improved Technologies and Integrated Orchard Health Management system in Fruit Crops.<br>4. Developing INM schedule and identification of suitable rootstocks for sustainable citrus production in NE Hill regions. |
| 5. Development of technologies for higher yield in important flower crops and turf grass management | 1. To standardize package of practices in lilium<br>2. To standardize Integrated weed and nutrient management practices in gladiolus.<br>3. To standardize agro-techniques for commercial cultivation of Eustoma.<br>4. To standardize management practices in turf grasses.<br>5. To develop cost effective production technology for ornamental potted plants.<br>6. To develop value added products and postharvest management of flowers. |

| Project | Objectives |
|---|---|
| 6. Development of technologies for realizing production potential of new varieties and hybrids of vegetable crops | 1. To develop agro-techniques and irrigation schedules for enhancing crop and water productivity of major vegetables<br>2. To develop Integrated Crop Management modules for enhancing productivity and input-use efficiency in vegetable based cropping system<br>3. To improve productivity, nutritional quality and profitability of important vegetable crops through nutrient management and other agro-inputs<br>4. To assess and optimize different weed management protocols for major vegetable based production systems.<br>5. Diversification of high value vegetable crops for higher productivity and livelihood security<br>6. Evaluation of new upcoming genotypes of vegetable crops in All India Co-ordinated Programme |
| 7. Integrated approaches for pre- & post-harvest loss reduction and quality enhancement in fruits and vegetables | 1. Development of novel technology (ies) for ripening and shelf-life extension of fruits and vegetables.<br>2. Optimization of ripening aid for fruits during transportation<br>3. Non-chemical approaches for loss reduction, extension of shelf life and postharvest quality of selected fruits.<br>4. Development of shelf stable fresh-cut fruits and vegetables through different packaging strategies |
| 8. Development of nutraceutical & functional food from horticultural produce and cereal & pulse based convenience food products | 1. Development of functional ingredients through novel approaches and preparation of functionally enhanced shelf stable products using the same<br>2. Development of starter culture(s) for fermented functional and /or healthy vegetable and fruit drinks<br>3. Development of convenience food products based on cereals and pulses |
| 9. Development of Hi-tech cost effective technologies for protected horticulture | 1. Development and evaluation of production technology for different flower crops under different protected structures and open field conditions.<br>2. Development and standardization of production technology for vegetable crops under different protected structures and open field conditions.<br>3. Development and standardization of fertigation protocols including water, nutrient and energy budgeting for flower and vegetable crops under protected structures and open fields.<br>4. Evaluation of different protected structures and standardization of design parameters including ventilation requirements for growing vegetable and flower crops. |

**c. School of Crop Protection**

| Project | Obectives |
|---|---|
| 1. Biosystematics of insects, fungi, bacteria and nematodes of economic importance | 1. Biosystematic studies on hymenopterous, coleopterous, hemipterous, lepidopterous and dipterous insects of economic importance<br>2. Studies on Diversity, Conservation, Taxonomy and Phylogeny of Fungi and Bacteria<br>3. Biosystematic studies and documentation of agriculturally important nematodes |
| 2. Studies on population dynamics / epidemiology, host-plant relationship, tritrophic interactions, and development of pest management strategies in relation to climate change and contemporary cropping systems | 1. Pest monitoring and forewarning for different cropping systems using GIS and remote sensing techniques<br>2. Assessment of yield Losses due to multiple pests and development of decision support tools<br>3. Exploration of resistant sources for sustainable pest management and documentation of genetic stocks<br>4. Conservation of biodiversity and bio-control of pests<br>5. Development and optimization of strategies for Integrated Pest Management modules for major pests during crop season and storage |
| 3. Studies on biochemistry, physiology and molecular biology of insects and nematodes of economic importance | 1. Physiology of insects of agricultural importance vis a vis nutrition, endosymbionts, vector virus interaction, thermal stress receptors and xeobiotics.<br>2. Exploration of RNAi and bacterial isolates for pest management and Bt resistance in insect pests.<br>3. Exploration of novel traits for resistance to insect pests in maize.<br>4. RNAi based gene silencing for management of root knot nematodes in vegetables and ornamental crops |
| 4. Development of novel chemicals, toxicological evaluation, structure-activity relationships and formulations for crop protection | 1. Development of active molecules for crop protection<br>2. Development of formulations for smart delivery of crop protection inputs<br>3. Toxicity investigations of agrochemicals for insect pest management |
| 5. Assessment and management of contaminants in agricultural produce and in the environment | 1. Standardization and validation of methods for detection and quantification of contaminants in raw agricultural commodities, processed food and environmental samples<br>2. Management and assessment of contaminants in the agricultural commodities and in the environment |

| Project | Obectives |
|---|---|
| 6. Identification of important plant viruses and virus like pathogens, their characterization, diagnostics and application of emerging technologies for management and host virus interaction | 1. To understand the evolution and distribution of important plant viruses and virus like organisms affecting economically important crops<br>2. To develop, upscale serological and molecular diagnostics of important plant viruses/phytoplasmas for screening and production of virus free economically important crops<br>3. To explore plant viruses as useful genetic resources<br>4. To dissect molecular basis of interaction of plant viruses and virus like pathogens with their hosts and vectors<br>5. To develop sustainable management options for managing viral/phytoplasmal diseases under different cropping systems. |
| 7. Virulence, variability, pathogenomics and diagnostics of major fungal and bacterial plant pathogens | 1. Virulence, variability analysis and host-pathogen interactions for major fungal and bacterial plant pathogens.<br>2. Development of diagnostics for major fungal and bacterial plant pathogens.<br>3. Pathogenomics of important fungal pathogens to decipher the functions of major genes. |
| 8. Interactions of parasitic and beneficial nematodes with rhizosphere, microbes and insect pests | 1. To study the biological and functional variations in entomopathogenic nematodes vis a vis insect pathogenecity and efficient recycling in the fields.<br>2. Isolation and characterization of insecticidal genes from indigenous isolates of Photorhabdus spp |

**d. School of Natural Resopurce Management**

| Project | Objectives |
|---|---|
| 1. Restoration & Improvement of Soil Health | 1. To develop chemical and biological interventions for enhancing nutrient use efficiency and restoring fertility of different soils<br>2. To develop and evaluate the conventional and conservation agriculture practices for improving carbon-sequestration and soil health |
| 2. Safe Use of Wastewater in Agriculture | 1. To assess impacts and risks associated with wastewaters irrigation<br>2. To devise alternative land-water management strategies/ cropping systems for reduced soil/consumer health hazards due to wastewater irrigation<br>3. To develop cost-effective wastewater remediation strategies and business models for safe and sustainable use of non-conventional water sources |

| Project | Objectives |
|---|---|
| 3. Integrated crop and resource management for enhanced productivity and profitability | 2.1 Enhancing cropping system productivity and profitability under irrigated conditions (Rice-wheat, Maize-wheat, Soybean-wheat, Pigeon pea-wheat and Cauliflower-based cropping system)<br>2.2 Enhancing cropping system productivity and profitability under rainfed conditions and limited irrigation (Pearl millet–mustard / chickpea, maize- chickpea/lentil/mustard, Pigeon pea-mustard)<br>Developing efficient strategies for managing emerging weeds in different cropping systems |
| 4. Risk Assessment & Management of Hydro-climatic Hazards on Natural Resource Degradation & Agricultural Sustainability | 1. To quantify the impact of hydro-climatic hazards and adaptive capacity on vulnerability of agricultural production systems<br>2. To develop crop yield forecasting and early warning systems for risk management in agriculture<br>3. To recommend suitable resource management strategies for sustained productivity of target region<br>4. To develop e-resources and knowledge management systems for effective dissemination of efficient adaptation strategies. |
| 5. Assessment and mitigation of greenhouse gas emission and air pollution in agriculture under current and future climatic condition | 1. Assessment and mitigation of greenhouse gas emission in the Indo-Gangetic Plains under current and future climatic conditions<br>2. Quantification of air pollution and its impacts on crop productivity in the Indo-Gangetic Plains |
| 6. Agri-residue and Biomass Management | 1. Design and development of technologies for utilization of biomass as feed and other value added products<br>2. Developing efficient low cost technologies for utilization of biomass as fuel<br>3. Design and development of mechanical and biological techniques for *in-situ/ex-situ* biomass degradation |
| 7. Development of Technologies & strategies for scale neutral farm mechanization | 1. Design and development of machinery for mechanization of horticultural crops<br>2. Development of Ergonomic protocols and gadgets for reduced occupational health hazards and drudgery<br>3. Design and development of equipment for resources conservation technology<br>4. Design and development of solar powered machines and gadgets for processing and storage of agricultural produce |

**e. School of Basic Sciences**

| Project | Objectives |
|---|---|
| 8. Deciphering physiological, biochemical and molecular mechanisms of abiotic stress tolerance and nutrient use efficiency of crop plants | 1. Identification of donors, mechanisms and component traits for nutrient use efficiency (NUE) and tolerance to drought and heat stresses in rice and wheat.<br>2. Genomics for identifications of genes and promoters for enhancing abiotic stress tolerance of rice and wheat.<br>3. Development of transgenic rice and wheat for enhancing drought and heat tolerance. |
| 9. Genetic modification of soybean for improved nutritional / flavour quality | 1. Biochemical screening of soybean germplasm for nutritionally significant principles<br>2. Identification and characterization of promoters and candidate genes of the targeted pathways associated with nutritionally significant phytochemicals in soybean<br>3. Development of soybean transgenics for enriched nutritional quality. |

**f. School of Social Sciences**

| Project | Objectives |
|---|---|
| 1. Enhancing smallholder's productivity and agricultural growth through technology, sustainable intensification and ecosystem services | 1. To develop a model linking agricultural growth, rural poverty, investment and energy requirement.<br>1. To assess the relationship between farm size and productivity and develop a diversification plan.<br>2. To examine the linkage of sustainable intensification, ecosystem services and food security. |
| 2. Commercialization and Impact of Improved Technologies | 1. To assess the adoption and impact of selected technologies<br>2. To evaluate the impact of knowledge intensive technologies for enhancing profitability and mitigating risk<br>3. To analyse the policy and institutional options for speedy out scaling |
| 3. Development of innovative agricultural extension models | 1. Institutionalization and out-scaling of IARI-Post office extension model<br>2. Devising extension approaches for climate change adaptation and livelihood security<br>3. To design and validate ICT based extension model |

| Project | Objectives |
|---|---|
| 4. Enhancing nutritional security and gender empowerment | 1. To assess the consumption pattern and nutritional status of target group.<br>2. To design, develop and validate agri-nutri multimedia modules for enhancing nutritional security<br>3. To conduct capacity building interventions on nutritional security.<br>4. To assess the technological gap in agri, horti and fodder production in context of nutritional security<br>5. To study the effectiveness of institutional interventions on nutritional security and suggest suitable strategies for convergence.<br>6. To evaluate the impact of nutritional education interventions and capacity building programmes.<br>7. To assess the organizational climate and training needs of extension professionals for gender empowerment.<br>8. To design and validate e learning module for extension professionals for gender empowerment. |
| 5. Impact of policy reforms on development of agricultural markets and food processing industries | 1. To study the effect of market innovations on inclusiveness and efficiency of agricultural markets<br>2. To examine the growth, factor intensity, investment and productivity of food processing industry<br>3. To assess the industry-farmer linkages and benefits accrue to the farmers |
| 6. Maximizing farm profitability through entrepreneurship development and farmer led innovations | 1. To study feasibility of taking up specialty agriculture production and scaling up of farmer led innovations for Agripreneurship development.<br>2. To study the capacity building needs of famers and design suitable capacity building modules for agripreneurship and outscaling farmers' innovations.<br>3. To study backward and forward linkages, conduct network analysis for learning exchanges among various stakeholders for Agripreneurship and FLI promotion.<br>4. To validate the Farmer led innovations for Agripreneurial potential.<br>5. To design a framework for agricultural entrepreneurship development and developing a strategy for institutionalization of Farmer Led Innovations. |

| Project | Objectives |
|---|---|
| 7. Outscaling agricultural innovations for enhancing farm income and employment | 1. To conduct agro-ecosystem analysis of selected villages in NCR.<br>2. To identify and assess suitable technologies for enhancing farm income and employment.<br>3. To empower farmers and farm women through capacity building.<br>4. To develop effective forward and backward linkages for sustainable agricultural development. |
| 8. ZTM & BPD Unit for commercialization of IARI Technologies | 1. To identify the potential technologies, ready for commercialization and develop into marketable technologies and upscale them into viable agri-business under public-private partnership framework.<br>2. To develop a mechanism for transferring technology from IARI to public or private sectors by utilizing the R&D backup of the institute.<br>3. To impart consultancy and training for preparing prospective entrepreneurs and value-added human resources.<br>4. To help entrepreneurs in ideation, business plan and establishing their startup companies in agriculture sector.<br>5. To strengthen R&D focus of the institute towards more applied research through backward linkages from industry. |

## C. Outreach programmes

### a. School of Crop Improvement

| Projects | Objectives |
|---|---|
| 1. Strengthening of Wheat Programme in Eastern India (IARI Regional Station, Pusa, Bihar) | 1. To strengthen the existing infrastructure of centre for increasing productivity of wheat crop in Eastern India<br>2. To develop the centre for technology assessor and grower and act as incubator for disseminating the required appropriate technology for specific situation in Eastern India<br>3. Agronomic management of wheat crop in different edaphic conditions of Eastern India and<br>4. Dissemination of improved technology for cultivation and seed production of wheat in different farming situations of Eastern India |
| 2. Strengthening of Wheat Programme in Central India (IARI Regional Station, Indore) | 1. Early maturity under timely and late planting conditions to improve per day productivity and to save irrigation water.<br>2. Early heat and drought tolerance to utilize residual moisture and limited irrigation availability under October planting after kharif harvest.<br>3. Diverse genes for resistance to leaf and stem rusts.<br>4. High protein, high β-carotene and strong gluten in durum wheat for used as "nutritious chapatti" and semolina (suji) to alleviate the problem of "malnutrition".<br>5. High protein and good chapatti making quality in aestivum wheat.<br>6. Developing limited irrigation wheat cultivation technology to improve "water use efficiency" in Central India.<br>7. Identification of diverse sources of rust resistance with particular reference to stem rust in durums and leaf rusts in aestivums for incorporating the same in breeding programmes.<br>8. Developing/identifying durum wheat genotypes with desired quality traits with special emphasis on high β-carotene content.<br>9. Popularisation of durum wheat cultivation and consumption to eliminate secondary build up of rusts and to provide "nutritional security" to Indian population.<br>10. Popularization of wheat cultivation in tribal and remote areas to assure their needs of "food and feed" in order to check their migration to cities |

| Projects | Objectives |
|---|---|
| 3.Establishment of two Out-station Collaborative Research Centres in Punjab and Madhya Pradesh | 1. Breeder and Foundation seed production and distribution<br>2. Organization of participatory seed production with farmers<br>3. Processing of seed and quality testing<br>4. Yield and disease evaluation through trials<br>5. Selection among advanced lines for suitability<br>6. Product refinement and demonstration at CORC farm and local farmers for participatory evaluation of the varieties<br>7. Exhibition of IARI varietal technologies |

**b. School of Social Sciences**

| Project | Objectives |
|---|---|
| Strengthening extension education programme of developing innovative models and techniques for higher productivity and profitability in agriculture | 1. To develop participatory methodology for promotion of diversified agriculture for rural and peri-urban areas involving SAUs, ICAR Institutes and VOs.<br>2. To develop an alternate extension mechanism for dissemination of farmer technologies and information through linkage with post offices and KVKs.<br>3. To mobilize farmers for group action and entrepreneurship development. |

## D. Strengthening and Modernizing Research Facilities

| IARI Schools | Projects | Objectives |
|---|---|---|
| **School of Crop Improvement and School of Basic Sciences** | Genomics and Phenomics facilities for accelerating crop improvement and crop protection technology development | 1. To decipher the plant traits from the genomics information<br>2. To predict the phenotype in diverse challenging environments<br>3. To pyramid plant traits in desirable combinations to develop designer crops with enhanced productivity, quality and climate resilience per unit quantity of input use. |
| **School of Horticulture and School of NRM** | Strengthening of Protected Horticultural research | 1. Development and standardization of IPM based production technology of Vegetables for different protected conditions<br>2. Development of Varieties/Hybrids of selected vegetables and flower suitable for cultivation under protected conditions<br>3. Development of grafting technology for vegetables seedlings.<br>4. Standardization of Propagation technology of Rose, Carnation and Dahlia.<br>5. Studies on nutrient dynamic, fertigation scheduling and estimation of water and nutrient productivity for protected cultivation of different horticultural crops.<br>6. Development and Evaluation of Hydroponics/ Aquaponics technology for production of high value vegetables and flowers.<br>7. Studies on appropriate mechanization strategies for protected horticulture.<br>8. To stimulate entrepreneurial development in the area of protected cultivation on commercial scale. |
| **School of Crop Protection** | National Facility for Insect Rearing and Xenobiotic-cum-Transgenic Bioassays | 1. Collection of nucleus cultures of key insect pests of agricultural importance and development of their mass rearing technologies of most important selected key pests.<br>2. Development of quality protocols of test insect pests.<br>3. Development of ready-to-use diets for insect rearing.<br>4. Development of bioassay techniques for xenobiotics like insecticides, bioinsecticides, microbials in vivo and in situ.<br>5. Development of bioassays for plant incorporated protectants like Bt toxins and also for in situ transgenics.<br>6. Development of formats for test results and their presentations.<br>7. Services related to insect rearing and bioassays including publications, workshops, etc |

| | | |
|---|---|---|
| | Diagnosis and management strategies of virus and virus like diseases of crops | 1. To develop and/or validate grower friendly immuno and nucleo-based diagnostics for viruses infecting field and horticultural crops.<br>2. To develop management strategy for viral diseases affecting Solanaceous and Cucurbitaceous crops.<br>3. To produce virus free planting material |
| **School of NRM** | Modernization of the IARI Research Farm using Solar Energy and Micro-irrigation | 1. Development and operationalization of a wireless sensor controlled automatic surface (basin/ border) and drip/ sprinkler irrigation systems for enhancing farm irrigation water use efficiency.<br>2. Development of solar energy farms for supplemental energy supply to modernized irrigation systems.<br>3. Demonstration of modern precision irrigation systems for wider adoption and up-scaling |

## E. Programmes for NEH and TSP

| IARI Schools | Projects | Objectives |
|---|---|---|
| **Programmes for NEH** | Integrated programme to promote IARI technologies and other relevant agricultural technologies for economic development of NEH region | 1. Transfer of technology for appropriate farm mechanization, improving soil health and livestock management<br>2. Quality seed production including hybrids and new varieties in priority crops like maize, rice, pearl millets, mustard and vegetables<br>3. Develop seed processing, drying and storage facilities along with facilities for value addition<br>4. Develop soil and water testing facility, protected cultivation with drip irrigation for off season vegetable cultivation and seed production<br>5. Develop strategies to increase overall agricultural production in north east |
| **Tribal Sub Plan** | Integrated programme promoting IARI technologies and other relevant agricultural technologies for economic development of tribal areas | 1. Raising of model nurseries for virus free planting material of large cardamom and khasi mandrain on the farmers field in the North Eastern India<br>2. Establishing demonstration plots in the farmer's field<br>3. Conducting awareness among the farmers about the package of practices for cultivating both the crops<br>4. Conducting short on/off farm training regarding various aspects of cultivation of both the targeted crops<br>5. Develop supply chain for the mango produced by the farmers who are involved in treating their produce in the hot water treatment plant which has already been established at Rayagada, Odisha<br>6. On-farm training programme for the mango growers will also be conducted to ensure proper harvesting D. and handling of the mangoes so that it fetches good returns to the growers |

## F. Human Resource Development

| IARI Schools | Projects | Objectives |
|---|---|---|
| **Human Resource Development** | Post-graduate education and research, and human resource development in Agriculture | 1. To impart M.Sc, M.Tech., and Ph.D. education to the students of IARI, New Delhi; IARI-Jharkhand and IARI, Assam<br>2. To enhance the skills of IARI faculties through regular faculty upgradation trainings in India & abroad<br>3. To impart trainings in the frontier areas of agriculture to faculties, scientists and research manpower from ICAR institutes and state Agricultural Universities<br>4. Strengthening Post Graduate Education through National and International Collaboration<br>5. Strengthen Central Library and Bio-Informatics |

# ACHIEVEMENTS

## I. SCHOOL OF CROP IMPROVEMENT

### A. GENETICS, GENOMICS AND PLANT BREEDING

A total of 26 projects were carried out during the period 2009-2016.

**(1) WHEAT**

The most significant achievement is the release of 20 wheat varieties for different production conditions (irrigated timely and late sown, rainfed and restricted irrigation and conservation agriculture) of wheat cultivation (Table 6).

**Table 6 : Twenty wheat varieties for different production conditions**

| S. No. | Variety | Year of release | Production Condition | Av. yield (t/ha) |
|---|---|---|---|---|
| **NORTHERN HILL ZONE** | | | | |
| 1 | **HS 542 (Pusa Kiran)** | 2015 | Rainfed , Early sown | 3.29 |
| 2 | **HS 562** | 2016 | Rainfed & Irrigated Timely sown | 3.68/5.27 |
| **NORTH WESTERN PLAINS ZONE** | | | | |
| 3 | **HD2967** | 2011 | Irrigated, Timely sown | 5.11 |
| 4 | **HD3086** (*Pusa Gautami*) | 2014 | Irrigated, Timely Sown | 5.46 |
| 5 | **HD3043** | 2012 | Restricted Irrigation, Timely Sown | 4.23 |
| 6 | **HD3059** (*Pusa Pachheti*) | 2013 | Irrigated, Late Sown | 4.30 |
| 7 | **HD3117** | 2016 | CA Late sown | 4.79 |
| 8 | **HDCSW 18** | 2016 | CA Early sown | 6.30 |
| 9 | **HD2985** (*Pusa Basant*) | 2011 | Irrigated, Late Sown | 3.77 |
| **NORTH EASTERN PLAINS ZONE** | | | | |
| 10 | **HD2967** | 2012 | Irrigated, Timely Sown | 4.45 |
| 11 | **HD3118** *(Pusa Vatsala)* | 2015 | Irrigated, Late Sown | 4.17 |
| **CENTRAL ZONE** | | | | |
| 12 | **HI 8713*** (*Pusa Mangal*) | 2013 | Irrigated, Timely Sown | 5.23 |

| S. No. | Variety | Year of release | Production Condition | Av. yield (t/ha) |
|---|---|---|---|---|
| 13 | **HI 8737***(Pusa Anmol) | 2015 | Irrigated, Timely Sown | 5.34 |
| 14 | **HD 4728*** *(Pusa Malwi)* | 2016 | Irrigated, Timely Sown | 5.42 |
| **PENNINSLAR ZONE** | | | | |
| 15 | **HD2987** (*Pusa Bahar*) | 2011 | Rainfed & Restricted Irrigation, Timely Sown | 1.75<br>3.15 |
| 16 | **HD3090** (*Pusa Amulya*) | 2014 | Irrigated, Late Sown | 4.21 |
| **SOUTHERN HILL ZONE** | | | | |
| 17 | COW-2 | 2011 | IR, TS, State of Tamil Nadu | 404 |
| 18 | **HW5216** *(Pusa Navgiri)* | 2013 | Restricted Irrigation, Timely Sown | 4.56 |
| 19 | **HW1098** *(Pusa Nilgiri)* | 2015 | Irrigated, Timely Sown | 4.55 |
| 20 | COW-3 | 2015 | IR, TS, State of Tamil Nadu | 4.76 |

- The share in breeder seed production of IARI varieties at national level is continuously showing upward trend. During 2009-10, IARI varieties' share was around 14 per cent of total breeder seed production which increased up to 31.1 percent during 2014-15. On an average share of IARI wheat varieties was 20.1% of total breeder seed produced during 2009-16.

- ***Unprecedented area coverage by wheat variety HD 2967*** **(Fig. 4):** Released for NWPZ and NEPZ under timely sown conditions. It tops in the list of breeder Seed demand and annual production of breeder seed touched the unprecedented mark of **4050 q**. Besides, the production of TL or IARI seed by the institute and registered growers at large scale is further indicative of its wider spread in wheat growing areas.


**Fig. 4 Wheat Variety HD 2967**

- ***HD3086*** **(Fig. 5)** ***(Pusa Gautami):*** Released for timely sown irrigated conditions of NWPZ of the country with average yield of 5.46 t/ha. It is resistant to yellow rust and brown rust. This thermo tolerant variety has high protein content (12.5%), sedimentation value (37ml), Glu-1 Score (10/10) and extraction rate (70.5%) suitable for bread making.


**Fig. 5 Wheat Variety HD 3086**

### *1.1 Breeding for abiotic (drought and terminal heat tolerance) stresses*

a. Drought and terminal heat stress are two most important abiotic stresses in wheat. Trait based germplasm lines were identified for physiological and agronomical traits related to drought in wheat. Using biparental and RIL mapping populations, 61 QTLs on chromosome 17 and 44 on chromosome 16 were identified in two different crosses viz., DBW 43 x HI 1500 and GW 322*2 x WH 730, respectively.

b. Molecular and morpho-agronomical characterization of root architecture was studied in a set of 158 diverse wheat genotypes of Australian (72) and Indian (86) origin at seedling and reproductive stages for drought tolerance. Molecular markers (802 SNPs and 120 SSRs) and physiological characterization of wheat working collection has brought out C306 and its derivatives as distinct group.

c. Used molecular breeding strategies such as marker assisted backcross breeding (MABB) and marker assisted recurrent selection (MARS) in wheat. Validated and pyramided 12 QTLs for drought tolerance using MARS in wheat.

d. Mapping populations for drought and heat tolerance were developed.

e. Genetically diverse terminal heat tolerant genotypes were identified using molecular markers, and physio- morphological traits. Using BIL population of cross HD 2733 *2 x WH 730, 16 QTLs were identified on chromosome 11. Interrelationship studies revealed that for improving grain yield under terminal heat stress condition, breeder should aim for selecting genotypes with higher harvest index, more number of spikes/plant, bolder grains and stay green traits.

***1.2 Breeding for biotic stresses***

Among the biotic stresses rust (black, brown and yellow) are major diseases spread all over the country. Following new rust resistance genes were transferred from wild relatives

a. A seedling gene for leaf rust resistance was transferred successfully from diploid species *Ae. markgrafii* (2n=2x=14, genome CC) in cytological stable bread wheat background.

b. Leaf rust resistance was successfully transferred from tetraploid species *Triticum militinae* (2n=4X=28; geneome AAGG).

c. Transfer of rust resistance from other species was also undertaken. i.e. from *Ae. geniculata, Ae. speltoides, T. spelta, T. turgidum* etc.

***1.3 Use of molecular markers in transferring/pyramiding rust resistant genes:***

a. A set of **25** chloroplast specific microsatellite markers **(cp-SSR)** were designed in wheat and successfully validated for specificity of amplification.

b. Marker assisted backcross breeding (MABB) was used to develop several NILs for rust resistance genes, Lr19/Sr25, Lr24/Sr24, Lr34, Sr26, Yr10 and Yr15 in the background of wheat varieties HD2932, HD2967 and HD2733.

c. Rust resistance genes *Lr*19/*Sr*25 and *Lr*28 were pyramided in the genetic background of wheat variety HD2687 using molecular markers.

d. Besides rust resistance genes *Lr*24/*Sr*24, *Lr*28 and *Yr*15 were pyramided in the variety HD2687. *Yr* 15 was also individually transferred in HD2687. Rust resistance genes *Lr*24

+ *Lr*28, *Lr*28 + *Lr*37 and *Lr*24+*Lr*37 were pyramided in the genetic background of wheat variety WH147.

e. Molecular marker assisted pyramiding *Lr19/Sr25* and *Yr15* in wheat: *Lr19/Sr25* and *Yr15* genes were pyramided in wheat variety HS240.

f. Sources of resistance to stem rust race *Ug99* and its variants identified: and three bread wheats *viz*., DL 788-2 (Vidisha), HD 2987 (Pusa Bahar) and HI 1531 (Harshita) showed resistance to African stem rust race Ug99 and its variants during screening in Kenya.

g. Developing NILs of *Lr* genes present in leaf rust differentials: Nine homozygous resistant lines carrying *Lr1*, *Lr2a*, *Lr2c*, *Lr3a*, *Lr9*, *Lr10*, *Lr15*, *Lr17a*, and *Lr20* have been developed in NP 4 Background.

h. 2087 germplasm lines were tested at seedling and at adult stage of plant growth against most virulent and prevalent pathotype 77-5 of leaf rust and pathotype 40A of stem rust. 173 germplasm lines were characterized as Adult Plant Resistant (APR) lines to leaf rust. Similarly, 78 lines were identified to carry adult plant resistance for stem rust. At least four genes were observed among 12 bread wheat genotypes *viz*., `CPAN 1676', `CPAN 1796', `CSP 44'; `Frontana', `HD 2009', `HD 2135', `HUW 37', `HW 517', `Nainari 60', `Pavon 76', `VL 404' and `WG 138' in addition to known APR

i. Five rust resistance genes from different sources were mapped on to different chromosomes and their closest markers were identified, which can be used in marker assisted selection in future (Table 7).

**Table 7: Five rust resistance genes from different sources**

| S. No. | Genetic Stock | Rust | Genes mapped | Chr# | Closest marker Identified |
|---|---|---|---|---|---|
| 1 | WR95 | Stem rust | *SrWR1* (recessive gene) | 5DL | *Xcfd3* and *Xwmc215* (8.6cM and 12.8cM away from the gene) |
| 2 | WR95 | Stem rust | *SrWR*2 (dominant gene ) | 2BL | *Xwmc317* (8.2cM) |
| 3 | Trinakria | Leaf rust | *LrTrK* (Dominant) | 5BS | *Xgwm234* (6.3cM) |
| 4 | Selection G12 | Leaf rust | *LrSelG12* (Incompletely dominant gene) | 3BL | *Xgwm114* (28.3 cM)and *Xgwm547* (6 cM) |
| 5 | *Secale cereale* | Leaf rust | *Lr45* | 2AS | $G372_{94}$ and $G372_{185}$ |

j. Assessment of genetic diversity and inheritance of rust resistance in wheat**:** 104 SSR markers were used for assessing genetic diversity in wheat. 278 alleles were identified across the genotypes. Cluster analysis revealed maximum genetic distance (GD = 0.843) between FLW13 and FLW20, depicting their distant relatedness, while cultivars HS240 & HS295 showed least genetic distance (GD = 0.624) suggesting their relatedness. Genetic stock HS 431 was found to possess single recessive gene pair for controlling leaf rust resistance against most virulent pt. 121R63-1. Similarly, test stock FLW 13 was found to possess single dominant gene for inheritance of stripe rust resistance against 46S119 and 78S84 pathotypes.

k. Competitive ability and fitness potential among leaf rust pathotypes: 77-5 (121R63-1) pathotype of leaf rust showed better competitive ability in comparison to pathotypes 77, 77-2, 104-2 and 106. It exhibited low incubation and latent period, high number of uredial pustules and more urediniospores /cm2, indicating its high fitness potential. High competitive ability and fitness potential explains its predominance for the last 15 years in India.

l. Gene pyramiding through backcross programme using major/seedling leaf, stem and stripe rust resistance genes, *Lr19/Sr25, Lr24/Sr24, Lr28, Lr32, Lr35, Lr37/Yr17, Lr39, Lr45, Lr47, Lr52/Yr47, Lr53* and *Lr57/Yr40, Sr14, Sr22, Sr24/Lr24, Sr25/Lr19, Sr26, Sr27, Sr29, Sr30, Sr33, Sr35, Sr36/Pm6* and *Sr44, Yr10, Yr15, Yr25* and *Yr35* respectively

m. Frequent breakdown of resistance due to the emergence of new pathotypes paved the way for the use of minor/adult plant resistance (APR)/race non specific resistance genes viz., *Sr2+, Lr34+, Lr46+, Lr67, Lr68+* in the breeding programme for imparting durable rust resistance.

n. Molecular mapping and validation of the microsatellite markers linked to the *Secale cereale* derived leaf rust resistance gene *Lr45* in wheat: Markers G37294 and G372185 closely linked to the gene can serve as robust co-dominant markers for utilization of *Lr45* in wheat improvement.

o. Four genes for resistance to stem rust pathotype 40A, and 8 each for stem rust pathotype 117-6 and leaf rust pathotype 12-2 were identified among five durum genotypes *viz*., B '662', 'ED 2398-A', 'HG 110', 'IWP 5019' and 'Line 1172'. A total of 7 diverse genes for leaf rust resistance were identified among 5 durum genotypes *viz*., `AKDW 4339', `B 276', `CPAN 6118', `Guji 'S', and `VD 2001-14' using leaf rust pathotype 12-2 (1R5). Five diverse genes for leaf rust resistance were identified among 4 durum genotypes *viz*., `HD 4672', `MPO 615', `Raj 6562' and `RS 749' using pathotype 12-5 (29R45). Three diverse genes for seedling resistance to stem rust pathotype 117-6 were identified among durum genotypes `GW 1114', `HD 4672' and `RS 749'

p. Identification of 4 durums *viz*., HD 4672 (Malav Ratna), HI 8498 (Malavshakti), HI 8627 (Malav Kirti) and HI 8663 (Poshan) resistant to stem rust race *Ug* 99 and its variant.

q. Biosystematics of pathogens of economic importance: Based on morphological studies, the fungi associated with head scab of wheat was identified as *Fusarium graminearum* and *F.solani* The fungi associated with leaf blight of wheat viz., *Bipolaris sorokiniana, B. rostrata, Bipolaris* sp. and *Alternaria* sp. have been identified. Three species of *Chaetomium* viz., *C. globosum*, *C. megalocarpum* and *C. botrychodes* (biocontrol agent) have been isolated and identified

### 1.4 *Breeding for Conservation Agriculture*

a. The institute has initiated the breeding wheat varieties for conservation agriculture (CA). Continuous evaluation of breeding material bred and selected under CA showed significant genotype x management interaction. It is also found that yield gain in wheat can be consolidated by exploiting genotype x management interaction. The efforts made in development of varieties led to release of two varieties viz., HDCSW18 (early sowing) and HD 3117 (late sowing) under conservation agriculture.

b. Evaluation of released varieties since 1905 revealed that increased duration with delayed heading and better biomass accumulation are major contributor for yield gain. Duration can be further prolonged, though marginally by early seeding and exploiting *Vrn* and *Ppd* genes under CA.

### 1.5 *Breeding for quality traits*

a. Three QTLs were identified for high thousand grain weight in the population Synthetic 46/ HD2932

b. A large number of germplasm including pre-green revolution varieties, landraces, exotic trait specific wheat lines, wild species and all released varieties of bread wheat in India were consolidated. 2500 genotypes were evaluated for preliminary tests such as Thousand kernel weight (TKW), Grain protein content (GPC), SDS-sedimentation value (SV), kernel hardness index (HI) and Hectolitre or test weight (TW). More than 50 promising genotypes were identified from these analyses.

c. Nutritional quality traits such as grain iron and zinc have been analysed in 2500 genotypes. The varieties ranged between 20-45ppm for grain iron and zinc concentrations. Wild species and landraces showed two to three fold higher amounts above the varieties.

d. A biparental mapping population developed from the cross of Indian bread wheat cultivar WH542 and synthetic derivative (*Triticum dicoccon* PI94624/*Aegilopssquarrosa* (409)//BCN from CIMMYT, Mexico) consisting of 324 RILs was selected for mapping. A total of 11 QTLs located on chromosomes 2A, 3A, 4A, 5A, 7A and 7B were identified in different environments. This population (176 RILs) was genotyped further with SNPs on 35K chip.

### 1.6 *Development of genotypes for diversified uses:*

Breeding varieties that yield biscuit quality specific flour is an important objective in quality breeding. Cakes and cookies require wheat with soft grain and weak and extensible dough. Genes and their markers responsible for imparting these traits have been developed and used in a marker assisted breeding programme. Two genotypes DBW14 and HI1563 were targeted for MABB. Gene for softness (*PinAD1a*) has been mobilized into DBW 14 while the genes *PinAD1a, GluB3b and GluD3c*) are being mobilized into HI1563 from Australian donors. For this 110 SSR were found polymorphic for DBW14 X Barham and 100 SSR were found polymorphic for HI1563 X Barham and used in background selection.

## (2) RICE

**Table 8 : Rice varieties released**

| S. No. | Name of the Rice Variety | Year of Release | Average yield (t/ ha) | Days to maturity | Area for which it is recommended for Cultivation |
|---|---|---|---|---|---|
| 1 | Pusa Basmati 1509 | 2013 | 4.25 | 120 | Basmati growing areas of Uttar Pradesh, Punjab and Delhi |
| 2 | Pusa 6 (Pusa 1612) | 2013 | 5.07 | 126 | Punjab, Haryana, Delhi, J&K |
| 3 | Pusa 1592 | 2015 | 4.72 | 125 | Punjab, Haryana, Delhi, J&K |
| 4 | Pusa Basmati 1609 | 2015 | 4.60 | 120 | Basmati growing areas of Delhi, Uttarakhand, Punjab and Western Uttar Pradesh |
| 5 | Pusa Basmati 1637 | 2016 | 4.20 | 130 | -do- |
| 6 | Pusa Basmati 1728 | 2016 | 4.18 | 145 | -do- |

**2.1 *Pusa Basmati 1509* (Fig. 6):** It is a semi-dwarf early maturing Basmati rice variety, with 120 days seed to seed maturity, the shortest duration for any Basmati rice variety released in the world. It has an average yield of 41.4 q/ha. Owing to its early maturity, cultivation can help saving upto 5 irrigations (about 33% of irrigation water) compared to Pusa Basmati 1121. Economizes the cost of agri-inputs and permitting higher cropping intensity resulting in better economic gains to the farmers.

**Fig. 6: Rice Variety 1509**

***2.2 Pusa Basmati 1637* (Fig. 7):** Pusa Basmati 1637 is a MAS (marker assisted selection) derived near isogenic line of Pusa Basmati 1 possessing *Pi9* gene for blast resistance. Its average yield is 4.2 t/ ha in 130 days. PB 1637 being resistant to both leaf and neck blast will help in reducing the use of fungicides significantly, thus economizing cost of cultivation and also minimizing the risk of pesticide residue, which is a major concern in both domestic and global Basmati trade thereby consolidating the export to European Union where the minimum residue limit for tricyclazole (a fungicide used for controlling neck blast disease in rice) has been fixed at a bare minimum of 0.01ppm.

**Fig. 7: Rice Variety 1637**

***2.3 Development and Evaluation of Pusa Basmati 1 NILs with seven genes for blast resistance:*** In order to develop isogenic lines of Pusa Basmati 1 carrying seven different genes (*Pi54, Piz5, Pita, Pi1, Pib, Pi5 and Pi9*) for blast resistance, advanced backcross derived lines have been developed. 40 homozygous advanced backcross derived lines carrying genes; *Pi54, Pi1, Pita, Pi9, Pi5, Pib, Piz5* and 80 homozygous lines carrying genes *Pi54, Pi1, Pita* have been evaluated and promising lines identified.

***2.4 Marker assisted improvement for salinity stress:*** Pusa Basmati 1121 and Pusa Basmati 1 are sensitive to soil salinity. Marker assisted backcross breeding program was initiated to incorporate a major QTL *'Saltol'* into the genetic background of these varieties from a non-Basmati donor source FL478 without hampering the grain and cooking quality traits of the Basmati rice varieties. The improved genotypes with *Saltol* QTL governing salinity tolerance in the background of Pusa Basmati 1121 and Pusa Basmati 1 have been identified and confirmed for salinity tolerance both under hydroponics and salinity microplots.

***2.5 Marker assisted improvement for blast in BPT5204:*** A replicated trial of 27 homozygous advanced backcross derived lines carrying genes, *Pi54, Pi1* and *Pita* in the background of BPT5204 was conducted at three locations namely New Delhi, Pusa and Aduthurai during *Kharif* 2014. Based on two years of evaluation at three locations, three NILs namely Pusa1850-16 (*Pi54+Pi1*), two three gene pyramids (Pusa1850-27 and Pusa1850-33) were identified as promising for nomination in the national trials for evaluaion.

***2.6 Marker assisted incorporation of drought tolerance in rice varieties:*** Marker assisted backcross breeding was carried to incorporate the QTLs governing drought tolerance such as *qDTY1.1* from N22 and *qDTY3.1* from IR81896-B-B-142 into the genetic background of Pusa Basmati 1 and Pusa 44, respectively. A total of six $BC_3F_3$ families homozygous for *qDTY1.1* and 36 families homozygous for *qDTY3.1*in the genetic background of Pusa 44 have been identified.

***2.7 Development of dwarf high-yielding short grain aromatic rice lines:*** With view to develop high yielding, dwarf, short grain aromatic rice varieties, which are on par in grain and cooking quality with Kalanamak, a short grain aromatic rice variety from eastern UP, Kalnamak was crossed with a semi-dwarf short grain aromatic rice breeding line Pusa 1176. One of the line Pusa 1638-07-48, which has grain dimensions, husk colour and cooking quality typical of Kalanamak. These lines hold great promise for enhancing the production and productivity of short grain aromatic rices in Kalanamak belt of Uttar Pradesh.

***2.8 Registration of elite genetic stocks resistant to bacterial leaf blight and blast diseases:*** Seven germplasm including two improved versions of PRR 78 namely, Pusa1602-06-24-5-45 (INGR12002, IC0593847) carrying gene *Piz5* and Pusa1603-06-11-4-19 (INGR12003, IC0593848) carrying gene *Pi54,* conferring resistance to blast disease, two improved versions of each of Pusa 6B namely, Pusa 1605-05-38-3-1 (INGR 10121) and Pusa 1605-05-38-3-2 (INGR10122) and PRR 78 namely, Pusa1601-05-46-1-1 (INGR 10123) and Pusa 1601-05-46-5-3 (INGR 10124), having resistance to bacterial blight. and an early maturing semi-dwarf Basmati rice genotype, Pusa 1509-03-1-7-2 (INGR12052, IC0593942), have been registered with NBPGR, New Delhi.

***2.9 Molecular mapping of QTLs governing resistance to Bakanae disease in rice*:** A rapid protocol for screening bakanae resistance in rice has been developed and QTL mapping was conducted in a RIL population generated from a cross between highly susceptible parent Pusa Basmati 1121 and highly resistant parent Pusa 1342. A major QTL, *qBK1.2* with phenotypic variation of 24.07 % and two minor QTLs, namely, *qBK1.1*and *qBK1.3*on chromosome 1 have been identified.

**(3) MAIZE**

***3.1 Breeding for abiotic and biotic stresses:***

a. Drought and water-logging are the two most important abiotic stresses of maize growing areas in India. Large set of maize inbreds were systematically screened at seedling as well as vegetative stages of the crop growth under drought and water-logging stress condition. By using whole-genome transcriptomics tools, several genes and pathways responsible for water-logging stress tolerance have been identified. Additionally, several maize inbreds with those adaptive traits as well as having better root morphology, survivability and grain yield were identified. The selected inbreds were used in hybrids breeding program and several promising single cross hybrids have been developed.

b. During the project period, a large set of maize inbreds were screened every season under natural as well as artificial epiphytotics against *Turcicum* leaf blight (TLB), maydis leaf blight (MLB) and banded leaf and sheath blight (BLSB). Resistant lines for single as well as multiple diseases have been identified. Experimental hybrids were developed using potential inbreds with disease resistance and good agronomical traits. Promising single cross hybrids have been identified for disease resistance as well as with good yield potential. F2-derived mapping populations were derived to map the QTLs for *Turciucm* leaf blight.

**3.2** ***Breeding for quality traits:***

a. ***MAS-derived provitamin-A rich hybrid:*** Marker-assisted selection was employed to introgress favourable allele of β-carotene hydroxylase (*crtRB1*) into the parental inbreds of extra early hybrid, Vivek QPM-9. Mean kernel β-carotene in the MAS-derived hybrid (APQH-9) (Fig. 8) was 17.8 μg/g, while it was 2.1 μg/g in the original hybrid. It also possesses high tryptophan (0.80% in endosperm protein). During *kharif* -2014 and -2015, the improved hybrid was evaluated in NHZ and PZ under the AICRP. It is country's first multi-nutrient rich maize hybrid developed through breeding approaches.

**Fig. 8: Cobs of APQH 9, rich in provitamin A and quality protein**

b. ***Marker-assisted pyramiding of crtRB1 and lcyE in QPM hybrids:*** QPM inbreds, HKI161, HKI163, HKI193-1 and HKI-193-2 (parents of QPM hybrid: HQPM-1, HQPM-4, HQPM-5 and HQPM-7) were targeted for introgression of both *crtRB1* and *lcyE* alleles using marker assisted selection. The newly reconstituted hybrids possess high mean provitamin-A (9-13 μg/g) compared to original hybrids (<2.5 μg/g). Grain yield, plant- and cob- characteristics of improved hybrids were similar to original versions. They also possess similar levels of high lysine and tryptophan.

**c. *MAS-derived QPM hybrids:*** Recessive *opaque2* allele was introgressed into the parental inbreds of HM-4, HM-8 and HM-9. The MAS-derived QPM version of HM-4 (AQH-4: 0.73% tryptophan, 2.7% lysine in protein), HM-8 (AQH-8: 0.92% tryptophan, 3.9% lysine in protein) and HM-9 (AQH-9: 0.79% tryptophan, 3.9% lysine in protein) possess higher essential amino acids compared to original hybrids. The improved versions of these hybrids were evaluated in different zones (NWPZ for HM-4; PZ for HM-8 and NEPZ for HM-9) under AICRP during *kharif* 2014 and 2015. The grain yield of the improved version was found to be *at par* with the original hybrid.

**d. *Pyramiding of opaque2 and opaque16 for enhancement of lysine and tryptophan:*** Parental inbreds of HQPM-1, HQPM-4, HQPM-5 and HQPM-7 possessing *opaque2* allele were targeted for introgression of *opaque16* allele from Chinese source germplasm using marker-assisted selection. The reconstituted hybrids (*o2o2/o16o16*) possessed 50-60% more lysine and tryptophan over their original hybrids. The grain yield potential and other morphological characteristics were *at par* with their original versions. This is the first ever attempt in India to combine both *o2* and *o16* in single genetic background.

**e. *Marker-assisted introgression of VTE4 for enhancement of vitamin-E:*** Provitamin-A rich version of QPM inbreds that are parents of four popular hybrids (HQPM-1, HQPM-4, HQPM-5 and HQPM-7) were targeted for introgression of *VTE4* favourable allele. Progenies homozygous for *crtRB1, lcyE*, *opaque2* and *VTE4* have been selected in four genetic backgrounds. Further, parental inbreds of ASKH-1 and ASKH-2, two promising *sh2sh2*-based sweet corn hybrids were targeted for enrichment of provitamin-A and vitamin-E through introgression of *crtRB1* and *VTE4.* Backcross populations of inbreds viz., SWT-16, SWT-17 and SWT-18 with favourable alleles of *sh2*, *crtRB1* and *VTE4* were selected.

**f. *Marker-assisted introgression of lpa mutants for enhancement of bioavailability of Fe and Zn:*** Elite inbreds such as HKI161, HKI163, HKI193-1, HKI193-2, HKI323, HKI1105 and HKI1128, were targeted for introgression of *lpa1-1* and *lpa2-1* using marker-assisted selection. $BC_1F_1$ populations were genotyped using associated markers of *lpa1-1* and *lpa2-1*. Foreground positive segregants with high genome recovery were backcrossed to recurrent parents to develop $BC_2F_1$ populations.

**g. *Identification of marker for shrunken2 and sugary1 gene for enhancing kernel sweetness:*** Three F2 populations of V390 x MGSU-201, V390 x MGSU-202 and V359 x MGSU201 were analyzed using bulk segregant analysis. The analysis identified seven linked SSR markers for *su1* and four SSR markers linked to *sh2*. Across populations, umc2061 was identified as the nearest marker from su1 with genetic distance of 0.3, 0.6 and 1.6 cM, while *umc2276* could be located at 1.2 and 1.5 cM from *sh2*. These two markers can be effectively utilized in marker-assisted selection of sweet corn trait.

**h. *Development of promising sh2sh2/su1su1-based sweet corn hybrids:*** Sweet corn inbreds and hybrids with *sh2sh2/su1su1* genetic constitution have been developed. These new genotypes possess higher brix value than the conventionally bred only -*sh2sh2* and -*su1su1* genotypes. Two promising entries from a set of 61 hybrids have been selected. These are the first set of double recessive sweet corn hybrids developed by public sector organization in India.

*i. **Development of promising waxy corn hybrids:*** Waxy inbreds with *wx1wx1* genetic constitution have been developed. Traditional maize kernels possess ~30% amylose and ~70% amylopectin. Waxy maize kernels contain ~100% amylopectin which is used for diverse purposes including industrial applications. 77 waxy hybrids were evaluated, and four hybrids desirable agronomic characteristics and high grain yield potential have been identified. These are the first set of waxy hybrids developed by public sector organization in India.

*j. **Development of pop corn hybrids:*** A set of 75 promising pop corn hybrids has been tested at three diverse locations viz. IARI, New Delhi, GBPUAT, Pantnagar and IIMR-WNC, Hyderabad. Two promising hybrid with high yield potential and popping quality characteristics were identified.

### (4) PEARL MILLET

During 2009-16 three varieties were released, the details are given in (Table 9).

**Table 9 : Pearl millet varieties**

| **S. No.** | **Name of the variety** | **Average grain yield (t/ha)** | **Days to maturity** | Area of adaptation |
|---|---|---|---|---|
| 1 | Pusa Composite 701 | 2.3 | 80 | Rajasthan, Gujarat, Haryana, Punjab, U.P, M.P. and Delhi |
| 2 | Pusa Composite 612 | 2.5 | 80-85 | Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh |
| 3 | Pusa Composite 443 | 1.8-2.2 | 76 | Drier parts of Rajasthan, Haryana and Gujarat (<400 mm rainfall) |

a. Pusa 1201(MH 1849) a dual purpose hybrid was identified for Delhi state and adjoining areas in 2016. Average yield of this hybrid is 3.08 t/ha and stover yield is 7.8 t/ha. It matures in 80 days. Pusa 1201 is highly resistant to downy mildew.

b. Pearl millet inbred line PPMI 904 having high iron (91 mg/kg**)** and zinc (78 mg/kg) has been registered in NBPGR.

c. 300 germplasm lines including elite breeding lines, released varieties, and inbred parents of the hybrids (CMS lines and restorer lines) were screened for variations in Fe and Zn contents. Iron values ranged from 20 to 123 ppm (PPMI 2001) in grain, whereas, zinc values ranged from 20 to 98 ppm (PPMI 683). Among the hybrids, Pusa 415 had the highest Fe (48 ppm) and Zn (41 ppm) contents, while Pusa Composite 443 recorded 60 ppm Fe and 44 ppm Zn.

d. Five restorers were evaluated for their restoration ability on fourteen female parents belonging to $A_1$, $A_4$ and $A_5$ male sterile cytoplasms. It was found that the restorers D 23, PPMI 761 were acting as complete restorers for $A_1$ cytoplasm, partial restorer and maintainer for $A_4$ and $A_5$ cytoplasms, respectively.

e. Inheritance of fertility restoration of the $A_1$ system of cytoplasmic-nuclear male sterility in pearl millet was investigated using six crosses developed by crossing two diverse male sterile lines (A-lines) with three diverse restorers (R-lines). It was found that fertility restoration of $A_1$ CMS system in pearl millet was governed by two major genes but with different types of epistatic interactions in different genetic backgrounds.

f. To study the effect of pollination on Zn and Fe content, six plants each from 25 genotypes were selected, and half of the spikes were selfed and half were left for open pollination. The variability for iron and zinc ranged from 20.78-102.56 and 18.05- 89.89 mg/kg, respectively. Out of 25 genotypes used for bagging and open pollination, nineteen showed significant differences ($p = 0.05$) in Fe and Zn content under bagging and open pollination during the two out of three year experiment. Self-pollinated grains showed significantly high iron and zinc densities as compared with that in open pollinated grains.

g. An association mapping panel comprising 130 pearl millet genotypes including two checks (ICMB 98222 and Dhanshakti) for high grain Fe content were evaluated at IARI, New Delhi, RS-IARI, Dharwad and RS- NBPGR, Jodhpur. Grain iron content ranged from 32.3 to 111.9 ppm, whereas, grain zinc content ranged from 26.6 to 73.7 ppm. Structure analysis using DARwin classified genotypes to the three subpopulations with admixture. *Xipes* 0096, *Xipes* 0810 and *Xpsmp* 2261 were associated with high grain iron and zinc contents over location and year.

## (5) CHICKPEA

### *5.1 Development and release of high yielding chickpea varieties:*

a. Developed eight high yielding and biotic and abiotic stress tolerant desi and kabuli chickpea varieties (Table 10), which have been released for commercial cultivation in different agro-ecological regions of India.

**Table 10 : Development and release of high yielding chickpea varieties.**

| S. No. | Name of variety | Average yield (t/ha) | Duration (days) | Area of adaptation |
|---|---|---|---|---|
| 1. | Pusa 3043 (desi) | 1.6 | 125-130 | NEPZ |
| 2. | Pusa 3022 (kabuli) | 1.8 | 145-150 | NWPZ |
| 3. | Pusa 2085 (kabuli) | 1.8 | 145-150 | NCR |
| 4. | Pusa Green 112 (desi) | 1.6 | 145-150 | NCR |
| 5. | Pusa 5023 (kabuli) | 1.7 | 145-150 | NCR |
| 6. | Pusa 5028 (desi) | 1.9 | 145-150 | NCR |
| 7. | BGD 103 (desi) | 1.6 | 90-95 | Karnataka |
| 8. | Pusa 1105 (kabuli) | 1.5 | 95-100 | Karnataka |

5.2 *Identification of new genes for time of flowering and stem growth habit in chickpea:*

a. Identified a new dominant gene, ***Efl-3***, for time of flowering in chickpea genotype BGD 132. The gene has great significance in breeding short duration chickpea varieties better adapted to environments characterized by terminal drought and heat stress.

b. Identified two recessive genes, ***dt1 and dt2***, for determinate stem growth habit in newly identified chickpea genotype BGD 9971. These recessive genes have great significance in the genetic restructuring of plant type in chickpea and breeding for better adaptation to cool climate, high fertility and irrigated environments.

5.3 *Genetic improvement of short duration chickpea:*

a. Genetics of flowering time in chickpea in a short season environment was studied Time of flowering is governed by duplicate dominant genes with cumulative but unequal effect.

b. Genetics of determinate stem growth habit understood in chickpea. The determinacy is governed by two recessive genes viz., dt1 and dt2. Utilization of genes identified for determinacy has the major impact on chickpea breeding for better adaptation to cool climate, high fertility and irrigated environments.

***5.4 Marker assisted pyramiding of genes for wilt races foc 2, 3, 4 in chickpea:*** Using WR 315 as donor for wilt resistance and elite chickpea genotypes Pusa 372, Pusa 362, Pusa 5023, Pusa 1103 as recipient parents, 28 pyramided lines having foc 3,4 alleles and four lines with foc 2,3,4 have been advanced to preliminary yield trials. Validated markers for wilt race *foc 2* (TR19), *foc 3* (TA 110), *foc 4* (TA 110) were used along with those for 100 seed weight (TR56, TA78) and pods per plant (TR29, TA 146).

a. Two QTLs each for seed weight, qSW-1 and qSW-2 (explaining 11.54 and 19.24 % of phenotypic variance, respectively) and plant height, qPH-1 and qPH-2 (explaining 13.98 and 12.17 % of phenotypic variance, respectively) were detected.

***5.5 Development of mapping populations****:* Developed a TILLING population using drought tolerant variety ICC 4958, two mapping populations for drought (Pusa 362 x SBD 377 and Pusa 72 x SBD 377), one for high temperature (Pusa 1103 x SBD 377), one for wilt (Pusa green 112 x FLIP 90-166) and two for yield (Pusa green 112 x SBD 377 and Pusa 372 x PG 0515). Two interspecific mapping populations are in $F_2$ stage (Pusa 1053 x ILWC 118 and KAK 2 x ILWC 118). Two mapping populations (BG 362 x BGD 132 and BGD 132 x BG 362) for time of flowering gene (*Efl-3*) advanced to $F_{7:8}$.

***5.6 Targeted breeding for erect types amenable to mechanical harvesting and for herbicide tolerance*****:** Erect genotypes (BG 261, BG 276, Pusa 1103, HC 5) selected from germplasm were used in making crosses for developing lines with erect plant type. Promising lines have been developed based on first pod height (>25cm), angle of lowest primary branch (>60˚) and higher seed yield. These lines are currently being tested in All India Coordinated trials and one entry BG 3062 is in AVT-1.

***5.7 Morphological and biochemical evaluation of germplasm/breeding lines for herbicide tolerance:*** Total 165 germplasm accessions/ cultivars/breeding lines were screened for tolerance to post-emergence herbicide imazethapyr. Estimation of branched chain amino acids (BCAA) for ALS activity was carried out in tolerant and sensitive lines. The tolerant genotypes identified based on non-significant reduction in the yield attributes and BCAA (valine, leucine and isoleucine) content were ICC 82104, ICCV 10, ICCV 96003, ICC 00305 and ICC 1710 while ICCV 97107 was the most susceptible.

***5.8 New source of rust resistance in chickpea:*** The genotypes FLIP-97020-1785, ICC-1558 and ICC-1745 were identified as tolerant to rust caused by *Uromyces ciceri.*

**(6) PIGEON PEA**

***6.1 Pusa Arhar 16*****:** Determinate early maturing (120 days) pigeonpea genotype Pusa Arhar 16 (PADT-16) with semi-dwarf stature (92 cm), compact Plant type, synchronous maturity with 20 qt/ha yield under improved Agronomy (Reduced Row to row Spacing of 30 cm) have been developed. These genotypes enable easy spraying of insecticide and harvesting by combine harvester.

***6.2 Pusa 2012-1:*** was Promoted into AVT-1(Early) of NWPZ it had Zonal Mean yield of 2704 kg/ ha (27.04 q/ha) which was 7.68 % Increase over the check (Pusa 992 had 2511 kg/ha yield) in the IVT(E) Trial in 2012-13. It was evaluated in AVT- 1(Early) in 2013-14.

a. Sixteen improved genotypes of pigeonpea have been contributed for testing under AICRP.

b. 30 new R lines (male fertility restorers) have been developed from interspecific cross *C. scarabaeoides x Pusa 33*

c. 10 lines with compact erect plant type, early maturity, with 4 to 5 seeds/pod and bold seeds (10 -14 g/ 100 seed weight) suitable for pigeonpea - wheat rotation have been developed during 2015

d. Genotypes with erect compact plant type and extra early maturity (120 days) have been developed.

***6.3 Evaluation of developed extra early maturing (105 to 125 days) genotypes:*** 621 extra early maturing advanced lines derived from bi-parental crosses and multiple crosses were evaluated in Augmented design with check varieties. 25 high yielding lines with early maturity, compact erect plant type and bold seeds were selected for evaluation in station trial. Some of the lines were having perfect synchronous maturity (120 days) & annual habit were selected.

***6.4 Development of new R lines with superior plant type:*** 40 new restorers developed. 30 Newly developed 'R' lines from inter-specific cross (*C. scarabaeoides* X Pusa 33) were evaluated for earliness, male fertility restoration and pod bearing and superior R lines identified for further use in the generation of $F_1$ hybrids during 2015-16. 10 R lines of short duration have been developed through selection from the crosses involving short duration A lines and restorers of medium duration.

**6.5 *Identification of heterotic pools and conversion of superior genetic background into A and B lines, and diversity for restorer alleles:*** Based on diversity analysis using 390 EST-SSR markers 2 A lines of $A_4$ Cytoplasm & 6 of $A_2$ cytoplasm, 2 B lines & 19 R lines wer grouped into diverse clusters. Genetically diverse A and R lines were identified which are ICPA2047 & ICPR2740; ICPA2043 & ICPR3472; ICPA2043 & ICPR4013; MS10A & AKPR9; MS10A & AKPR100 and GT288A & AKPR417.

a. 49 Genotypes were screened for water logging tolerance (Table 11) under field and pot culture experiment during 2011-2012 and water logging tolerant genotypes were identified based on screening for water logging tolerance under pot culture and field experiment for RWC, Chlorophyl A, Chlorophyl B, Total Chlorophyl , Carotenoid content and RWC.

**Table 11 : Genotypes screened for water logging tolerance.**

| Tolerant | Moderately Tolerant | Moderately sensitive | Highly sensitive |
|---|---|---|---|
| JBP 110-B, IPAB 7-2-1, ICPL 332, ICPL 20120, ICPB 2039, ICPH 2740 | ICPL 20241, KPBR 80-2-1, DA 11, ICPB 2047, ASHA(C) | ICPL 20092,<br>ICPL 20123,<br>KRL 43,<br>IPA 11-17,<br>MARUTI( C)<br>ICPL 20238, | MAL9, LRG 30, ICPL 99050,ICPL 20237, ICPL 20128, ICPL 14085, ICPH 2431, UPAS 12O (C), IPAB 7-2-7, IPAB 7-2-1-7, ICPL 7035 (C), ICPL 20126, ICPH 2671, ICPL 20125, ICPL 87051, |

**6.6 *Inheritance and molecular mapping of QTL governing male fertility restoration (MFR):*** First report on inheritance of male fertility restoration for $A_2$ cytoplasm Dominant Complementary genes were found to control fertility restoration in 3 crosses (MS 04 X AKPR417, MS 04 X AKPR9 and MS 04 X AKPR100). In remaining 4 crosses (GT288A X GTR 9, GT 288A X GTR 11, GT 290A X GTR 9 and GT 290A X GTR 11) fertility restoration was governed by a single dominant gene.

a. QTLs for plant height, primary branches/plant, pod bearing length (on primary branch), days to 50 % flowering, pods/plant, seeds/pod and 100 seed weight have been identified by genotyping and phenotyping (over two diverse environments) of 300 RILs derived from the cross Pusa Dwarf X H 2001-4 in short duration pigeonpea.

**6.7 *Following three RIL mapping populations have been developed:***

a. Seed yield components (Pusa Dwarf x H 2001-4)

b. Seed size and plant type (H 2001-4 x ICPL 7035)

c. Fusarium wilt resistance (ICPL 8863 x TTB -7).

**6.8 *Identification of QTLs for water logging tolerance:*** RIL mapping population of cross Pusa Dwarf X H2001-4 was evaluated for water logging tolerance and markers associated to water logging tolerance were identified using BSA during 2015-2016. Genotyping of this mapping population using SNP markers is underway.

## (7) MUNGBEAN AND LENTIL

**Table 12 : Mungbean and lentil varieties released**

| Crop | Name | Average yield | Days to maturity | Area of adaptation |
|---|---|---|---|---|
| Mungbean | Pusa 0672 (Fig. 9) | 10-11q/ha | 75-80 | Northern Hill zone |
| | Pusa 1371 | 10-11q/ha | 70-75 | Northern Hill zone |
| Lentil | L 4717 (Fig. 10) | 13-14q/ha | 100 | Central Zone |


**Fig. 9: Mungbean Variety Pusa 0672**


**Fig. 10: Lentil Variety L 4717**

a. Three germplasm were registered with NBPGR: L- 4602: Aluminium tolerance, PDL -1: Drought tolerance, L -4704: High grain Fe and Zn

b. Screening techniques for screening lentil and mungbean against drought, heat and Aluminum stress tolerance were standardized.

c. Screening techniques for screening against MYMV and powdery mildew in mungbean and wilt in lentil were standardized.

d. Donors for biotic and abiotic stresses were identified. Mungbean, viz., MYMV: ML 1628, PM: EC 5220024, HUM-16, Pusa Baisaki and Pusa Vishal. Lentil viz., Wilt: ILL 10921, IG 70238, Rust: L 4149, IPL 332, IPL 194, Stemphilium blight: P3235, LL1122, ILL10832 Immune and Resistant P2127, P3205, P3206, P3216, P8103, P8110, P8111, P8115, P13122, P13128, P13129, P13130, P13131.

e. Mode of inheritance for biotic and abiotic stresses was studied. viz., Mungbean, MYMV: Resistance was governed by two recessive genes, Lentil, Rust: A single dominant gene controls rust resistance, Wilt: Single dominant gene.

f. Molecular markers linked to rust resistance, heat and drought tolerance in lentil were identified. In lentil (Rust): Two SRAP and two SSR markers differentiated the resistant and susceptible bulks. SSR marker Gllc 527 was estimated to be linked to rust resistant locus at a distance of 5.9 cM.

g. Donors for grain Fe and Zn concentration in lentil and association mapping for grain Fe and Zn in lentil were identified.

   Grain Fe: LL 147, P 2102, DPL 21, FLIP 96-57, and P13122

   Grain Zn: FLIP 96-57, P15114, IPL 220, P16220, L 5120, 10-2-B-2, L 4603 and 10-3-Y-26

AM analysis identified three SSRs (PBALC 13, PBALC 206, and GLLC 563) associated with grain Fe concentration explaining 9% to 11% of phenotypic variation and four SSRs (PBALC 353, SSR 317-1, PLC 62, and PBALC 217) were associated with grain Zn concentration explaining 14%, to 21% of phenotypic variation.

**(8) MUSTARD**

Eight varieties (Table 13) were released for various agro-climatic regions of the country.

**Table 13 : Mustard varieties for various agro-climatic regions.**

| Name of variety | Year of release | Yield (q/ha) | Area of Adaptation | Salient features |
|---|---|---|---|---|
| Pusa Double Zero Mustard-31 | 2016 | 23.00 | NWPZ | First double low variety of Indian mustard in the country. |
| Pusa Mustard-30 | 2013 | 18.24 | CZ | Timely sown irrigated conditions, low erucic acid |
| Pusa Mustard-29 | 2013 | 21.69 | NWPZ | Timely sown irrigated conditions, low erucic acid |
| Pusa Mustard-28 | 2012 | 19.93 | NWPZ | Early sown, short duration, matures in 107 days, per day productivity is 18.63 kg/day/ha |
| Pusa Mustard-27 | 2010 | 15.35 | CZ | Early sown, short duration, 107 days maturity, 41.7% oil content |
| Pusa Mustard-26 | 2010 | 16.04 | NWPZ | Late sown irrigated conditions, possesses terminal heat tolerance |
| Pusa Mustard-25 | 2010 | 14.70 | NWPZ | Early sown, short duration, 105 days maturity, substitute of toria |
| Pusa Mustard-24 | 2009 | 20.25 | NWPZ | Timely sown irrigated conditions, low erucic acid |

a. Share of IARI mustard varieties in breeder seed indent ranged from 32.19% (2009-10) to 56 (2013-14) with an average of 40% annually in comparison to national indents.

***8.1 CMS diversification:*** Seventy three CMS progenies with different cytoplasmic backgrounds (*mori/eru/ber*) have been developed by repeated backcrossing with a set of 26 maintainer lines of which five CMS lines have been bulked and are being used in hybrid development.

***8.2 Restorer development:*** To transfer fertility restoration in 27 genetic backgrounds (which restores fertility in mori/eru/ber sterile cytoplasms), $BC_5F_3$lines were generated using paired crosses. Homozygous dominant plants of restorers (in $BC_4F_4$ and $BC_5F_3$ generations) developed through MABB for transferring *Rf* gene to **5** genetic backgrounds viz., ofNPJ 93, NPJ 112, SEJ 8, Pusa Jagannath and Pusa Agarni have been developed for their further utilization. Backcrosses ($BC_2$-$BC_4$) have been attempted to transfer the *Rf* gene, which restores fertility in *mori*, *eru* and *ber* sterile cytoplasms, to 45 nuclear backgrounds.

**8.3** ***Effect of cytoplasms and genetic backgrounds of parental lines on fertility restoration in hybrids:*** Isonuclear alloplasmic cytoplasmic male sterile (CMS) lines with *Moricandia arvensis (mori), Diplotaxis erucoides (eru), D. berthautii (ber)* cytoplasms were developed in the six diverse genetic backgrounds of *Brassica juncea* (NPJ 112, NPJ 139, LES 1-27, SEJ 8, EC 308575 and Pusa Agarni). To assess the effect of sterile cytoplasms and nuclear backgrounds of parental lines (A & R) on fertility restoration, crosses were attempted between these 18 CMS lines with six restorers possessing fertility restorer gene from *M. arvensis*. Comparison of the mean percent pollen fertility in 108 single cross hybrids (36 hybrids in each cytoplasm) revealed that the hybrids based on *mori* cytoplasm were significantly different from the ones possessing *ber* and *eru* cytoplasms. Paired comparisons of the mean pollen fertility (%) of hybrids revealed that pollen fertility in hybrids was influenced by the genetic backgrounds of parents. Despite low pollen fertility, in some genetic backgrounds of hybrids developed from *eru* and *ber* sterile cytoplasms, the seed set was observed normal which indicates that the new sterility inducing cytoplasms i.e. *eru* and *ber* can be used for exploitation of heterosis in Indian mustard.

**8.4** ***Evaluation and maintenance of introgression lines and exotic genotypes:*** Twelve white rust and *Alternaria* blight tolerant introgression lines derived from *B. juncea* x *B. carinata* cross (Varuna x BCS-1) have shown high degree of resistance to white rust, and tolerance to *Alternaria* blight. 110 progenies of exotic genotypes (EC 27, EC 28, EC 30, EC 60, EC 61 and EC 62) were raised and 70 progenies were selected following pure line selection for their purification and maintenance.

**8.5** ***Validation and development of molecular markers for erucic acid and white rust:*** Low erucic acid is controlled by two recessive genes acting in additive manners. Two *FAE1* genes, reported in ZEM1, donor for low erucic acid variety- Pusa Karishma were isolated and studied for detection of already reported SNPs for both *FAE 1.1* and *FAE 1.2* genes. All the already reported four SNPs in *FAE* 1.1 gene and three in *FAE*1.2 gene were found in Pusa Karishma. Thus, all seven SNPs reported for low erucic have been validated in the parents and are being used in MAS for low erucic acid. Further, 10 new SNPs in *fae*1.1 (in *Brassica juncea*) were also identified. Using a $F_7$ RIL mapping population derived from Varuna x Bio-YSR, a *B. rapa* derived SSR marker was tagged at a distance of 10.2cM from the gene of interest governing white rust resistance.

**8.6** ***MAS for white rust and quality traits:*** Molecular markers linked to white rust and oil quality traits were validated. Marker At2g36360 reported linked to white rust in Donskaja was found polymorphic between Donskaja and Pusa Mastard 24 / Pusa Mastard 30. The marker At5g41560 reported linked to white rust in BEC-144 and Heera, was found polymorphic only between BEC 144 and recipient parents PM24/ PM30, while it was monomorphic between Heera and PM24/ PM30. The SNP 591 and SNP 1265of *Fae1.1 were* found polymorphic between parents having high and low erucic acid content, whereas, for *Fae1.2* gene SNP 237 found to differentiate low and high erucic acid. These SNPs were converted into CAPs marker for their utilization in breeding program.

**8.7** ***MAS for introgression of low glucosinolates in released varieties:*** Using four gene-based markers, low glucosinolate has been introgressed successfully through MABB in two low erucic acid varieties *viz.,* Pusa Mustard-21 and Pusa Karishma from an Australian double low donor, EC-597325. Sixty nine phenotypically uniform progenies were bulked and superior progenies with double low trait were evaluated.

8.8 For maintenance breeding and development of '0' and '00' breeding material, biochemical analysis of 40246 single plants/bulks was done for various fatty acids, and 26836 progenies/SPs were identified with <2% erucic acid. Total 22767 single plants and bulks with low erucic acid (<2%) from breeding material, mapping populations and advanced breeding lines were screened for total glucosinolates content, of which 1971 progenies/SPs with <30 ppm of total glucosinolates were identified.

8.9 Fifteen mapping populations for mapping/tagging genes/QTLs for glucosinolates, erucic acid, white rust, drought tolerance, heat tolerance and other economic traits were developed.

8.10 Protocol for screening against high temperature at the seedling stage has been standardized. Four donors *viz.*, NPJ-112, NPJ-113, EJ 22 and NPJ-124 have been identified which possess a high degree of heat tolerance at seedling stage.

**8.11 Genetics of high temperature tolerance in Indian mustard:** High temperature tolerance at seedling stage is governed by polygenes. It was also found that different tolerant genotypes may carry different alleles/genes for high temperature tolerance. Further, it was observed that the component traits for high temperature tolerance are governed both by additive and dominance effects.

## (9) SOYABEAN

**Table 14 : Soyabean varieties developed.**

| S. No. | Name of the variety | Average grain yield | Days to maturity | Area of adaptation |
|---|---|---|---|---|
| 1 | Pusa 12 | 20-25 q | 124-131 days | Punjab, Haryana, Delhi, UP, and plains of Uttrakhand |
| 2 | Pusa 14 | 20-25 q | 124-130 days | Delhi NCR |
| 3 | Pusa 5 | 22-26 q | 120-128 days | Punjab, Haryana, Delhi, UP, and plains of Uttrakhand |

***9.1 Inheritance of resistance against CPMMV-D1:*** The inheritance of resistance to *Cowpea mild mottle virus* (CPMMV) strain D1 in Indian soybean was studied. The resistant genotypes, DS 12-5 and SL958 were crossed with susceptible genotypes F4C7-32 and JS335 respectively. Resistance reactions of F2 plants and individual F2 plant derived F3 families indicated that resistance was controlled by a single dominant gene.

***9.2 Mapping of resistance against CPMMV-D1:*** Crosses DS-12-5(R) x F4C7-32 (S) and SL958(R) x JS335(S) were used and Bulked Segregant analysis was done. Two primers Satt635 and Uo8405 were found to be polymorphic in parents, bulks and $F_2$ population. The order and genetic distance of marker and resistance gene are Satt635 (2.7cM) and Uo8405 (5.4cM) at chromosome 12.

***9.3 Regeneration of soybean (Glycine max L. Merrill) through direct somatic embryogenesis from the immature cotyledons:*** A simple and efficient system of soybean (*Glycine max* L.

Merrill) regeneration through direct somatic embryogenesis by using immature cotyledons as explants was standardized. Three cultivars PI542044, Sipani104 and Sipani192 were selected for the evaluation of their capacity for somatic embryo differentiation and further plantlet regeneration. The immature seeds (5-6 mm) were separated from the pods and cotyledon explant (4-5 mm) was excised after removing the seed coat and cultured on embryo induction medium comprising Murashige and Skoog (MS) salts (Murashige and Skoog, 1962), B5 vitamins (Gamborg *et al.*, 1968), 3% sucrose, 40 mg/l 2, 4-dichlorophenoxyacetic acid (2,4-D), gellan gum (0.2%), with pH adjusted to 7.0. The protocol developed can be used for regeneration and plantlet recovery in different genotypes, which could also be used for their genetic transformation.

**(10) DROSOPHILA**

**10.1** ***The chromatin remodeling protein INO 80:*** Two mutant alleles for gene *Ino80* were isolated namely *Ino80*$^{EP-3}$ and *Ino80*$^{EP6}$ using P element mediated excision. Knock out of *Ino80* from fly resulted in late embryonic lethal phenotype and these embryos showed homeotic transformation of segments A3-A8 to A2 type denticle belt. Decreased expression of *Scr*, *Ubx* and *Abd-B*; and an over expression of *Antp* in *INO80* null mutant embryos relative to wild type (*Canton-S*) Drosophila embryos. *Ino80* localizes upstream sequences of homeotic genes (Antp, Ubx, Abd-B and Scr) and *Ino80* is involved in regulation of homeotic gene expression.

**10.2** ***The Wnt genes:*** Seven mutant alleles were isolated and characterized for the gene *DWnt4*. Among Seven mutant alleles of DWnt4 (RF1, RF2, RF3, RF4, Hl11, HL34 and AL7) only one allele *DWnt4*$^{AL7}$ has SNP in second exon, with Serine to Glycin substation at 331 position. Quantification of *DWnt4* transcript through qPCR in mutant embryos showed significantly reduced transcript. Loss of *DWnt4* results in reduced denticles from ventral epidermis of embryos. Over expression of Wingless in *DWnt4* mutant did not rescue the denticle pattern but over expression of *DWnt6* or *DWnt10* rescues reduced denticles and restores the w.ild type denticle pattern in embryos.

**10.3** ***Characterization of WG, β CATENIN following over expression of DWnt6 and DWnt10 in DWnt4***$^{AL7}$ ***mutant:*** Ectopic *DWnt6* and *DWnt10* act as functional analogues of *DWnt4* in the ventral epidermis. Immunostaining with Wg and Armadillo after over expressing *DWnt6* and *DWnt10* in *DWnt4*$^{AL7}$ mutant background showed no Wingless expression and Armadillo expression as good as wild type, indicating Dwnt6 and DWnt10 are rescuing DWnt4 using canonical Wnt pathway. Germline clone for *DWnt4*$^{AL7}$and found that the ovaries dies at stage 6 of oogenesis. Facicline III is used as a marker to mark the follicle cells and DAPI as nuclear stain.

**10.4** ***Knockdown of DWnt4 causes loss of abdominal tergites and polarity of tergite bristles:*** Ectopic tergite bristles were found near spiracles upon over expression of *DWnt4*. *DWnt4* was knocked down using *DWnt4 UAS RNAi* driver, adult and pharate adults showed absence of tergite bristles, patches of missing abdominal bristles and loss of polarity of bristles. When abdomen of the dead pupae were mounted, we found that microchaetae and bristle precursors were present on the abdomen of *actGal4>DWnt4UAS*-RNAi pharate adults.

## (B) SEED SCIENCE & SEED PRODUCTION TECHNOLOGY

1. **Basic studies:** Standardization of the technology used for the measurement of remobilization of stem reserve (NSC) to developing seed and its influence on seed quality there upon under normal irrigation and water-deficit conditions, was undertaken.

2. **Seed vigour traits in wheat and rice:** In case of rice non-structural carbohydrates (NSC) stored in the stem during pre-anthesis were studied to determine the capacity of translocation of stem reserves to the developing seed/grain. Results indicated that drought tolerant genotypes are capable of translocations of higher amount of NSC to developing seed. Further, higher amylase activity in seed of tolerant genotype was recorded during germination. In case of wheat it was recorded that seed vigour is exhibited right from the start of germination, i.e., speed of germination which is followed by rapid development of a vigorous root and shoot systems. In case of root, deeper tap root length and root weight density while in case of shoot, higher leaf area index and number of tiller are the traits associated with seed yield.

3. **Seed quality in single zero *B.juncea* genotypes differing in seed coat colour:** Seed germination was significantly affected by seed coat color in *B. juncea* genotypes. Significantly low germination was observed in yellow seed coat color genotypes (91.8%) in comparison to black seed coat colour genotypes (93%). Similar trend was observed in Vigour Index I and Vigour Index II indicating that seed with darker seed coat was more vigourous compared to lighter ones. It was observed that yellow-seeded genotype had lower anthocyanin, melanin and phenol content compared to black-seeded genotypes. Due to presence of above phenolic compounds, the dark coloured genotypes were found to be accompanied with slow water uptake and higher mean germination time (1.66d) compared to yellow seeded genotypes (1.1d). The imbibitional behaviour was significantly associated with seed colour, melanin and phenol content.

4. Better indices of soybean seed quality assurance as changes in seed hardiness and volatile aldehydes were identified.

5. PGPR bio-formulations for seed quality enhancement and seed-borne disease management in *Solanaceous* and *Cruciferous* vegetables were developed.

6. **Hybrid seed production technology studies**

   Hybrid seed production technology in Indian mustard, wheat, bitter guard, brinjal and early maturing cauliflower were standardized. Under ‘protected cultivation condition’, seed production technology of tomato and bitter guard were also standardized.

7. **Seed priming studies**

   a. **Pigeonpea:** varietal differences for water imbibitions pattern were observed in four varieties of pigeon pea. It took 30h for pigeon pea seeds to start the radicle *protuberance.* Soaking of pigeon pea seeds in water for 10h at 25$^0$C resulted in significant improvement of seed germination, vigour index I and vigour index II over untreated control seeds. The germination of variety Pusa 992 was found to be relatively sensitive to higher temperatures than other three varieties viz., Pusa 991, Pusa 2001 and Pusa 2002. Significantly higher germination, vigour index I and vigour index II over control were observed when exposed at $40^0$C for 6h.

**b. Specialty maize:** Maize varieties, hybrids, parental lines and genetic pools of different compositional groups were evaluated for physiological seed quality and imbibitional behaviour. Among different groups; sweet corn genotypes were most prone followed by QPM types and waxy and popcorn genotypes were least susceptible to germination under low temperature (15 and $20^0$C). Among the seed enhancement treatments Hydropriming (17h/25°C) was best for improving seed emergence and early vigour both under field and lab conditions as compared to other treatments (halo-priming ($KNO_3$), matrix priming (Vermiculite), bio-priming (*Trichoderma viridae*). Sweet corn lines (double recessive mutants, shrunken, shriveled lines) and QPM genotypes absorbed higher quantity of water and waxy types the least, indicating differential behavior due to compositional variation.

**c. Cucumber:** Cucumber cv. Pusa Uday seeds were osmoprimed (-1.0 MPa PEG 6000 for 3 days), haloprimed ($KH_2PO_4$ 60 mM for 24h) and hydroprimed (soaking in water for 24h). Solid matrix priming (SMP) of the seed was performed by mixing seed with moist vermiculite followed by incubation for 25h at 25°C. After the completion of priming treatments, seed lots were dried under ambient conditions to reduce seed moisture to original value. Observations were recorded on germination, speed of germination and seedling vigour. Solid matrix priming followed by halopriming and osmopriming significantly improved germination and speed of germination.

i. Seven seed enhancement treatments were evaluated to improve seedling emergence in late sown wheat variety WR 544. The experiment was sown under late sown conditions in the month of January. Pre-germinated seed improved field emergence by 19% over control. Enhancement treatments also reduced mean emergence time (MET).

ii. Various pre-sowing seed treatments on the seedling emergence and crop yield in direct seeded paddy Pusa RH-10 revealed that solid matrix priming using mannitol improved field emergence by 10 per cent. Primed seed emerged rapidly as compared to the control. Priming also improved crop performance *vis-a-vis* control under direct seeded conditions.

iii. Priming of tomato and onion seed using osmoticum (PEG 6000), $KNO_3$. Solid matrix (vermiculite) or water soaking improved germination and speed of germination. After priming, seeds were ultra-dried over saturated solution of KOH (RH 9.0%). Primed and ultra-dried seed maintained germination above control even after 3 months of storage.

**d. Development of seed testing protocols**

i. Seed testing protocols in Anise and ashwagandha were standardized. Seed standards in ashwagandha were also determined. Standardization of SSR marker technology for testing hybrid seed purity in maize, pearl millet and brinjal were undertaken.

Tissue crushed supernatant-based PCR protocol for ensuring the seed purity through molecular markers was standardized.

ii. Protocol for pelleting the seeds with Nano Clay Polymer Composite (developed at Division of Soil Science) for effective delivery of micronutrients was standardized.

e. **Modern tools for varietal identification:**

i. Development of protocols for image analysis in rice, mustard and chickpea for varietal identification was standardized.

ii. Methodology for efficient and rapid DNA extraction, and alternative method to Grow-Out-Test (GOT) for genetic purity testing in cotton was standardized. Characterization of rice varieties including land races was undertaken based on DUS test characteristics and molecular markers.

f. **Identification, cloning and characterization of genes associated with cytoplasmic male sterility (CMS) and designing PCR based markers for seed purity testing in pearl millet:** Primers targeted for intergenic regions of 37 mt-genes were designed and synthesized. mt-gene anchored TRAP analysis using 9120 primer combination revealed 3 primer combinations, which could be used to assess the purity of A line against the B line admixture in $A_1$ CMS lines of pearl millet. Identified primers were validated using the $A_1$ CMS lines in different nuclear background.

g. **Seed storability studies:** Enhancement of storability in cowpea: Studies on enhancing storability of cowpea seed using zeolite seed 'drying beads' were conducted. Seeds were either dried in sun or with drying beads at 10 and 40% RH. The moisture content of the seed was reduced to around 5.0 and 3.0% on fresh weight basis. The dried seeds were packed in moisture impervious packets and stored in ambient storage. After 4 months of storage under ambient conditions, seeds dried with zeolite beads maintained germination above 90% whereas a loss of 4% in germination was recorded in control.

h. **Standardization of mechanical processing parameters and safe seed storage:** Evaluation of seed processing of different crops such as wheat and Paddy showed that consistent seed quality could be achieved by efficient use of processing machines irrespective of the harvested seed quality. The maximum improvement in seed quality was achieved by specific gravity separator. The major seed quality (germination percent and physical purity) could be achieved up to 95, 99.8 and 94, 99.8 in wheat and paddy respectively, which is significantly higher than Indian Minimum Seed Certification Standards (germination 85%, 80% and physical purity 98% respectively). During processing overall seed recovery of field and vegetable crops was more than 80%.

i. **Mechanization of Seed Production System**

A system of stripping and threshing has been developed for Pigeon pea, wherein the cost of stripping and threshing was reduced by 78 and 88%, respectively as against conventional method. Total cost of operation (threshing) reduced from Rs. 24000 per hectare to Rs. 4234 per hectare and overall threshing efficiency increased from 83% to 98.2%. Rotavator was found to be most efficient and economical for puddling operation as with 13% less fuel resulted in better puddling than disc harrow in terms of time & cost of operation, seed bed quality and seed yield.

**Seed production:** Breeder seed produced (quintals) by Seed Production Unit, IARI, IARI RS, Karnal, Indore, Pusa Bihar and Katrain during 2009-16 (Table 15)

**Table 15 : Breeder seed data by Combined Seed production Unit.**

| Crops | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | Total |
|---|---|---|---|---|---|---|---|---|
| Wheat | 4262.7 | 4637.19 | 3777.84 | 4415.34 | 4230.56 | 4789.24 | 5158.90 | 31271.78 |
| Barley | -- | -- | -- | -- | -- | 5.00 | **3.00** | 8.00 |
| Paddy | 299.84 | 456.67 | 380.8 | 311.57 | 456.44 | 494.50 | 438.30 | 2838.12 |
| Coarse Cereals (Maize, pearl millet etc.) | 40.4 | 14.2 | 45.74 | 34.7 | 3.668 | 6.99 | 0.90 | 146.598 |
| Pulses | 179.51 | 89.31 | 67.16 | 72.51 | 50.34 | **73.76** | **71.83** | 604.42 |
| Oilseeds | 10.23 | 55.26 | 35.48 | 45.48 | 26.16 | **7174** | **76.03** | 7422.64 |
| Forage crops | 14.22 | 13.82 | 22.01 | 5.3 | 8.86 | **21.55** | **5.00** | 90.76 |
| Vegetables & Flowers | 118.40 | 66.08 | 121.06 | 17.02 | 29.27 | **32.28** | **--** | 384.11 |
| **Total** | **4925.3** | **5332.53** | **4450.09** | **4901.92** | **4805.29** | **12597.32** | **5753.96** | **42766.42** |

Truthfully labelled seed produced (quintals) by Seed Production Unit, IARI, IARI RS, Karnal, Indore, Pusa Bihar and Katrain during 2009-16 (Table 16)

**Table 16 : Truthfully labeled seed data by Combined Seed production Unit.**

| Crops | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | Total |
|---|---|---|---|---|---|---|---|---|
| Wheat | 1892.7 | 2579.89 | 2816.76 | 4027.27 | 3208.01 | 4761.38 | 3150.50 | 22436.51 |
| Barley | -- | -- | -- | -- | -- | 1.50 | 0.90 | 2.40 |
| Paddy | 2939.05 | 2927.26 | 3004.36 | 2895.28 | 2687.9 | 4455.33 | 3482.89 | 22392.07 |
| Course cereals (Maize, pearl-millet etc.) | 180.66 | 189.7 | 63.46 | 33.54 | 0.95 | -- | 17.92 | 486.23 |
| Pulses | 125.58 | 100.68 | 104.025 | 121.38 | 119.16 | 97.33 | 100.78 | 768.935 |
| Oilseeds | 114.667 | 89.59 | 66.51 | 33.69 | 1107.85 | 185.45 | 124.51 | 1722.27 |
| Forage crops | 14.06 | 13.59 | 6.12 | 3.66 | 5.597 | 10.00 | 4.55 | 57.58 |
| Vegetables | 77.61 | 93.73 | 108.40 | 86.67 | 80.36 | 106.50 | -- | 553.28 |
| Flowers | 0.98 | 0.113 | 0.20 | 0.31 | 0.75 | 5.70 | -- | 8.05 |
| Fruits | 0.48 | 0.068 | 0.107 | 0.0557 | 0.052 | 10131 Nos | -- | 0.76 |
| Tobacco | 2.64 | 6.98 | 13.25 | 10.88 | 8.467 | -- | -- | 42.22 |
| Dhaincha | 2 | 0 | 13.6 | 21.25 | 9.83 | 4.13 | 6.24 | 57.05 |
| **TOTAL** | **5350.43** | **6001.61** | **6196.79** | **7233.99** | **7228.93** | **9627.32** | **6888.29** | **48527.35** |

## (II) SCHOOL OF HORTICULTURE

### (A) FRUIT SCIENCE

a. Four mango hybrids, namely, Pusa Pratibha (Fig. 11) (Amrapali x Sensation), Pusa Shreshth (Fig. 12) (Amrapali x Sensation), Pusa Peetamber (Fig. 14) (Amrapali x LalSundari) and Pusa Lalima (Fig. 13) (Dushehari x Sensation); Pusa Round (Sweet orange) (Fig. 15) and Pusa Abhinav (Fig. 16) were released by Delhi State Seed Sub-Committee for National Capital Region. Mango transcriptome sequences for Neelum (PRJNA193588) and Dushehari (PRJNA193591) were registered with NCBI.

Fig. 11: Mango-Pusa Pratibha

Fig. 12: Mango-Pusa Shreshth

Fig. 13: Mango-Pusa Lalima

Fig. 14 Mango-Pusa Peetamber

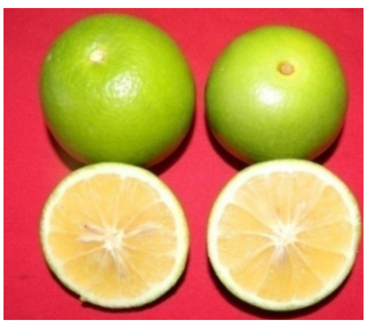

Fig. 15: Sweet Orange-Pusa Round

Fig. 16: Sweet Orange-Pusa Abhinav

b. Sweet orange Pusa Sharad, acid lime Pusa Udit and seedless grape hybrids Pusa Aditi (Fig. 17) and Pusa Thrisar (Fig. 18) were identified and released during 2014.


Fig. 17: Grapes- Pusa Aditi

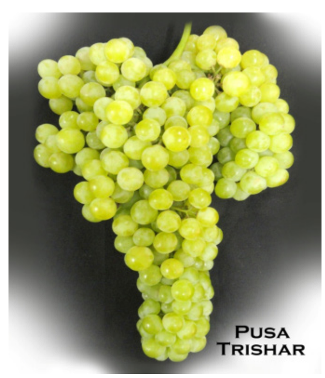


Fig. 18: Grapes- Pusa Trishar

c. In mango, rootstock Kurakkan and Olour; and *Karnakhatta* for lemon were effective for saline conditions.

d. Integrated nutrient management strategies were standardized for Amrapali mango and Kinnow mandarin, while 60 ppm $GA_3$ was effective for berry elongation new grape hybrids.

## (B) VEGETABLE SCIENCE

### New varieties/ hybrids developed/ identified/ released

Six varieties and one hybrid of different vegetable crops like garden pea cv. Pusa Shree (Fig. 19) for Zone I (J&K, Uttarakhand, Himachal Pradesh), ash gourd Pusa Sabzipetha for Zone VIII (Karnataka, Tamil Nadu and Kerala) and PusaUrmi for ZoneVI (Rajasthan, Gujarat, Haryana and Delhi) and VIII (Karnataka, Tamil Nadu and Kerala), brinjal cv. Pusa Kaushal (Fig. 21) for Zone I, IV and VI (J&K, HP, Uttarakhand, Punjab, Delhi, UP, Bihar, Jharkhand, Rajasthan, Gujarat, Dadra & Nagar Haveli, Daman & Diu) and DBHL-20 for Zone IV (Punjab, Delhi, Uttar Pradesh and Bihar), bitter gourd cv.PusaAushadhi (Fig. 20) for Zone VI (Rajasthan, Gujarat, Haryana and Delhi), and cauliflower cv. Pusa Ashwini (Fig. 22) for zone IV (Punjab, U.P., Bihar and Jharkhand states) were released through AICRP-VC and notified by CVRC.

**Fig. 19: Garden pea :Pusa Shree**

**Fig. 20: Bitter gourd: Pusa Aushadhi**

**Fig. 21: Brinjal: Pusa Kaushal**

**Fig. 22: Cauliflower: Pusa Ashwini**

Besides, one variety of bottle gourd cv. Pusa Santushti could be notified for cultivation in Zone- IV.Onion cv. Pusa Shobha (Sel – 126) was identified from AINRPO&G for zone III (Delhi, UP, Haryana, Bihar and Punjab), IV (Rajasthan and Gujarat) and V (MP, Chattishgarh and Orissa).

Besides, 14 varieties (onion-Pusa Riddhi (Fig. 24), bunching onion-Pusa Soumya, broad bean-Pusa Udit, summer squash-Pusa Pasand, cucumber-PusaBarkha, ridge gourd-Pusa Nutan, cauliflower-Pusa Kartiki, carrot-Pusa Rudhira& Pusa Asita, radish-Pusa Shweta, Pusa Jamuni& Pusa Gulabi, bitter gourd-Pusa Rasdar& Pusa Purvi) and Cherry tomato (Pusa Cherry Tomato 1)and 1 hybrid (carrot-Pusa Vasuda) (Fig. 23), were notified by CVRC for cultivation in NCT of Delhi.

**Fig. 23: Carrot: Pusa Vasuda**

**Fig. 24: Onion: Pusa Riddhi**

Nine varieties and one hybrid namely Pusa Sarda (Fig. 25) and Pusa Madhurima in musk melon, Pusa Utkarsh in long melon, Pusa Raunak in round melon, Pusa Seedless Cucumber 6 (Fig. 26) (parthenocarpic) variety of cucumber, Pusa Kesari VitA-1 (β-carotene rich) in cauliflower, Pusa Bhindi – 5 (Fig. 27) of okra, PusaPrabal (Fig. 28) of garden pea, Pusa Green of *Chinopodium* (Bathua) and Pusa Shrestha of Sponge gourd hybrid, were identified by ICAR-IARI Variety Identification Committee.

**Fig. 25: Musk melon : Pusa Sarda**

**Fig. 26: Cucumber: Pusa Seedless 6**

**Fig. 27: Bhindi : Pusa Bhindi - 5**

**Fig. 28: Garden pea: Pusa Prabal**

**1. Genetic stocks registered**

a. Sponge gourd DSG-6 (IC-0588956; INGR 12013), resistant to *Tomato Leaf curl New Delhi Virus* and predominantly gynoecious bitter gourd PreGy-1 (IC-059254; INGR 12014) were registered at NBPGR.

**2. Promising selections**

a. For resistance against YVMV, the advanced breeding lines of okra DOV 66 and DOV-12 and hybrid DOH-1 having dark green attractive pods were developed and are in AICRP-VC trials.The promising selections of muskmelon for high yield coupled with better fruit quality and tolerance to *Fusarium* wilt were DM-159 (22.6 t/ha, 12.1$^{0}$brix) and DM-154 (22.1t/ha, 11.8 $^{0}$brix) identified. The cauliflower varieties and hybrids were evaluated at 4 different elevations in hills, namely, Katrain, Solan, Bajaura and Almora and DC-76 and DCH-1076 were found promising at Katrain (1500m msl) & DC-309 and DCH-1001 at Solan (1200m msl).

b. The gynoecious line PVGy-201 in bitter gourd was licensed to M/S Namdhari Seeds Pvt. Ltd., Bengaluru and M/S Ankur Seeds Pvt. Ltd., Nagpur for commercialization through ZTM & BPD Unit of the institute.

c. Based on transcriptome analysis in bitter gourd a total of 477 annotated unigenes were found to be significantly differentially expressed in bitter gourd female flower. *Mc-ACS2* mediated biosynthesis of ethylene in individual flower buds is found to be associated with the differentiation and development of female flowers. Two co-dominant markers, namely SSR-13251 and SSR-15516 were found to be tightly linked to the *F* locus (gynoecious trait) in cucumber at 1.5 and 4.5 cM, respectively. Six new Indian tropical gynoecious lines have been generated by using MAS. In cauliflower, two flanking SCAR markers (ScOPO-04$_{833}$ and ScPKPS-11$_{635}$) linked to black rot resistance gene *Xca1bo* at 1.6 cM distance have been developed and two flanking SSR markers BoGMS1330$_{193/183}$ and BoGMS1322$_{126/116}$ were found to be linked to downy mildew resistance gene *Ppa3* at 4.3 and 8.6 cM distance, respectively. In tomato, introgression of *Ty1*/*Ty3*and *Ty2* is in progress to develop ToLCNDV resistant varieties.

Inter-specific crosses of cauliflower were attempted with to alien *Brassica* species *viz*. *Brassica nigra* (IC56072) and *Brassica juncea* (Pusa Vijay) to transfer black rot resistance. The advancing of the crosses is in progress through embryo rescue technique. The protocol for *in-vitro*gynogenesisfor haploid induction in onion was developed.

**(C) Floriculture and Landscaping**

**New varieties/ hybrids developed/ identified/ released**

a. During the period, varieties of marigold namely Pusa Arpita (Fig. 30), (French marigold) and Pusa Bahar (African marigold) (Fig. 29), chrysanthemum such as Pusa Anmol, Pusa Centenary, Pusa Chitraksha (Fig. 32), Pusa Sona, Pusa Aditya (Fig. 31), Pusa Kesari, Pusa Arunodaya and Pusa Guldasta, Gladiolus namely Pusa Kiran, Pusa Shubham, Pusa Unnati, Pusa Srijana Pusa Vidhushi (Fig. 34) and Pusa Red Valentine (Fig. 33) were released by Delhi State Seed Sub-Committee for National Capital Region. Open pollinated seedlings such as SD-4 (Pusa Mahak) (Fig. 35) for garden display and fragrance and SD-3 (Fig. 36) for loose flower purpose which performed consistently better were identified for further evaluation in the recent years.


Fig. 29: African Marigold: Pusa Bahar


Fig. 30: French Marigold: Pusa Arpita


Fig. 31: Chrysanthemum: Pusa Aditya


Fig. 32: Chrysanthemum: Pusa Chitraksha


Fig. 33: Gladiolus: Pusa Red Valentine


Fig. 34: Gladiolus: Pusa Vidushi


Fig. 35: Rose: SD-4 (Pusa Mahak)


Fig. 36: Rose: SD-3

b. Technologies like gladiolus varieties were commercialized with Mr. Sudhir Aggarwal, Mathura, Five Chrysanthemum varieties with M/S Saveer Biotech Ltd., New Delhi and dry flower technology with Floral Images, New Delhi.

c. *In-vitro* protocols were developed for multiplication of rose, marigold, lilium, bougainvillea and gladiolus. Molecular profiles for *Rosa* species and varieties using different markers were developed. Pigment profiling of pigments of flowers such as rose, marigold, chrysanthemum and bougainvillea using HPLC and drying techniques for retention of flower pigments and their antioxidant activities were standardized. The protocols were standardized for successful *in vitro* induction of anthocyanin pigments in rose and chrysanthemum and carotenoids in calendula by manipulating the carbon source (sucrose) and altering the nutrient status of the culture medium.

d. Initiated systematic research work on turfgrasses and their management during 2011 for the first time in India. Dry flower technology w.r.t. seasonal flowers, marigold, chrysanthemum, rose, foliage plants and other flora were developed.

e. Technologies were demonstrated in the farmers field, Krishi Vigyan Melas, etc. and supplied seed and planting material to number of growers in NCR regions and different states like Jammu and Kashmir, Haryana, U.P. ,etc. to promote the floriculture.

f. We have strong Linkages in Research & Development with public sector organizations viz. PPV & FRA, DST, DBT and NHB for funding to carry out research in niche area in floricultural crops.

**(D) FOOD SCIENCE AND POSTHARVEST TECHNOLOGY**

a. Developed indigenous clay particles for foliar spray in order to improve the quality and reduce the incidence of pests, fruit cracking, sun burn, in pomegranate and apple fruits.

b. Minimally processed pomegranate arils were packed in 70 micron thick PP film (vacuum and MA packaging) and stored at 6±1$^{o}$ C tem. for 30 days. The vacuum packed arils retained 4 times higher anthocyanin (110.5mg $L^{-1}$) up to 30$^{th}$ day of storage than MA packed pomegranate arils.

c. Developed β-carotene rich pumpkin flour for food fortification, ready to serve water melon drink,

d. Standardized anthocyanins in fusion in potato matrix ranging from 200-500 mg/Kg, without transgenic approach for attractive purple colorand$\alpha$-glucosidase inhibitory activity in potato products.

e. Technologies for roasted yellow soy nut,black soy nut,Pearl Puff, Pusa Nutri-Cookies, multigrain cookies and trypsin inhibition in roasted soybeans were standardized.

f. Stanadardized the technologies for poped ready-to-eat Green chickpea flakes and soy based product named as 'Pusa Vita'.

**(E) TEMPERATE HORTICULTURE (LOCATION- SHIMLA)**

a. A unique walnut clone "**Pusa Khor"** and promising apple rootstock **"Pusa Apple Rootstock-101"** identified at the regional station.

b. The strawberry variety Douglas performed well in Jharkhand and the variety Belrubi performed well in West Bengal.

## (F) TEMPERATE HORTICULTURE (LOCATION- KATRAIN, KULLU)

a. Cabbage hybrid 'KGMR-1" was released and notified as 'Pusa Cabbage-1' by CVRC and hybrid 'KTCBH-81' has been identified for release for zone-I.

b. A Knolkhol variety 'Pusa Virat' developed at the station was released by H.P. State Seed Sub Committee. One CMS based cauliflower hybrid, Pusa Snowball Hybrid-1 was identified for release.Carrot hybrid 'Pusa Nayanjyoti was released for cultivation in Himachal Pradesh by the State Variety Release Committee.

c. Intervarietal lilium hybrids PKLH-1 and PKLH-2 were developed. A kale variety KTK-64 has been advanced and evaluated in AVT-II under the AICRP (VC) trials.

d. This station is producing of vegetable seeds of 58 varieties of 26 vegetables in addition to the parental lines of 8 hybrids developed at the station.

## (G) CENTRE FOR PROTECTED CULTIVATION TECHNOLOGY (CPCT)

a. The centre has carried out more than 50 training programmes related to Protected Cultivation Technologies to farmers and officials of entire country during the Year 2009-16.

b. The CPCT has recommended that 10.0 lakh seedlings in plug trays may be grown in five batches from 500 square meter nursery greenhouse. Plastic Low Tunnel with Drip Fertigation Technology (Fig. 37) for off-season vegetable cultivation has been found to be the efficient technology for off season cultivation of vegetables mainly major cucurbits during winter season by modifying the micro-climate around the plants and advanced from 30-40 days over their normal season of cultivation

**Fig. 37: Plastic Low tunnel technology for off Season cucurbits production**

c. Standardized drip-fertigation technology for growing off season cucumbers in naturally ventilated polyhouse by obtaining maximum yield 3.34 kg/ plant i.e. 92.8 t/ha in the variety Oscar by applying N:P:K:: @250:188:312 kg/ ha.

**Fig. 38 Cucumber crop inside naturally ventilated polyhouse**

d. Parthenocarpic cucumber variety "Fadia," (Fig. 38) produced highest total fruit yield of 95.71kg which gave net return of Rs.1122.50 and B:C ratio 2.09 based on 50m$^2$ area per crop with combination of the optimum NPK dose @ 25:17:26 kg/1000 m$^2$as compared to other varieties and NPK doses in plain area during off-season.

e. Soil less cultivation for production of vegetables (Fig. 39): Pots of size 4 inch filled with soil less media (coco peat, vermiculite and perlite in the ratio of 3: 1 :1) were found suitable for growing spinach (5.7 kg/pot) and amaranthus (9.5 kg/pot), 6 inch were best for kale (6.7 kg), lettuce (600 g), garden mint (1.7 kg), pokchoi (11.5 kg), Swiss chard (10.5 kg) and 9 inch pots for tomato (5.5 kg ), broccoli (13.35 kg) and cabbage (14.00 kg).

**Fig. 39: Crops grown in different pots using soil less media**

f. Design of structure for ground water recharge: Recharge structure of 80m x 50m dimension having depth of 1.8 m was designed and develop to conserve excess runoff generated during rainy season (July to August) from 3 ha cultivated area to improve the quality of existing ground water through dilution and making it suitable for irrigation. Total produce of Rs. 250895 was produced from the designed structures with benefit cost ratio of 2.2.

g. The microclimate profile inside the greenhouse with tomato under different operating conditions was evaluated and forced ventilation was found to reduce the canopy temperature by 5-6°C compared to natural ventilation. Thermal screen reduced the canopy temperature by 3-4°C in forced ventilation greenhouse. There was 70-80% reduction in PAR at 1m height and 2-3°C difference in temperature was observed along the height of canopy.

h. Studies on plant densities in chrysanthemum variety ' Zembla' (Fig. 40) was performing better w.r.t. plant height (134 cm) when planted at 64 plants/$m^2$ followed by plants at 48 plants/$m^2$ under naturally ventilated greenhouse. Gerbera variety Kormoran produced highest number of leaves (23) per plant and early flowering (55 days after transplanting) and variety Feliks performed better w.r.t. flower size (9.7cm diameter) under semi-climate controlled greenhouse (Fig. 41).

**Fig. 40: Evaluation of varieties planted with different densities**

**Fig. 41: Evaluation of gerbera varieties under semi-climate controlled green house**

IARI bred varieties namely Pusa Anmol, Pusa Centenary, Pusa Chitraksha and Thai Chen Queen were studie (Fig. 42) for bud induction under long days (>13 h) to their reaction time for bud induction which varied from 41 (Pusa Anmol) to 78 days (Pusa Centenary) All varieties showed a strong photo-morphogenesis, turned generative and lead to the formation of normal bud except in Pusa Chitraksha. The sample plants were then transferred to photoperiod @ 11h with PAR exposure at 70-110 µmol $m^{-2}$ $sec^{-1}$ where in all the varieties could flower normally.

**Fig. 42: Diurnal response in IARI bred varieties of chrysanthemum**

## III SCHOOL OF PLANT PROTECTION

### (A) AGRICULTURAL CHEMICALS

a. Controlled release of nano formulations of β-cyfluthrin, carbofuran, azadirachtin A, thiamethoxam, thiram, carbendazim, imidacloprid, azoxystrobin, etc. developed using poly (ethylene glycol) (PEG) based amphiphilic copolymers. The bioefficacy of developed formulations showed better efficacy than corresponding commercial formulations. Three patents have been filed and four technologies have been licensed to two companies.

b. National patent on Pusa Hydrogel invention granted; license of bench scale process of product synthesis given to six industries during 2009-2016; revenue of Rs. 1.6 crore generated. Improved hydrogel composites exhibiting water absorption potential 800-1100 g/g invented and the process of synthesis upscaled to 5 Kg finished product. One national patent, one PCT and four international patents filed. National patent granted and FER of international patents responded to. New hydrogel with 40% reduction in cost per Kg has shown performance at par with Pusa Hydrogel in wheat-soyabean. Validation in progress.

c. Bench scale protocols for hydrogel based: PGPR formulations, combo formulations of Tagetes extract and $MgSO_{4;}$ integrated compositions employing *Trichoderma harzianum* and $ZnSO_4$, micronutrient (B and Zn) formulations, combo-formulations of *Trichoderma harzianum* and *Pseudomonas florescence* developed. National patent on PGPR formulations filed; is in advanced stage of grant.

d. Potential bioactive molecules identified and/or synthesized: Zerumbone from *Zingiber zerumbet*, Fenchone oxime N-O-isovalerate ($AI_{50}$ 0.0016%) demonstrating comparable performance to the neem biopesticide azadirachtin ($AI_{50}$ 0.0010%); 4-Benzylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazole (*In vitro* $LC_{50}$=19 µg/ml, *M. incognita* in cowpea); N-Hexyl-N-[1-(2-hydroxyphenyl)ethyl]amine as fungicide ($ED_{50}$ 4.92 $mgL^{-1}$ against *S. rolfsii* compared to commercial hexaconazole having $ED_{50}$ 1.27; against *R. bataticola*, N-Decyl- derivative-$ED_{50}$ 6.86 $mgL^{-1}$ as compared with hexaconazole 6.35 $mgL^{-1}$). Process refinements and validations in progress.

e. Pesticide remediation/decontamination protocols developed utilizing rice husk, modified clays, granular carbon, nano metal oxides, ozone, microbial culture, plants for removal of pesticide / heavy metals / polyaromatic hydrocarbons. Validations in progress.

f. Multi-residue method for detection of 38 compounds consisting of 20 organo-chlorine pesticides was developed in Gas Chromatography – Mass Spectroscopy (GC-MS) in Selective Ion Monitoring mode from Basmati Rice matrix; developed methods being validated to upgrade scope of Pesticide Referral Laboratory.

g. Total of 12 patents filed and 395 research articles published in reputed journals during 2009-2016.

### (B) ENTOMOLOGY

**National Pusa collection**

a. In National Pusa Collection of Entomology Division during this period total of 501 insect specimens were augumented. Ten New genera, 71 new species and 8984 specimens were added.

b. Amongst rice germplasm screened for resistance against BPH over the years, the lines, Ptb33, Rathu Heenati and T-12 have been found to promising.

c. Traps for fruit flies modified and validated by mass trapping of *B. dorsalis* complex at Pusa Campus which could reduce the population of flies by 90 per cent.

d. Forewarning model for peach fruit fly is developed, by weekly monitoring the population for seven years. This model is validated for three years.

e. About 13 culturable bacteria were isolated and characterized from the gut of melon fruit fly. Five volatiles identified from the gut bacteria of melon fruit fly. The synthetic forms of identified volatiles and few related compounds were tested for attractancy of melon fruit fly in olfactory multi-arm cage. All the volatiles attracted more female flies compared to male flies.

f. The mode of inheritance of resistance to *Bacillus thuringiensis* (*Bt*) toxin Cry1Ac and Cry2Ab was studied in the *P. gossypiella* along with some of the traits associated with fitness. The inheritance of Cry2Ab resistance appeared to be governed by multiple alleles/genes. Cry1Ac and Cry2Ab resistance was associated with fitness costs like larval and pupal periods when resistant and susceptible parental populations were reared on the diet without toxin, and appeared to be inherited in F1, F2 and backcross progenies.

g. Variation in the cadherin gene sequence between Cry1Ac resistant BH-R strain and the wild strain of *H. armigera* were identified. Cry1Ac tolerant BH-R strain showing 227.9 fold over susceptible VA-S strain were found to carry mutant alleles of the cadherin gene.

h. Insect proof climate control chamber (a rearing facility for sucking pests including whitefly) was commissioned under the aegis of NAIP during 2012.

i. Recorded Nine biotypes of whitefly, *Bemisia tabaci* in India with Asia I and Asia II 1 being the predominant ones in southern and northern India

j. Documented high level of resistance to eight insecticides belonging to organophosphates, pyrethroids and neonicotinoid groups in *B.tabaci* populations collected across six agro climatic zones in India.

k. Molecular diagnostics have been developed for detection of phosphine resistance using CAPS (Cleaved Amplified Polymorphic Sequence) markers for phosphine resistance gene, rph2 in stored product insect pests, *T. castaneum and R. dominica*.

l. Scanning Electron Microscope Facility developed during this period which was used for providing service on payment basis to many users not only in IARI but also others from different SAUs and ICAR institutions within and outside Delhi

## (C) NEMATOLOGY

a. Biodiversity analysis of several economically important plant-parasitic nematodes (PPNs), EPNs from new geographical areas of India. Augmentation of National Nematode Collection of India (NNCI) totalling 2500 type accessions. Digitization of NNCI specimens as identification referral to taxonomists working remotely.

b. Completed whole genome sequencing and transcriptome of *Meloidogyne graminicola* and *Heterodera avenae*, and transcriptome sequencing of *Meloidogyne indica* infecting neem, *M. javanica, H. cajani* and *Heterorhabditis indica* (entomopathogenic nematode). Development of *in silico* resource of *H. avenae* and *M. graminicola* transcriptome databases (HAT-DB and MGT-DB) for public access at IARI website.

c. Functional characterization of number of candidate genes using host delivered RNAi approach, e.g. neuromuscular role of FMRFamide-like peptides, digestive role of *Mi-cpl-1* gene, housekeeping role of splicing factor, integrase, annexin, effector genes like *msp1, msp 18, msp28, msp20*. For the first time established interaction between effector genes and other cell wall-degrading enzymes during parasitism of *M. incognita*. Generation of Arabidopsis, brinjal, tobacco and tomato and transgenic events showing resistance to *M. incognita*.

d. Developed a highly stringent novel pluronic gel-based method for rapid screening of rice accessions for nematode resistance. Role of major hormone-regulated plant defence pathways was central to resistance response. Identified several highly promising rice genoptypes resistant to *M. graminicola* that can be deployed in resistance breeding

e. *Galleria mellonella* cadavers infected with entomopathogenic nematode, *Heterorhabditis indica* could be used for the management of white grubs in sugarcane in western UP.

f. Soil solarization with minimal dose of nematicides and organic amendment with brassica crops, neem cake, sunnhemp, *Calotropis procera* etc. to reduce nematode infestation in environmentally-friendly manner.

g. Filed both Indian and international patents for a method to control root knot nematodes.

## (D) PLANT PATHOLOGY

a. A total of 41,000 fungal specimens and 60 fungal cultures have been digitized and designated 55 new species and 13 new genera. DNA barcode based identification scheme for *Fusarium, Phoma, Curvularia, Bipolaria, Trichoderma, Chaetomium, Aspergillus* and *Penicillium* was developed.

b. Race profiling of all nationally important plant pathogens such as *Fusarium oxysporum* f. sp. *ciceris, Xanthomonas oryzae* pv. *oryzae, X. campestris* pv. *campestris, Ralstonia solanacearum* was accomplished.

c. Disease resistance genes for mitigating rice blast *viz., Pi9, Pi54, Pi12 (t), Pizt, Piz5, Pita2 and Pita;* rice bacterial blight *(Xa11, xa13,* and *Xa2)* were identified and introgressed in major cultivars. Mechanism of disease resistance in wheat imparted by *Lr24* was elucidated.

d. Detection methods for fungal pathogens (*Bipolaris sorokiniana*; *B. oryzae; Fusarium fujikuroi*; *Puccinia striiformis tritici; F. oxysporum* f. sp. *ciceris; Rhizoctonia solani),* bacterial pathogens *(Ralstonia solanacearum; Xanthomonas campestris* pv *campestris*; *X. oryzae* pv *oryzae)*, and viruses (large cardamom chirke virus (LCCV); Peanut mottle virus (PeMoV); Bean common mosaic virus (BCMV); Garlic common latent virus; Lettuce mosaic virus (LMV); Banana streak MY virus (BSMYV); Rice tungro spherical virus (RTSV); Cardamom bushy dwarf virus and Grapevine leafroll associated virus -3. were standardized

e. Whole genome of *T. indica* (KB-1_UP); *P. striiformis tritici* (Race 38S102); *Magnaporthe oryzae* (RMg_Dl) *Fusarium fujikuroi* (F250) and *Ralstonia solanacearum CaRs_Mep* and viruses like Babuvirus, CTV, ICRSV, CMV, Croton yellow vein mosaic virus, Cotton leaf curl virus, potato leaf curl virus, BSMYV, and Groundnut bud necrosis virus were sequenced and submitted.

f. Biocontrol technologies using *Chaetomium globosum* (Cg2), *Talaromyces flavus* (Cf2), *Pseudomonas fluorescens* (DTPF-3), *Bacillus subtilis* (DTBS-5) and *B. amyloliquefaciens* (DSBA-11) were standardized for disease management

g. Developed Affymetrix chip for parallel detection of more than 1100 viruses and 30 viroids that helped the detection of new viruses and viroids in grapes

h. Advanced Virology center is a referral virus center playing a pivotal role in virus free production of tissue culture plants of banana, potato, sugarcane and ornamentals

**(E) VIROLOGY FOR HORTICULTURE CROPS (LOCATION -PUNE)**

The papaya selections PS-1 (yellow pulp) and PS-3 (pink pulp) were resistant to *Papaya ring spot virus* those were registered with the Plant Germplasm Registration Committee (ICAR), New Delhi.

a. Molecular characterization of whitefly transmitted *Geminivirus* infecting muskmelon and tomato was carried out using Rolling Circle Amplification to amplify the full genome. The genome sequence analysis revealed the association of *Tomato leaf curl virus* (ToLCV) *New Delhi virus* with muskmelon whereas ToLCV*Karnataka virus* was associated with tomato.

b. Novel phytoplasma subgroup 16SrI-X was found associated with bottle gourd [*Lagenariasiceraria* (Mol) Standl.] virescence and phyllody disease in India. The obtained 16S rRNA gene sequences (LT594117 and LT594118) showed 99.12 % homology with a strain AYWB ('*Ca*. Phytoplasmaasteris', CP000061).

c. Papaya phytoplasma disease belonging to 16SrII group causing axillary shoot proliferation and yellowing of upper young leaves was reported in India (GenBank Acc. No. JQ346525).

d. Serious invasive insect pest known as South American tomato pinworm, *Tutaabsoluta* (Meyrick, 1917) was observed for the first time infesting tomato crop in Maharashtra, India.

## (F) VIRUS RESEARCH (LOCATION- KALIMPONG)

a. Citrus Tresteza virus (CTV) isolates collected from different areas were graft inoculated on standard indicator hosts *viz.* rough lemon, kagzi lime and Rangpur lime for observation of symptom variation. Indexing of citrus plants collected from different area of Darjeeling was undertaken by DAS ELISA, 87% of the mandarin plants growing in the station were found CTV positive, the percentage of CTV infection in different orchards of Darjeeling hills were also worked out. Amplification of desired length of foorkey genome was found from dissected oesophageal gland of *M. kalimpongensis* through PCR confirming its vectoring ability. 57.14 % transmission of foorkey by *M. kalimpongensis* was recorded under caged condition. *C. maxima* was also recorded to be resistant against both severe and mild isolates of CTV through vector as well as graft transmission.

b. Nine aphid species such as *Toxoptera auratii, T. citricida, Aphis gossypii, A. spiraecola, A. craccivora, A. nerii, B. helichrysi, A. solani, M. persicae* were identified to infest citrus. Sequences of cytochrome oxidase subunit I of these aphid species were submitted to GenBank (Accession no. KR856185, KR856186, KR856183, KR856184, KR866112, KR019065). *M. kalimpongensis* was predominant in large cardamom plantations above 900 m altitude and *P. nigronervosa* was found prevalent in areas below 1000 m altitude. Abundance of *T. aurantii* was more in high altitude citrus plantations above 500 m altitude. Whereas dominance of *T. citricida* was found in orchards below 500 m altitude.

c. Under controlled conditions, 28°C was found optimum for growth and oviposition of *Diaphorina citri.* No oviposition was observed at 11°C and below.

## (IV) SCHOOL OF NATURAL RESOURCE MANAGEMENT

## (A) SOIL SCIENCE & AGRICULTURAL CHEMISTRY

**a. Pusa Soil Test and Fertilizer Recommendation Meter (Pusa STFR Meter)**

The institute developed a tool, named Pusa Soil Test and Fertilizer Recommendation (STFR) Meter. It is highly useful particularly for the areas where soil testing facility is not available. The present innovative technology would serve as robust complement to the existing STL network, making soil testing available at farmers' doorstep. It is a low cost, user-friendly, digital embedded system and programmable instrument. Pusa STFR Meter consists of a meter, a mini-shaker, a reagent-kit (for 50 soil samples) and other important accessories needed for soil testing. Pusa STFR Meter now analyzes as many as 14 important soil parameters viz., pH, EC, organic carbon (OC), available nutrients [P, K, S, Zn, B, Fe, Mn, Cu and N (based on OC)], gypsum requirement and lime requirement. Data storage capacity was enhanced for 50 samples in switch-off condition. Provision of using a numerical key pad was made for convenient data handling. It could be connected to PC through a computer-interface and the results can be communicated to the farmers through instant SMS on a pre-registered cell phone. So far, it has been licensed to thirteen firms for commercial manufacturing and marketing. Total revenue generated through commercialization of this technology is 53 lakh.

**b. Novel fertilizer products for zinc:** In view of abysmally low use efficiency of applied micronutrient (about 2%), Institute developed slow-release novel micronutrient fertilizer i.e. zinc (Zn) loaded nano clay polymer composites (NCPCs). A breakthrough is achieved in terms of enhancing the use efficiency of Zn applied through NCPCs up to 10%, which is about five times of that of conventional fertilizers.

c. **Nitrogen and phosphorus management protocols under conservation agriculture:** Nitrogen and phosphorus management options were evaluated and standardized for conservation agriculture, where use efficiency of N and P could be achieved up to 65 and 25%, respectively.

d. Soil-test crop response (STCR) based ready reckoners for fertilizer prescriptions were developed for winter maize (var. Buland), marigold (var. Pusa Arpita), sesame (var. TKG-21), mustard (var. Pusa Mustard 26) and lentil (Pusa Shivalik).

**(B) MICROBIOLOGY**

*a.* **Bioinoculants for nutrient and disease management:** Liquid formulations of N, P, K, & Zn biofertilizers, Pusa Compost Biofertilizer, Soil based arbuscular mycorrhizae (AM) biofertilizer and BGA Biofertilizer have been developed and technology for mass production has been commercialized. About 20 companies have taken these technologies and revenuer to the tune of Rs 25 lakhs has been generated including 2% royalty. Identified potent bacterial, fungal and cyanobacterial strains having antagonistic activity against plant pathogens causing charcoal rot, Fusarium wilt, damping off diseases. Field evaluation showed a disease reduction of 15-20% with use of these agents. Biofilmed biofertilizers using fungal and cyanobacterial matrix were found to enhance crop productivity in rice and cotton.

The biofertilizers produced from the division covered more than 20,000 ha of land during 2012-2017; both in organic and integrated nutrient management of different crops with saving on N (20%), 15% (P) and K (10%).

*b.* **Bioprospecting for biodiesel and Bioethanol:** Two microalgae strains, *Chlorella sorokiana* and *Botryyococcus* sp. were identified to be potent candidates for biodiesel production. A nutritional strategy was developed to enhance the accumulation of lipids**.** Developed process of biological delignification of paddy straw by using *Tramus hirsute* and *Myrothecium roridum*

*c.* **Bioprospecting for Genes/Alleles and molecules from microorganisms:** Genes for salt tolerance, ACC deamainase (*acdS*) and P-solubilization –PQQ synthase, *PqqD* and *PqqE* were isolated from *Halobacillus* sp., Pseudomonas/Rhizoba and *P. striata* respectively and validated in *E. coli***.** *Whole Genome Sequencing by Illumina MiSeq and PacBio Platforms for six bacterial strains viz: Arthrobacteragilis* strain L77; *Halolamina pelagica* strain CDK2; *Burkholderia cenocepacia* strain PS27; *Halomonas elongata* strain HEK1,*Bacillus thuringiensis* strain AKS7 and *Pseudomonas stutzeri* KMS 55.

*d.* **Microbial Resources:** The division has the largest culture collection for Rhizobia and cyanobacteria in the country. A collection of other bacteria isolated from various niches, PGPR, Biocontrol agents Lignocellulolytic fungi, and thermo tolerant yeasts have augmented this collection.

## (C) WATER TECHNOLOGY CENTER

During the reporting period, Water Technology Centre pioneered to develop following field/ watershed scale water management technologies:

a. Water management approaches - including renovation of community ponds, laser levelling of 72 ha agricultural land, laying of 10 km long underground pipeline system and installation of sprinkler, rain gun, drip irrigation systems on 62.85 hectares and 50-naturally ventilated shade nets/ poly houses could lead to a saving in irrigation water by 20-56% and increased per ha-income from wheat (Rs. 3,000-8,000), pigeon pea (Rs. 4,500-8,500), mustard (Rs. 1500-2000), maize (Rs. 20,000) and vegetables (Rs. 40,000-95,000) over the conventional checks. Integrated water related interventions through deepening of open wells, renovation of water harvesting structures (WHS), laser levelling, underground pipeline system, sprinkler, drip and rain gun irrigation systems etc in Mewat, Alwar and Dhar region enhanced the yield of wheat and mustard crops by about 25-35 per cent and helped in saving of irrigation water by 40-60 per cent. Renovation of WHS led to rise in water table by 65-95 cm and help reduce the migration.

b. Keeping the situation of freshwater scarcity and importance of reuse of wastewater in agriculture in view, an eco-friendly wastewater treatment facility involving emergent wetland plants (such as Typha latifolia) and native media and microorganisms that mimic natural processes operative in any natural wetlands was engineered at pilot (rural household) scale in 2009 and then eventually up-scaled to a 2.2 million litres per day - capacity system in 2012 for treating and reusing Krishi Kunj colony sewage water at IARI farm. The technology was also out-scaled to Farah, Mathura for treating 75,000 liters per day **(**LPD**)** of rural domestic wastewaters**.** The so developed and operationalized innovative eco-friendly wastewater treatment technology was observed to be associated with zero chemical, skilled manpower and energy demand and has at least 50-65% lower Capital expenditure than any conventional wastewater treatment technology. The aforementioned technology has been recommended for its extension to 400+ Indian cities by MoU and for national level adoption and implementation by the Parliamentary Committee of Agriculture on Demands for Grants of the MoA.

c. Several drip assisted production technologies were developed and were standardized and disseminated to the farmers of the NCR region:

- Drip assisted pigeon pea production technology was standardized under varied fertigation schedules. The findings revealed that weekly fertigation each with 1.77 kg N, 3.53 kg $P_2O_5$ and 2.35 kg $K_2O$ per ha, with 100% crop water requirement resulted in maximum yield of 2.54 t/ha.

- Investigations revealed that as compared to the traditional planting method, a bi-weekly fertigation schedule in drip assisted baby corn technology is capable of yielding 26% to 52% higher corn yield and is associated with about 30 to 60% higher B:C ratio (ranging from 1.86 to 3.68). Further round the year Baby corn technology was found to be associated with 191 % higher B:C ratio than conventional Baby corn-Wheat system, and 27% higher B:C ratio in comparison to the solo baby corn technology.

- Water productivity and economics of drip assisted Kharif Onion-Wheat-Mung bean production technology, as a replacement for Paddy-Wheat System, were also worked out. The investigation revealed that the proposed production technology is associated with about 45% lower system Irrigation water requirement, 420% higher system IWUE and 47% higher B:C ratio than traditional R-W system and 30% higher B:C ratio than traditional R-W-M system. It was further observed that replacing just 25% of paddy growing areas in the northern states with drip assisted *kharif* onion production technology can save more than 50,000 MCM water. Best management practices for irrigated *mungbean* production for summer season was developed and tested at IARI farm on large scale on 55 acre with average yield of 0.5 t/ha.

- Package of practices for cultivation of exotic vegetable crops *viz.* lettuce (high density planting in open field); red capsicum (grown in low cost naturally ventilated green house) & squash (off season in low tunnel) were developed. For lettuce: 2- day irrigation interval based on daily water use rate with 100 kg N $ha^{-1}$ application 17.5x30 cm crop geometry was found to be the best combination; red capsicum: the maximum net return of Rs. 171586 per 1000$m^2$ was obtained with high dose of 400 kg N $ha^{-1}$ and 360 kg K $ha^{-1}$ for the crop duration of 8 months. Squash: the maximum net return of Rs. 31500 per 1000 $m^2$, benefit cost ratio – 2 with RDF (N:P:K, 30 : 22:17 kg $ha^{-1}$ for the duration of 75 days.

- Automatic drip irrigation system having soil moisture sensor with GSM technology and controller was developed which can be operated through mobile after getting SMS alert in the form of text message '111', '110' for operating solenoid valve and for controlling the operation of pump.

- Developed a protocol for assessing energy requirement and carbon foot print of groundwater irrigation. Sensitivity analysis was conducted to assess the impact of various groundwater recharge and pumping scenarios on energy requirement and carbon footprint of groundwater abstraction. Results indicated that the pump efficiency has maximum impact on carbon footprint and that an increase in efficiency from 36.5 to 50 % may decrease the carbon footprint from 365 to 267 million ton. Groundwater recharge did not show much impact on carbon footprint. It was estimated that carbon footprint would increase by 11.67 million tonnes for one meter decline in water table under specified recharge and pumping conditions.

- Crop growth and yield simulation models (*viz.*AquaCrop, DSSAT, SWAP) were calibrated and validated using the experimental data of rice, wheat and maize under both non-saline and saline irrigation regimes besides direct seeded rice (DSR), SRI and puddled rice cultivation methods with different cultivars. DSSAT model performed better (75-92% accuracy) than the AquaCrop model (70-88% accuracy) in prediction of grain yield of rice and wheat cultivars under different rice cultivation methods. Further, it was observed that the AquaCropmodel requiring only 35 input parameters could able to predict the grain yield of wheat under saline environment with 80-85% accuracy as compared to SWAP model (110 input parameters) with 90-95% accuracy.

- Surface fertigation in basin and furrow irrigation systems with different fertigation strategies showed that nitrogen application during entire irrigation duration was found to be best for blocked end basin irrigation system compared to either first half or second half of irrigation duration. It enhanced fertilizer use efficiency by 15-20%.

## (D) AGRICULTURAL PHYSICS

a. Developed satellite remote sensing based methodology for crop identification, acreage estimation, phenology observation and crop condition assessment.

b. Developed web based Crop Simulation model – web InfoCrop Wheat and a web based Decision Support System to monitor soil physical health. A web based Decision Support System was also developed to fore warn the onset of white rust disease and aphids in mustard based on the real time daily weather data.

c. Weather –based bi-weekly agromet advisory services to the farmers of NCR region through SMS / E-mail /telephone. These bulletins were also sent to ATIC, KVK Shikohpur, KVK Ujawa, IKSL, NGO, e-choupal, Krishi Darshan, DD Kisan and local Hindi newspaper

d. Near real time Satellite based Remote sensing for crop condition monitoring

## (E) AGRONOMY

a. The bio-mass utilization unit managed by agronomy division is converting all crop and tree wastes into useful composts. Integrated farming system (IFS) model for small and marginal farmers in north-Indian situations under irrigated ecology need to be duplicated and validated. The major IFS enterprises undertaken are crops (horticultural and field crops) + dairy + fishery + duckery + poultry + biogas + agro-forestry in the IFS model of 1.0 ha area. This IFS model generates a gross and net returns of Rs. 8,12,984 and 3,40,787, respectively annually with labour requirement of 675 mandays per annum.

b. The division has developed through extensive field experimentations the tillage, nutrient management (including organic sources, green manures, biofertilizers, fertilizers, newly coated fertilizers, sensor-mostly SPAD meter/ GreenSeeker/ Nutrient Expert guided precision N management), water management- including plant sensor guided irrigation, sprinkler & drip irrigation, moisture conservation, weed management practices,) and also determined the suitability of different crop genotypes, for enhancing the productivity and profitability of dominant cropping systems, Rice-wheat, Maize-wheat, Soybean-wheat, Pigeonpea-wheat and Cauliflower-based cropping system.

c. Apart from developing production-cum-resource conservation technologies for individual crops and major cropping systems, two integrated farming systems one each for irrigated agro-ecology and rainfed agro-ecology, suiting to small farms of 1 ha area have been developed.

## (F) AGRICULTURAL ENGINEERING

a. **Technologies for horticulture mechanization:** Development of gladiolus planter, tractor operated carrot harvester, manually operated multi-crop planter for small vegetable seeds, Integral power equipment for small farm mechanization, tractor operated onion transplanter, battery operated four wheel weeder, variable height platform

b. **Machines for resource conservation:** Development of planter for system wheat intensification, paddy straw collector-cum-chopper, modified aqua-ferti seed drill, plot drill for permanent raised bed, pulse planter for ridge and bed planting, Urea Ammonium Nitrate (UAN) Applicator.

c. **Solar powered gadgets and machines:** Development of low cost storage structures, solar powered fruit and vegetable grader, refrigerated storage, vegetable seed dryer, EC storage structure for fruits and vegetables.

d. **Equipment for precision farming:** Development of pneumatic precision planter**,** direct paddy seeder **.**

**(G) ENVIRONMENTAL SCIENCE**

a. Developed the InfoCrop V2.1, a crop growth decision support system Available at http://www.iari.res.in

b. Assessed the regional impacts of climate change and adaptation gains for wheat, mustard and potato.

c. The farm level adaptation technologies for livelihood security of farmers were implemented in about 40 villages in climatically vulnerable 4 districts.

d. Vulnerability mapping of Indian agriculture at the district level was assessed using exposure to hazards, sensitivity to climate and adaptive capacity to recover from stress based on past data.

e. The inventory of greenhouse gases emission was prepared for Indian agricultural sector for the base year 2010. The Institute has quantified GHGs emission from soils under cereals, millets, oilseeds, pulses and vegetables in northwest India. Different strategies for mitigating GHG emission from agricultural soils have been tested.

**(H) AGRICULTURE KNOWLEDGE MANAGEMENT UNIT**

a. Under National Agricultural Innovation Project (NAIP) a subproject of component-1 entitled "'Strengthening of Digital Library and Information Management under NARS (**e-GRANTH**)" provides digital access to different library resources for National Agricultural Research System **(NARS)** in India which comprises of Agricultural Research Institutions and Agricultural Universities. Under this initiative IDEAL platform and Krishikosh systems has been developed to digitize the NARS library resources for enhancing the efficiency and accessibility of the library resources to cater the increasing need of the scientific/research/teaching community.

b. CeRA provided linkages with 147 institutions (SAUs and ICAR Institutes) under NARES. Access to more than 4000 journals in the area related to all the aspects of agricultural sciences are being made available. This has large impact on the research system in improving quality and quantity of research outputs through easy access to accredited scientific literature which was becoming difficult due to rising cost of foreign journals. Libraries were not financially strong to purchase hard copies of these journals. Sharing through online CeRA resulted in efficient access at very low cost.

## V. SCHOOL OF BASIC SCIENCE

## (A) PLANT PHYSIOLOGY AND BIOCHEMISTRY

### 1. NON-DESTRUCTIVE HIGH THROUGHPUT METHODS FOR PHENOTYPING

a. **Hyperspectral signature based non-destructive henotyping method**

- Non-availability of real-time, high throughput and non-destructive methods for quantification of relative water content (RWC) is one of the major bottlenecks in large-scale phenotyping of germplasm for drought tolerance.
- A high throughput hyperspectral method was developed to assess excised leaf water loss (ELWL; ability of genotype to quickly sense water deficit and close its stomata) and relative water content (RWC) of rice under lab conditions in rice and wheat. The spectral indices based method can predict RWC with considerable precision (RMSE ~ 5%). The spectral indices based method is very fast (takes about 2 min per observation) and can be used for non-destructive measurement of plant water status.
- Hyperspectral signature-based high throughput method to quantify RWC in rice was developed. The continuum removal factor ($CR_{\lambda}$ at 1450 and 1930nm) was identified as the best method to determine RWC in rice under lab conditions. Conventional spectral indices based models, continuum removal based single wavelength (band depth and continuum removal factor) models, Multiple Linear Regression, Partial Least Square Regression and Support Vector Machine and Spectral Unmixing based models were developed and validated in rice and wheat.

b. **Development of spectral indices based models to predict RWC under Potculture in rice**

**Phenotyping method for study of root growth: A tube based rhizotron**

- A rhizotron was developed for observation of roots in PVC tubes. Clear glass tubes (38 mm dia x 200 mm length) were inserted horizontally into PVC pipes (16 cm dia) at different depths. The distribution of roots adjacent to the walls of clear glass tubes was observed by inserting a small camera (Web Camera with LED lights) into the glass tubes. The real time root observations can be visualized and stored in a laptop or mobile attached to the camera. The root length of wheat observed from camera and root length of extracted roots was positively correlated (r = 0.79).

c. **Rapid and non-destructive field phenotyping of crop biomass in wheat and rice**

- Crop biomass is one of the most important representative trait of crop performance directly associated with - crop growth, yield, HI, RUE, WUE, NUE, fodder availability, carbon capture etc. There was a highly significant linear relation between log(biomass) and log(projected area) in both wheat and rice crops. This relationship can be used for non destructive estimation of biomass under field conditions as indicated by the significant correlation between observed and predicted aboveground dry weight in wheat.

## 2. GLOBAL CLIMATE CHANGE AND ABIOTIC STRESS TOLERANCE

### a. Heat and drought tolerance in wheat

***Starch metabolism in developing grains of wheat under heat and drought stress:*** High temperature adversely affects starch biosynthesis in the endosperm and thus, reduces grain quality and yield in wheat. Hence, starch granule formation and soluble starch synthase (SSS) activities were studied in grains of wheat genotypes with contrasting heat tolerance.

- Electron microscopic studies showed that thermotolerant cv. C306 maintained higher number of endosperm cells with well filled starch granules as compared with thermosensitive cv. PBW343.
- Kinetics studies on SSS enzymes from grains of maize and wheat revealed that maize SSS has a lower $K_m$, higher $V_{max}$ and thus higher catalytic efficiency ($V_{max}/K_m$) as compared with wheat SSS. Maize grains were found to have highly active (3-4 times) and more thermostable SSS as compared with wheat (Fig. 43).
- Studies on grain starch content, SSS activity and expression of *SSS* and *GBSS* (granule bound starch synthase) genes revealed a strong association between expression and activity of SSS with genotypic differences in grain growth of wheat under drought.

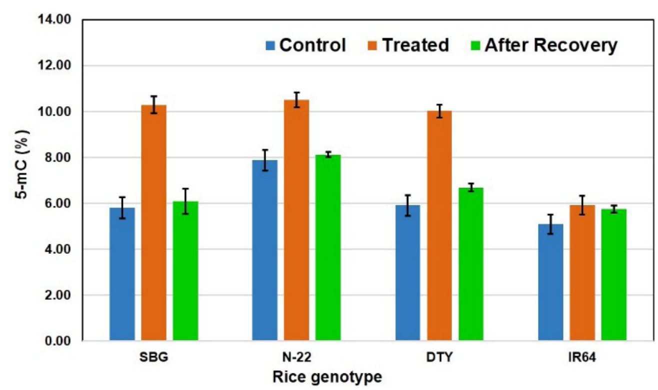


**Fig. 43: Maize soluble starch synthase is more thermostable than wheat starch synthase**

b. ***Role of heat shock proteins in heat stress tolerance of wheat:*** Heat shock proteins (HSPs) confer cellular tolerance to heat stress. *HSP* genes are induced by heat shock transcription factors (HSFs) during heat stress. Hence research work was carried out to clone and characterize HSPs and HSFs from wheat.

- Heat stress inducible expression levels of *HSFs* (*HSFA2b*, *HSFA4a* and *HSF8*) and HSPs (*HSP16.9*, *HSP17*, *HSP90* and *HSP101c*) genes were higher in the flag leaf of heat tolerant wheat genotypes as compared with heat sensitive wheat genotypes. Some of these genes were cloned from heat tolerance genotypes.

c. ***De novo assembly for the identification of heat-responsive genes in Triticum aestivum:*** More than 23000 and 22000 unigenes were identified in wheat *cvs*. HD2985 and HD2329 predicted to be stress-associated transcripts. Most of the transcripts identified were associated with HS-tolerance, metabolic, defence, and signalling pathways.

- We are the pioneering institute to submit raw data on "Whole Transcriptome Analysis of wheat for heat stress tolerance". The project was submitted in Sequence Read Archive (SRA) of NCBI with accession no PRAJNA172054.

d. ***Novel-heat responsive miRNAs identification in wheat:*** We could identify more than 1200 conserved miRNAs and 37 novel heat-responsive miRNAs in wheat under the HS by RNA-seq; 6 of the identified miRNA were validated to be heat-responsive in nature. Identified heat-responsive miRNA were observed to regulate the expression of SAGs like HSP17, CDPK, MAPK, etc.

e. ***Characterisation and genetic manipulation in RuBisCO activase protein for improved thermostability:***

- 12 putative wheat Rca genes were identified using transcriptome data. The identified Rca transcripts from wheat along with Rca reported from Arabidopsis, and rice was used to draw the phylogeny tree. The identified Rca was grouped into five different families based on the sequence.
- The identified wheat Rca showed maximum homology of 97% with Rca reported from rice (AAL87177) and 87% homology with Rca identified from Arabidopsis and Rice (grouped under family-I).
- 37 *Rca* gene sequences of plants from NCBI GenBank were aligned with the cloned wheat *Rca* gene (acc. no KP257297) by ClustalW alignment. Six potential hot spots at position 272, 144, 115, 117, 118, 138.

f. ***Hormonal regulation of drought tolerance in wheat:*** Exogenous application of ascorbic acid (AsA) and cytokinin conferred enhanced drought tolerance to wheat by (Fig. 44) delaying leaf senescence and reducing oxidative stress. Endogenous AsA content under drought stress correlated with the drought tolerance in wheat.

- Dehydroascorbate reductases (DHAR) gene involved AsA regeneration and IPT gene for cytokinin synthesis were cloned from wheat cultivar DBW39.
- Genes for ethylene and polyamine biosynthesis were cloned form wheat. Higher polyamine accumulation may help impart drought tolerance in wheat.
- The effect of foliar spray of synthetic CK, 6-benzylaminopurine (BAP, 40 μM) was examined in wheat cultivars C 306 and PBW 343 under drought stress. Drought stress significantly reduced RWC, MSI, chlorophyll and carotenoid contents, photosynthesis, starch and nitrogen metabolism, but enhanced protease activity in wheat. Foliar application of BAP mitigated these adverse effects and enhanced the grain yield stability.

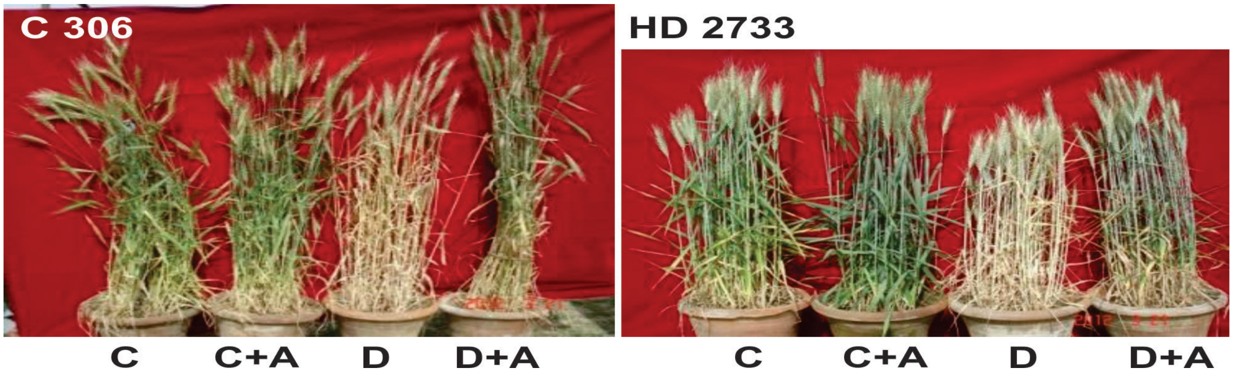


**Fig. 44:** ***Ascorbic acid prevents drought-induced senescence and confers drought tolerance to wheat*** **(C, well irrigated; C+A, well irrigated plants sprayed with ascorbic acid @ 100ppm; D, drought; D+A, plants sprayed with ascorbic acid and subjected to drought stress).**

**g. High temperature stress tolerance in rice**

- High temperature tolerance of 71 rice genotypes (including Nagina 22 as a check) was evaluated in the field conditions during summer season. The maximum air temperatures during vegetative stage was above 40$^{o}$C and at flowering ranged from 32 to 44$^{o}$C, which are about 10$^{o}$C higher than the optimum temperatures. Genotypes were raked based on spikelet fertility and grain yield per hill.

- NERICA-L-44 was identified as the most heat tolerant genotype based on survival percentage, spikelet fertility (85%), 1000 - grain weight and grain yield.

- High temperature stress also affected grain quality. The grain quality of Nerica L-44 was the best among the genotypes evaluated under high temperature stress. Thus, Nerica L-44 can be used for introgression of thermotolerance to develop climate change resilient rice cultivars.

- Microarray analysis was carried out to compare the panicle transcriptome of heat tolerant rice cv. Nerica-L-44 and sensitive cv. Pusa Sugandh 5. Pathway analysis of revealed that genes for jasmonic acid (JA) biosynthesis, polyamine pathway, phenyl propanoid biosynthesis, pyruvate metabolism, and starch and sugar metabolism were specifically upregulated in high temperature tolerant cv. Nerica-L-44.Real-time RT-PCR analysis confirmed the higher expression levels of genes for JA and polyamine synthesis in heat tolerant Nerica-L-44, suggesting the potential role of JA and polyamine in spikelet fertility under heat stress.

- High night temperature (>22$^{o}$C) adversely affects heat-sensitive flowering and grain filling stages in rice by reducing spikelet fertility and consequently yield and grain quality while the vegetative stage and most of the other yield components (number of grains per panicle, panicle weight, panicle length, and 1000-grain weight not shown) remain unchanged (Fig. 45).

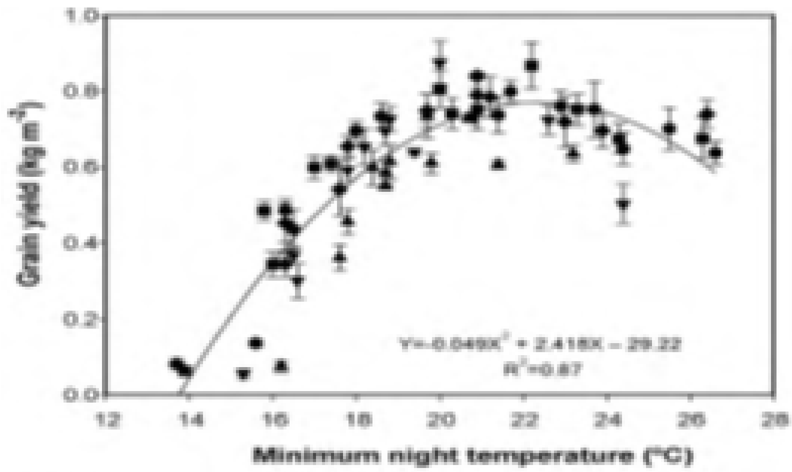


**Fig. 45: Grain yield of aromatic and non-aromatic rice in response to mean minimum night temperature**

h. ***Hormonal basis of abiotic stress induced spikelet sterility in rice:*** Spikelet sterility is one of the major causes of yield reduction in rice under abiotic stresses in rice. Previous studies showed that high temperature stress induced reduction in the endogenous auxin content was responsible for loss in pollen viability in barley and *Arabidopsis*. Hence, we examined role of auxin in stress-induced spikelet sterility in rice.

- Heat and drought stresses downregulated the expression of genes for auxin (IAA) biosynthesis and signaling. Drought and heat stress-induced reduction in endogenous IAA content was found to be associated with spikelet sterility in rice under drought and heat stresses. Exogenous IAA application minimized the spikelet sterility under these stresses (Fig. 46).

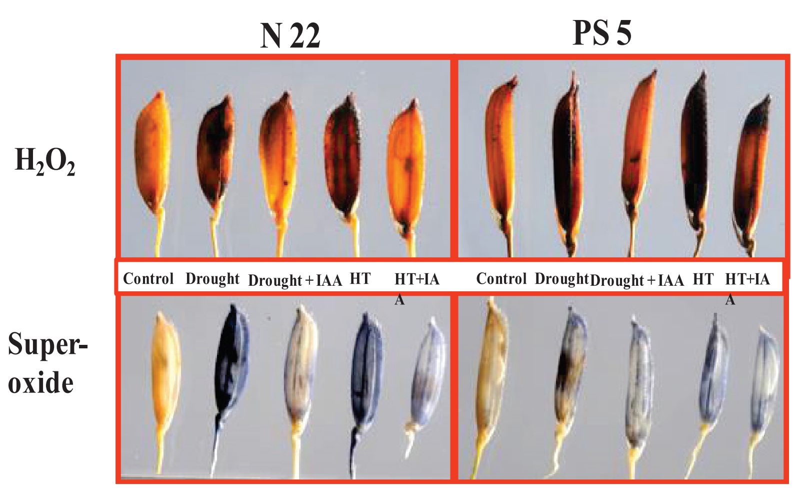


**Fig. 46: Exogenous application reduces stress-induced ROS accumulation in rice spikelets under drought and heat stresses in rice**

- Genes for IAA biosynthesis and signalling were cloned from rice cv. Nagina 22. Gene expression analysis revealed that most *YUCCA* genes and their transcriptional regulators *SPL*, *NGA* and *TFL* were down regulated in the spikelets of rice genotypes under stress. Further auxin co-receptors *TIR1* and *AFB2*, ARF target gene *HAF* TF, 3 out of 4 *PIN* genes, and all 5 *ARFs* analysed in present study were significantly downregulated by drought/heat stresses in rice panicles.
- These results showed that drought or heat stress-mediated decline in endogenous IAA level and impairment of IAA signalling components required for both male and female reproductive development are the major causes of reduced spikelet fertility in rice.
- Exogenous auxin as foliar application, and genetic manipulation of auxin synthesis and signalling will be useful to mitigate the stress-induced reproductive damage, and stabilize the grain yield of rice under drought and heat stresses.

3. **Cloning and functional validation of stress-responsive genes**

**a. *Functional genomics of ABA Receptor genes in rice:***

Plant stress hormone ABA plays major role in drought tolerance of plants. We contributed significantly to understand the plant stress hormone Abscisic Acid (ABA) signalling, and mechanism of action of ABA receptor (ABAR) in stress responsive gene expression in Arabidopsis. Overexpression of PYL13, a variant version Arabidopsis ABAR, enhanced drought tolerance of transgenic Arabidopsis (Collaboration with Purdue University, USA).

- Since the ABA receptors (ABAR) imparted stress tolerance to Arabidopsis, we carried out genome-wide analysisto identify ABA receptors in rice, and found that rice genome encodes 12 genes for ABARs. 3D structure prediction analysis revealed that 2 of them are non-functional. Hence we cloned all the ABARs that were predicted to be functional from rice cultivar Nagina 22.
- To understand the function of these genes, transgenic rice line (MTU1010/Pusa sugandh 2) overexpressing these genes from stress inducible RD29A promoter were developed for *ABAR2, ABAR3, ABAR4, ABAR5, ABAR6, ABAR7, ABAR8, ABAR9, ABAR10* and *ABAR11* genes. In addition for ABAR6 gene, constitutive overexpression and RNAi lines were also developed in the background of Pusa sugandh 2.
- Genetic transformation of rice with ABAR6 gene resulted in enhanced drought tolerance of rice transgenics under greenhouse conditions. Since ABA is a major regulator of transpiration and water use efficiency, these two traits were analysed in T2 transgenic and non-transgenic (NT) rice lines. Excised leaf water loss assay showed that water loss from the leaves of $P_{AtRD29A}$*::ABAR6* rice transgenics is slower than that of NT. Scanning electron micrography revealed that stomata are partially closed immediately after excision, and stomatal closure occur very fast in transgenics. The *ABAR6* and NT rice lines were subjected to 3 cycles of water-deficit stress (-80 kPa) and recovery, and water

use by these plants were evaluated by gravimetric measurements under greenhouse conditions for over a period of one month. Transgenic rice plants used about 30-45% less water as compared to NT plants. The results showed the potential of *ABAR6* gene for minimizing the water use by rice plants.

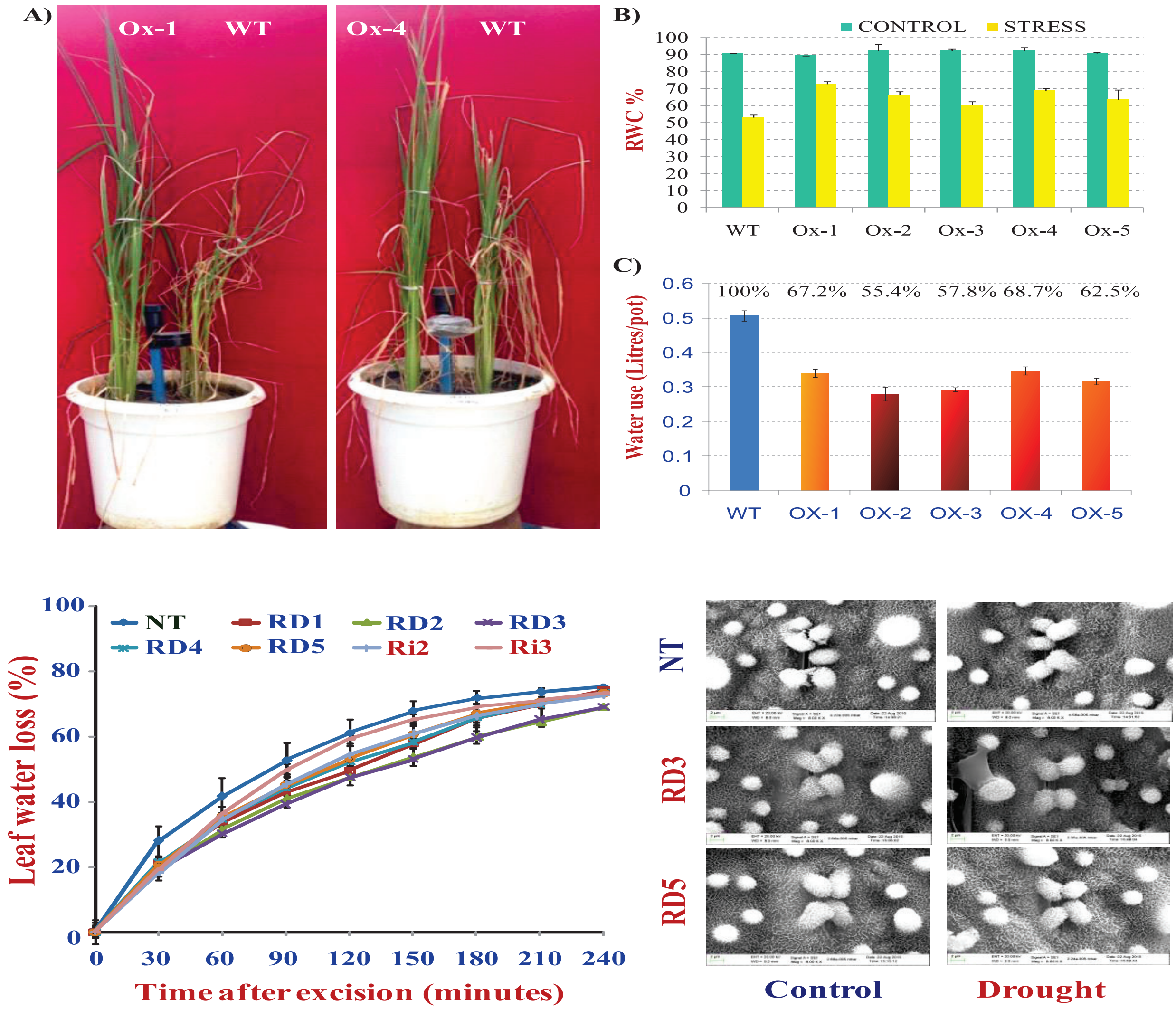


**Fig. 47: Stress inducible overexpression of ABAR6 enhances drought tolerance in rice.** A) Recovery of transgenics and WT after drought (-90 kPa) stress, B) Maintenance of RWC at -90 kPa SMP, C) Water use per 4 plants per day. Lowe panel (Left): ELWL; Lowe panel (right): SEM of stomata in non-transgenic (NT) and transgenic rice plants (RD3 & RD5).

### b. *Inducer of CBF Expression 1 (ICE1) pathwa*y for multiple stress tolerance

The ICE1-CBF pathway of cold acclimation and freezing tolerance is conserved across plant species. Our transgenic analysis in Arabidopsis revealed that in addition to cold tolerance, overexpression of *AtICE1* also enhanced drought stress tolerance. Hence rice transgenics overexpressing *AtICE1* were developed. Rice transgenic plants showed enhanced cold, drought and salt tolerance.

***4. Cloning of stress inducible root-specific genes and promoters from rice***:

Root system architecture (RSA) plays key role in nutrient and water acquisition. RSA is regulated by drought stress. Towards identification of candidate genes for RSA and root-specific stress-induced promoters, 30 candidate genes which showed drought regulated root specific expression in microarray analysis was selected. Semi-quantitative RT-PCR expression analyses of these genes were carried out to analyse their expression in root and shoot tissues of rice seedlings imposed with osmotic stress. Based on their tissue-specific and stress inducible expression, eight genes were selected for quantitative real-time RT-PCR validation. The qRT-PCR results showed that osmotic stress significantly upregulated the expression of *OsFBX132*, *OsHD-ZIP*, *OsMYB47*, *OsPP91* and *OsUSP* in the root tissues of rice. In tolerant rice cv IC305692, *OsFBX132*, *OsHD-ZIP* and *OsMYB47* induction was lower, but *OsPP91* and *OsUSP* induction was higher in roots under osmotic stress as compared with that of susceptible genotype RCPL1-3C. These ABA and osmotic stress upregulated root specific genes and their promoters will be highly useful to elucidate the mechanisms of root development under drought stress in rice.

***5. MicroRNAs (miRNAs) biogenesis pathway***

MicroRNAs are important for plant development and stress responses. However, factors regulating miRNA metabolism are not completely understood. We identified SICKLE (SIC), a proline-rich protein critical for development and abiotic stress tolerance of Arabidopsis. Loss-of-function *sic-1* mutant plants exhibitedhypersensitivity tochilling and salt stresses. We showed that SIC is a unique factor required for the biogenesis of some miRNAs and degradation of some spliced introns and important for plant development and abiotic stress responses. Similarly, STABILIZED1 was discovered as specific accessory protein necessary for miRNA/tasiRNA biogenesis and stress tolerance in Arabidopsis (Collaboration with Purdue University, USA). We identified orthologs of genes for miRNA biogenesis from rice, and found that expression of many of these genes are regulated by abiotic stresses in rice. This suggest their potential role in stress responses in rice. Work was initiated under DBT, Govt of India funded project to understand miRNA biogenesis and its role in abiotic stress tolerance in rice.

***6. AP2/ERF transcription factors:***

A 964 bp genomic sequence of AP2/ERF transcription factor was cloned in PBI121 followed by transformation in *Agrobacterium.* The construct was mobilized in *Arabidopsis*. T2 transformants showed less wilting and maintained higher turgor under stress. Characterization of drought stress inducible promoter Os-AP2/ERF-N22: *In silico* analysis of the promoter revealed the presence of two ABA responsive element (ABRE), three drought responsive element (DRE), 19 MYB recognition element and ten WRKY *cis* elements. Water stress inducible nature of the promoter was demonstrated in *Arabidopsis* and rice, using reporter gene (GUS)

- A genome-wide analysis of MYB family and coexpression network analysis of rice transcriptome across various tissues and environmental stresses led to the identification of stress responsive MYBs and 88 highly coordinated genes.
- We cloned and characterized several stress responsive genes and promoters. Stress

inducible overexpression of $P_{LEA4}$::BcZF1 (=ZAT12) was found to enhance multiple stress tolerance in mustard (Collaboration with NRCPB). This gene construct was used by IIVR to develop multiple stress tolerant tomato transgenics.

### *7. VIGS-mediated Modification of Fatty Acids Enhances Heat Tolerance:*

Cell membrane stability is one of the key components of high temperature stress tolerance. To study the effect of reduction in trienoic fatty acid (18:3) on thermotolerance, *Fatty Acid Desaturase 7* (*FAD7*) gene was downregulated by using VIGS (Virus-induced gene silencing) method in tobacco. The *FAD7* silenced plants exhibited marked reduction in linolenic acid (18:3) and increase in linoleic acid (18:2). These plants showed higher photosynthetic rate and PSII yield, and lower levels of $H_2O_2$ content and membrane leakage than that of non-VIGS plants at 42°C heat stress. Thus, increasing the ratio of 18:2/18:3 fatty acids in membrane lipids can enhance membrane stability and heat tolerance of plants.

### *8. Epigenetics of drought tolerance:*

To investigate the role of QTL for drought tolerance yield 1.1 (qDTY1.1) from rice genotype Nagina-22 (drought tolerant genotype), genome-wide cytosine methylation (5-mC) was estimated at reproductive stage in contrasting rice genotypes. Four genotypes: two drought tolerant; Sahbhagidhan, Nagina-22, one drought sensitive IR-64 with qDTY1.1 IR-64-$DTY_{1.1}$ and IR-64 -drought sensitive under control and drought stress (soil moisture content reduced to 30%) conditions. qDTY1.1 caused about 65% increase in global methylation under drought stress.20% of global methylation was retained even after withdrawal of the stress.Introgression of qDTY1.1 caused ◎2-fold increase in drought tolerance in IR-64, particularly at reproductive stage; however, it was still less tolerant than Nagina-22.

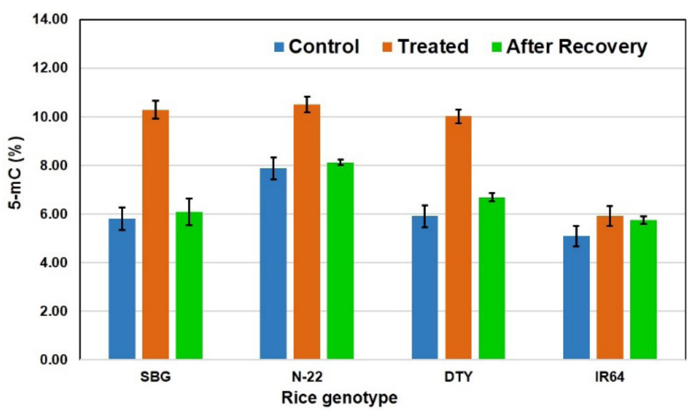


**Fig. 48: Global methylation status of contrasting rice genotypes (SBG= Sahbhagidhan, N-22= Nagina-22, DTY= IR-64-$DTY_{1.1}$ -drought tolerant; IR64= IR-64 -drought sensitive at reproductive stage.**

### 9. Genome Editing in rice:

Targeted genome editing using CRISPR/Cas9 has recently emerged as functional genomics and new breeding method for precisely editing the genomes to induce desirable allele. With this technology, it becomes easy to pyramid the required genetic variability into any established rice cultivar directly by targeted genomic sequences alterations; without any requirement of actual rice mutants and the time consuming plant breeding processes. Hence development of human resource in this area is very critical for crop improvement programmes of India. Towards this objective genome editing in rice has been initiated to improve WUE and drought tolerance of rice.

- The CRISPR-Cas9 constructs for rice *ABAR9* and *ABAR11* developed during the last year was used to transform rice cv. Kita-ake and MTU1010. Five events each are at T0 stage. The CRISPR-Cas9 constructs for rice *ABAR6, DROUGHT and SALT TOLERANCE (DST), FARNESYL TRANSFERASE alpha (FTA) & FARNESYL TRANSFERASE Beta (FTB/ERA1)* genes were developed. Transformation of MTU1010 is in progress to develop MTU1010 mutants with high WUE and drought tolerance.

### 10. Salt tolerance of plants

a. ***Conservation of SOS pathway of salt tolerance***

- In Arabidopsis, Salt Overly Sensitive (SOS) pathway regulates ion homeostasis and $Na^+$ exclusion, and thus provides salt tolerance. We cloned and characterized SOS1 (plasmamembrane $Na^+/H^+$antiporter), SOS2 (Serine-threonine protein kinase) and SOS3 (Calcineurin B-like Calcium sensor protein) genes from wheat and Brassica, and showed the conservation of SOS pathway and its key role in salt tolerance of wheat and Brassica.

- *Salinity* stress tolerance of wheat (Kharchia 65) was associated with greater expression of genes of salt overly sensitive (SOS) pathway genes (*SOS1, SOS2, SOS3, $H^+$-PPase* and *NHX1*), which codes for proteins involved in exclusion and sequestration of sodium, and thus resulting in lower $Na^+$ accumulation and higher $K^+/Na^+$ ratio.

b. ***High affinity potassium transporters***

- Isolation and characterization of high affinity potassium transporters and their up- as well as down-regulation revealed constitutive as well as inducible expression. Expression in biotic elicitor –methyl jasmonate (MJ) and salicylic acid (SA) induced contrasting wheat genotypes revealed mitigation of the effect of salt stress, and MJ showed better responses than that of SA.

- Genotype- and tissue-specific variation in cytosine methylation induced by 200 mM NaCl stress was observed in contrasting wheat genotypes, which resulted in differential gene expression of these transporters that downregulated expression of *TaHKT2;1* and *TaHKT2;3* in shoot and root of Kharchia-65 (salt-tolerant), which contributed to its improved salt-tolerance ability. *TaHKT1;4* showed root-specific expression and minor change in 5-mC content due to the salt stress, was found to be downregulated under the stress in salt-tolerant genotype, it was not observed to be regulated through changes in cytosine methylation. Thus, understanding epigenetic regulatory mechanisms for gene expression may enable improving abiotic stress tolerance in crop plants

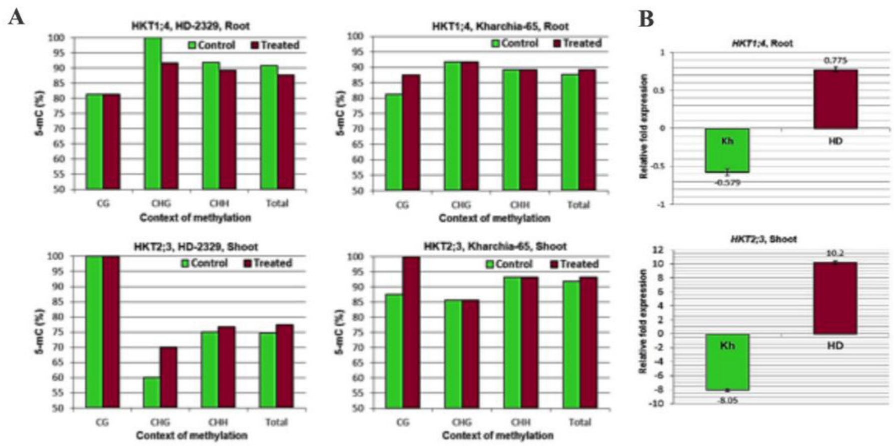


**Fig. 49: Cytosine methylation and gene expression studies in High-affinity potassium transporters (HKTs) of wheat during salt stress conditions.** (A) Methylated cytosine (5-mC) in *TaHKT1;4* root-specific (upper panel) and *TaHKT2;3*shoot specific(lower panel) in wheat genotypes: Kharchia-65 ( Salt tolerant) and HD-2329 (Salt sensitive) under control (non- treated) and treated (200 mM NaCl) conditions (B).Relative gene expression of *TaHKT1;4*root specific (upper panel) and *TaHKT2;3*shoot-specific(lower panel) in wheat genotypes: Kharchia-65 ( Salt tolerant) and HD-2329under control (non- treated) and treated (200 mM NaCl) conditions .

**11. Temperature stress tolerance in chickpea**

- Late sown chickpea experiences low temperature stress during vegetative growth and high temperature stress during reproductive stage. Twenty chickpea genotypes were tested for germination percentage and seedling vigour (I & II) under low temperature. Seedling vigour on dry weight basis was high in Pusa 2024, BG5023 and BG 1088 at 15$^{o}$C. These can be further exploited for early vigour under low temperature stress at vegetative stage.

- Fifty six diverse chickpea genotypes were screened for high temperature tolerance under late sowing in field condition. Eight genotypes namely Pusa 1103, Pusa 1003, KWR 108, BGM 408, BG 240, PG 95333, JG 14 and BG 1077 were identified as tolerant to high temperature under late sown conditions.

- Chickpea plants grown under elevated $CO_2$ maintained higher green leaf area, photosynthetic pigments and exhibited delayed senescence and maturity. This suggested that elevated $CO_2$ overcomes source limitation in chickpea.

## 12. Chemical growth regulators to mitigate abiotic stress effects in crops

***Chemical plant growth regulators to mitigate stress effects:*** Exogenous application of salicylic acid (10 mM) also enhanced the yield stability of wheat. Similarly, a field trial with chickpea var. Pusa 372 showed that foliar spray of BAP (40 ppm) with tannic acid (50 ppm) enhanced yield ($\geq$15%) under both rainfed and irrigated conditions. These chemicals enhanced membrane stability, photosynthesis, nitrate reductase activity and plant water status.

- Thiourea (1000 ppm), BA (40 ppm) and TDZ (10 ppm) applications increased yield in both *Desi* (Pusa 362) and *Kabuli* (Pusa 1108) varieties under water-deficit stress. The increase in yield was associated with reduced lipid peroxidation, ABA content, and significantly enhanced photosynthetic activity, TSS, proline level and antioxidant enzymes.
- Foliar spray of NAA (50 ppm) alone and in combination with thiourea (1000 ppm) and tannic acid (TA) (50 ppm)enhanced grain yield of chickpea by increasing growth, rate of photosynthesis, carboxylation efficiency, level of chlorophylls and carotenoids, and number of pods under rainfed conditions.
- A micronutrient-based foliar spray formulation was developed. It significantly enhanced the biomass and grain yield under late sown condition in wheat cv. HD 2987 and HD 2985.

## 13. NUTRIENT USE EFFICIENCY

### a. Nitrogen use efficiency (NUE)

***NUE in wheat:*** Wheat genotypes were evaluated for NUE under zero N ($N_0$) and 120 kg N ($N_{120}$) applications in the field conditions. The genotypes were ranked based on the relative change in biomass and grain yield at $N_0$ over $N_{120}$. Among the 110 genotypes, 23 were identified as N efficient, while 17 were categorized as inefficient.

- Out of 110, 40 genotypes were selected and re-screened in field for NUE. Based on cluster analysis of the 40 wheat genotypes, 5 each of N efficient and less N efficient genotypes were selected. Efficient- EC-556434, BT-Schomburgk, PBW-394, Arrino and Roller and Inefficient- Stretton, Kater-1, Bevy-1(Med), Triticale and Gluyas Early.
- Physiological characterization of selected wheat genotypes for tolerance to N-stress in hydroponics showed that N-efficient genotypes when grown under low N had 32% higher total leaf area in comparison to N-inefficient ones. Under low N, the protein content and the activities of NR, GOGAT, GS and GDH N-efficient genotypes as compared to N-inefficient.

### b. Phosphorus uptake efficiency (PUE)

(I) ***Root exudation index: screening organic acid exudation and phosphorus acquisition efficiency in soybean genotypes*** - Root exudation index (REI) developed as a physiological marker for efficient P acquisition in soybean. REI was calculated from total carbon exuded in the rooting media at sufficient and low P and used to classify genotypes for P acquisition efficiency. Genotypes with high REI performed equally well at both sufficient and low soil P availability; therefore, REI can be used as a criterion to screen efficient genotypes.

(II) ***Root acidification, a rapid method of screening soybean genotypes for low-phosphorus stress*** - A simple method was developed to screen soybean genotypes for low-P stress tolerance by quantifying the root exudate acidification using bromocresol purple dye. This method eliminated the use radio-labelled carbon. A significant linear relationship between exudate pH and carboxylate concentration suggested that measure of root acidification might predict the genotypic potential for low-P induced carboxylate efflux.

(III) ***PUE in mungbean:*** Organic acids (OAs) exuded from roots help solubilize non-available P in the soil, and thus enhance P uptake efficiency of plants. Hence phenotypic variations for OAs exudation from the roots of green gram genotypes were evaluated by using $^{14}CO_2$ feeding method. OAs released from the roots mainly consisted of oxalic and citric acids. Among the 44 genotypes, PDM 139 produced highest oxalic acid at low P conditions.

- High carboxylate exudation capacity and improved root traits were found to the key mechanisms for phosphorus uptake efficiency in greengram under P-deficiency stress.
- The major organic acid released from root was oxalic and citric while in the root apices, higher concentrations of oxalic, succinic and lactic acids were present. Genotype PDM-139 (P-stress tolerant) produced highest oxalic acid (5092.5 μg/g root FW) suggesting it was efficient in uptake of P.
- A high throughput and easy method using $^{14}CO_2$ of shoots was developed to screen large number of genotypes for P use efficiency.

(IV) ***PUE in maize:*** Identified two maize hybrids *viz*. PEHM-2 (tolerant) and HM-4 (non-tolerant) and their inbreds on the basis of their physiological and biochemical response to nitrogen and phosphorus stress by screening in hydroponics culture.

- Roots of PEHM-2 (NP-stress tolerant) grown at low-N, low-P and low N&P were used for construction of cDNA libraries by subtractive hybridization. Expression of a few hypothetical genes in all the libraries were found which warrants further study, particularly those expressed under low-N&P stress which might provide help in developing N&P stress tolerant plants.
- The metabolite profiles of PEHM-2 and HM-4 were compared in response to P-deficiency and restoration conditions. Significant variations in metabolite pools were observed under P-deficiency which was genotype specific. Out of 180 distinct analytes, 91 were identified. P-starvation resulted in accumulation of di- and trisaccharides and metabolites of ammonium metabolism, specifically in leaves, but decreased the levels of P-containing metabolites and organic acids. A sharp increase in the concentrations of glutamine, asparagine, serine and glycine was observed in both shoots and roots under lowP stress.

**c. Cloning of High-affinity nitrate transporter from *Brassica juncea* (L.)**

High affinity transporters (HANTs) contribute to nitrogen use efficiency in plants.

A *HANT* gene *BjNRT2.1* (GenBank # JQ305139.1) from *B. juncea* that expresses only at very low (0.01 mM) nitrate concentration was cloned. This gene will be used for developing wheat and mustard crops with high N uptake efficiency.

d. **Impact of Elevated $CO_2$ on Nutritional status of crops:**

- Effect of elevated $CO_2$ on grain quality and growth of wheat was studied. $CO_2$ enrichment promoted aboveground biomass, grain yield and test weight. However, grain protein concentration decreased significantly.
- In grains, the high molecular weight glutenin fraction significantly decreased under $CO_2$ enrichment. An overall decrease in the concentrations of proteinogenic amino acids per unit flour weight was observed under elevated $CO_2$. Minerals like Mn and Cu increased, while Zn, Fe and Mg decreased under high $CO_2$ in grains. The concentration of Lysine in grain also decreased in grains under elevated $CO_2$.

  These results suggesting the need for genetic improvement and change in nutrient management practices to maintain nutritional qualities in future climate change scenarios.
- Interactive effect of P (0 and 500 μM) and $CO_2$ enrichment (380 and 700 $\mu mol\ mol^{-1}$) showed positive effect on total dry matter accumulation in cereal species under sufficient P supply under $CO_2$ enrichment. Significant difference in root length, surface area and lateral root density was observed in response to elevated $CO_2$ and P nutrition.
- Low P and high $CO_2$ resulted in increased P utilization efficiency in cereal species maximum being in rye and lowest in durum wheat. Elevated $CO_2$ was also found to increase the expression of *TaHAPT* gene.

## 14. NUTRITIONAL QUALITY AND STORABILITY OF SEEDS

### Reduction of Off-flavor in Soybean

a. ***Identification of off-flavor causing volatiles in soybean:*** The volatile compounds produced by lipoxygenase (LOX) impart off-flavor to soybean.

   - Eleven off-flavor causing volatile compounds comprising of short chain aldehydes, ketones and their alcoholic counterparts were identified by using a Solid-phase Micro-Extraction and GC-MS analysis. An inverse relationship was found between PUFA ratios and hexanal to trans-2-hexenal ratios. The GC-MS analysis of volatiles produced during this process showed hexanal and trans-2-hexenal to be the major contributors towards the off-flavour.

b. ***Characterization of LOX enzymes:*** Our studies revealed that lipoxygenase catalysed peroxidation of poly-unsaturated fatty acids is the main cause of off-flavour development in soybean. A reciprocal relationship was observed between PUFA ratio (Linolenic/Linoleic acid ratio) and relative amounts of hexanal to trans-2-hexenal.

c. ***Gamma-radiation suppresses off-flavor in soybean:*** Three different doses (0.25, 0.5 and 1.0 KGy) of $\gamma$-radiation treatments on off-flavor generation in soybean was studied.

d. **Development of low phytate soybean**

Development of low phytate soybean is important to enhance its nutritive value. The *myo*-inositol-3-phosphate synthase (MIPS) is the key enzymes in phytate synthesis. Hence, expression profiles of *MIPS* family genes were studied in developing seeds and seedlings of soybean cv. Pusa 16.

e. **Cloning of genes for phytic acid synthesis and catabolism.**

- For silencing *MIPS1* gene in developing seeds, RNAi and antisense gene constructs were developed. The transgene was cloned under a seed-specific *VICILIN* promoter. For overexpression of phytase gene, the full length *PHYTASE* cDNA was cloned under a seed-specific *VICILIN* promoter.These three constructs were mobilized into *Agrobacterium*, and are being used for genetic transformation of soybean (Fig. 50).
- An efficient system of regeneration through direct somatic embryogenesis was developed. This system was will be useful in genetic transformation of soybean for reducing phytate content seeds.
- RNAi vectors for silencing the expression of candidate genes, of the phytic acid biosynthetic pathway, in the developing seeds were prepared using a seed specific promoter and transformed into soybean. Upto ~40% reduction in phytic acid content was observed in the seeds of selected lines of transgenic soybean (T4) transformed with *phytase* (ectopic overexpression) and *MIPS* (As,ihp) vectors (RNAi strategy) as compared to the non-transgenic controls accompanied by a corresponding increase in the bioavailability of Fe of Zn and Ca in both. Patent filed (PP No. 2432/DEL/2015)
- Submittedmicroarray based expression profiling data for differentially expressed genes (4443) in Indian soybean variety (BIOPROJECT (GEO) No. PRJNA292501) (first report) and also the 3D homology models of phytate pathway enzymes.

a)

| Cultivars | Phytic acid (g/100g) | Percentage reduction of Phytic acid (%) |
|---|---|---|
| Non transgenic control MIPS ihp T4 | 3.875 ± 0.13 | |
| MI75-42-23-11-3-3 | 2.30 ± 0.18 | 40.56 |
| MI62-27-12-19-3-4 | 2.89 ± 0.58 | 25.32 |
| MI51-32-22-1-13-6 | 2.27 ± 0.05 | 41.34 ☆ |
| MI65-22-42-11-23-7 | 3.01 ± 0.37 | 22.22 |

b)

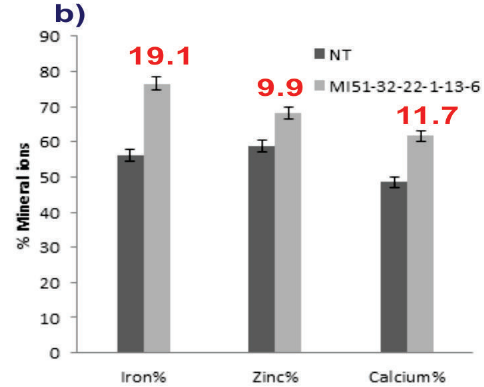


**Fig. 50: RNAi silencing of MIPS gene reduces seed phytic acid content and enhances bioavailability of micronutrients.** a) Phytic acid levels in WT and transgenic soybean, b) Bioavailability of Fe, Zn and calcium.

**f. Nutritionally important components of soybean seeds**

- Two hundred Indian soybean germplasm including wild types and its derivatives were screened for high $\alpha$-tocopherol content and found significantly highest concentration of $\alpha$-tocopherol between 8.8-10μg/g in AMS77, VLS85 and BRAGG varieties and lowest concentration of $\alpha$-tocopherol was found in DS2706 (1.36 μg/g) .
- Expression analysis of genes encoding three isoforms of $\gamma$-tocopherol methyl transferase ($\gamma$-TMT1 (gamma-tocopherol methyl transferase), $\gamma$-TMT2 and $\gamma$-TMT3 was carried out in in BRAGG and DS2706 and it was observed that, $\gamma$-TMT 1 and $\gamma$-TMT 2 did not show any significant difference ($P < 0.05$) in the expression level between the DS2706 and the Bragg whereas $\gamma$-TMT 3 showed significantly ($P < 0.05$) higher expression (1.5 to 3 fold) in Bragg as compared to DS2706.
- Soybean, due to presence of health-promoting bioactive compound isoflavones, is regarded as functional food. 31 new miRNAs along with their 245 putative target genes from soybean seed-specific ESTs. Amongst all, 5 miRNAs (GmamiRNA12, Gma-miRNA24, Gma-miRNA26, Gma-miRNA28, and Gma-miRNA29) along wither corresponding target genes were anticipated and confirmed for their probable role during isoflavone biosynthesis. Gma-miR26 was shown to target the 4-coumarate CoA ligase (Glyma.10G197900) which controls the flux movement towards isoflavone biosynthesis. GmamiRNA12, Gma-miRNA24, Gma-miRNA28, and Gma-miRNA29 miRNAs were shown to be involved in downstream control of glycosylation of synthesized isoflavones. Differential expression of Gma-miR26 and Gma-miRNA28 along with their corresponding target genes (Glyma.10G197900 and Glyma.09G127200) showed a direct relationship with the total isoflavone content.

**g.** ***Genome editing tools for improvement in the nutritional quality of soybean*****:** For developing low phytate and high tocopherol content, genome editing tools are being employed for altering the expression of enzymes involved in phytic acid and tocopherol biosynthesis pathway. Research work was initiated on CRISPR/Cas 9 mediated genome editing to improve tocopherol and reduce seed phytate. *pCas9-IPK1* binary constructs were developed. Similarly, CRISPR/Cas 9 constructs for $\gamma$-TMT3 as well as DE-ETIOLATED1 (DET1) were developed.

- Anthocyanin fingerprints of 57 pigmented soybean genotypes were investigated. The total anthocyanin content varied from 2- 940 mg/100 g seed coat. Using the most abundant anthocyanin form - cyanidin-3-glucoside (Cy3G) as a marker, the genotypes were subdivided into five groups with their representatives as: highest concentration of Cy3G was observed in black variety DS241 (939.56mg/100g), followed by chocolate type GG252 (214.32mg/100g), brown JS9214 (58.11mg/100g), green G2144 (19.06mg/100g) and yellow DS9712 (2.31 mg/100g). The major (Cy3G) and minor (Delphinidin-3-glucoside (D3G) and Petunidin-3-glucoside (Pt3G) anthocyanin contents were analysed using HPLC. To understand the enhanced nutraceutical potential of Cy3G in disease etiology, an *in vitro*cell line (BEAS2b) mimicking model was used. A decrease of 78%

ROS levels were observed when cell lines were treated with seed extracts of soybean genotype (BS1, of group 1) having (1023mg/100g) as compared negative control (BRAGG, of group 5).

## (B) POST-HARVEST PHYSIOLOGY

### Gladiolus Flower Senescence

a. ***Cloning and characterization of Ethylene Receptors:*** Ethylene receptorgenes (*GgERS1)* from ethylene insensitive gladiolus were cloned, and these genes were functionally validated in tobacco and tomato.

- Transgenic tobacco constitutively overexpressing gladiolus ethylene receptor *GgERS1b* gene under CaMV35S promoter was developed by using *Agrobacterium*-mediated genetic transformation. Physiological analysis on $T_1$ tobacco confirmed the ability of *GgERS1b* gene in delaying senescence. Flower senescence was delayed by four days in transgenic tobacco as compared with wild type plants (Fig. 51).
- Tomato transgenics for delayed ripening/senescence developed by over-expressing ethylene receptor gene (*GgERS1).* Physiological and molecular analysis of the transgenics postharvest life of tomato carried out at the Institute showed delayed ripening in the presence of ethrel, a source of ethylene. The photosynthetic rate, stomatal conductance, chlorophyll content and membrane stability index increased, while the fruit softening enzymes (pectin methyl esterase and polygalacturonase) declined in the transgenic tomatoes. No adverse physiological effects were observed.

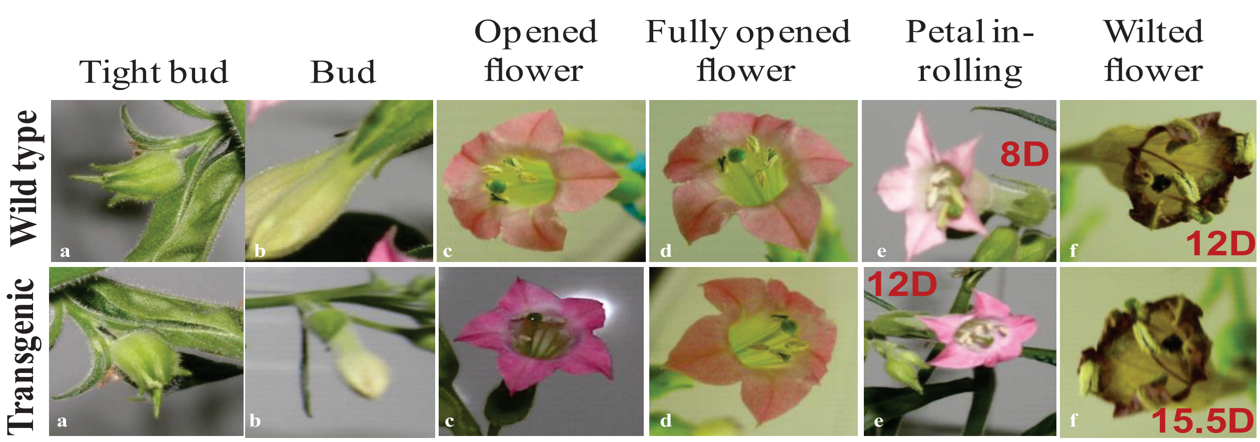


**Fig. 51 GgERS1b overexpression delayed leaf (top panel) and flower (bottom panel) senescence**

b. ***Nitric oxide (NO) in regulates flower senescence:*** Role of nitric oxide (NO) in regulation of flower senescence in gladiolus was studied and concluded that Sodium Nitroprusside (SNP) (NO Source, 100 ppm) enhances the vase-life of ethylene-insensitive gladiolus flowers by 4-5 days regulating senescence associated genes (SAG's).

c. **Cold induced sweetening in potato:** Cold-induced sweetening (CIS) in potato is caused by accumulation of reducing sugars during cold storage. To understand the molecular basis of genotypic difference in CIS, expression analysis of genes involved in asparagine synthesis and reducing sugar accumulation was carried out in potato tubers stored at room temperature, 4°C and 12°C. We analyzed reducing sugar accumulation by using HPLC method in 11 potato genotypes stored under room temperature, 12°C and 4°C. Kufri Surya, Kufri Frysona and Kufri Himsona accumulated less amount of reducing sugars at 4°C as compared with Kufri Chipsona 3 and other genotypes.

d. **Fruit ripening in tomato**

- Changes in the endogenous levels of mineral nutrients were analyzed during ripening of tomato fruits after harvest. With the progress of ripening, P, K, Fe, Zn and Cu content in the outer pericarp of tomato fruits increased due to remobilization from inner parts to the outer pericarp. The relationship between redistribution of different nutrients and shelf-life is being investigated.
- Ethanol vapour treatment was standardized to delay fruit ripening and to enhance storage life.

**Fig. 52: Ethanol vapor enhances shelf life of tomato:** Fruits of tomato cv. Pusa Ruby were harvested at green mature stage, treated with ethanol-vapours and stored at 25$^{o}$C. Ethanol treatment @ 1.2 ml/litre = 3.0 ml/Kg of fruits for 16 h

**Storability of seeds**

*f.* ***Storabilityof soybean seeds correlates with LOX enzymes:*** Fourteen soybean genotypes differing in seed viability were analyzed for LOX and hydroperoxidelyase (HPL) enzyme activities. Good storer genotypes exhibited significantly lower isozymes of LOX (L1, L2 and L3) and HPL activities than the poor storer genotypes.

*g.* ***Storability of magnetoprimed cucumber seeds:*** Storability of primed seed is important in determining the time lag between priming and sowing of seeds in the farmer's field. Hence, the storage potential of magnetoprimed seeds of cucumber cv. Barsati was evaluated by subjecting them to accelerated ageing. Faster aging of primed seeds was associated with higher $H_2O_2$ levels, lower levels of ROS scavenging peroxidases and enhanced loss of membrane integrity. Hence, primed seeds should be sown without delay to harness the benefits of magnetopriming.

**Yield enhancement techniques:**

e. ***Magnetopriming of seeds:*** Static and pulse-field magnetic seed treatment methods have been developed for different crops under normal and abiotic stress conditions. Pre-sowing static magnetic field treatment helps in seed invigouration of various crops like maize, cucumber, soybean, tomato and chickpea as it increases rate of germination and seedling vigor in these crops. It results in an increase in concentration of free radicals that are maintained in an **"oxidative window"** to enable seed invigouration through oxidative signaling It can ameliorate moisture deficit and salinity stress at seedling establishment stage in maize and chickpea respectively

- Dry seed priming with static magnetic field increases seedling vigour that can be exploited for ameliorating moisture deficit and salinity stress at seedling establishment stage. Enhanced seedling vigour was due to homoeostasis of reactive oxygen species maintained by coordinated action of antioxidative enzymes in the germinated seed.

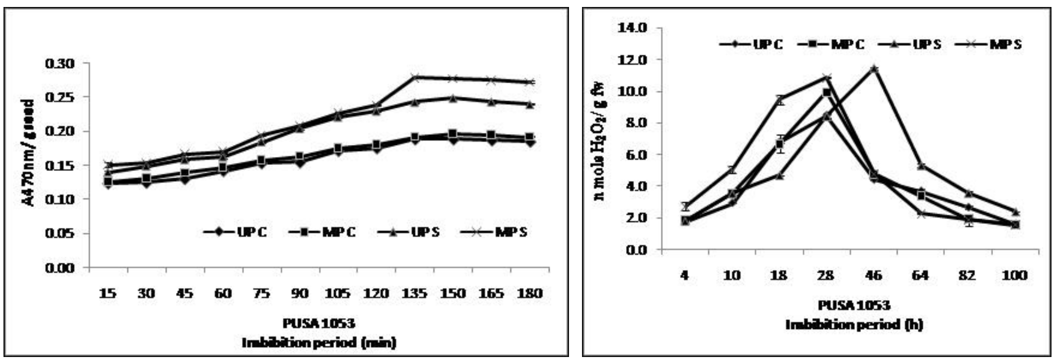


**Fig. 53: Superoxide radical ($O_2^{\cdot -}$) and Hydrogen peroxide ($H_2O_2$) production in magnetoprimed and unprimed seeds of chickpea. UPC= unprimed control; MPC = magnetoprimed control; UPS = unprimed saline; MPS = magnetoprimed saline.**

- Seed priming with plant hormones salicylic acid and methyl jasmonate were found to mitigate salt stress effect by enhancing total anti-oxidant enzyme activity and total phenol contents, and reducing lipid peroxidation in contrasting wheat genotypes (KRL210 and WH542).
- Pulsed (PMF) and static (SMF) magnetic field dose optimized in cherry tomato seeds (Selection 1) for improving seedling vigour. Enhanced seedling vigour was associated with production of high level of superoxide radical and gibberellic acid in PMF treated seeds.
- Wheat seeds of HD 2967 and Kharchia 65 were magnetoprimed with 50 mT static magnetic field for 2 h to evaluate the effect of magnetopriming on salinity tolerance. Enhanced rate of germination and seedling growth parameters under different salinity levels indicated that magnetopriming was effective in alleviating salinity stress at early seedling stage. Changesin $\alpha$-amylase activity compared to $\beta$ amylase showed a positive

correlation with rate of starch hydrolysis in magnetoprimed seeds under salinity. A 2.2 fold increase in the ratio of raffinose to sucrose in the magnetoprimed seeds of HD 2967 under saline conditions during the initial stages of germination suggested its contribution during germination.

- Static magnetic field dose of 150 mT 30 min treatment to the seeds of carrot cv. Pusa Rudhira increased seedling vigour marginally, and yield by 9% without any significant change in the marketable quality
- Significant enhancement in vigour indices was observed in cauliflower seeds cv. Pusa Paushja treated with SMF of 50mT for 1h. Crop from SMF treated seeds showed 27% increase in yield over the crop from non-primed seeds under field conditions.
- Chemical priming of chickpea seeds were evaluated for enhancing stress tolerance. Seeds of *desi* chickpea cv. Pusa 362 were primed by soaking them for four hours in thiourea (1000 ppm) and salicylic acid (100 ppm). Chemical priming induced heat tolerance in chickpea through enhanced germination, seedling vigour, MSI, level of proline, total soluble protein, total amino acid and activity of antioxidant enzymes and reducing lipid peroxidation under heat stress in lab conditions.

## VI. SCHOOL OF SOCIAL SCIENCE

### (A) AGRICULTURAL EXTENSION

An innovative IARI Post Office Linkage Extension Model was validated in five locations including Sitapur (UP), Buxar (Bihar), Sheopur (MP), Sirohi (Rajasthan) and Jammu (Jammu & Kashmir) for effective dissemination of farm information to the remotely located farmers.This model has connected 130 post offices in 56 districts of 13 states. The model has been found as an effective and successful means for making improved agricultural technologies available in the rural areas in relatively lesser time and cost. A cyber extension model was developed and two cyber extension Centres were established in Neelgaon and Chaudiya Manpara villages of Sitapur district in Uttar Pradesh. Mobile phone agro advisory regarding wheat and mustard cultivation practices was sent through SMS in weekly interval to farmers. Mobile based advisory services were analyzed in partnership with CABI under Direct 2 Farm project. The content for paddy cultivation was developed and communicated through voice based SMS to the farmers of Vaishali district of Bihar and other operation area of CABI D2F project.The feedback surveys during crop production stages through PRA, focus group discussion and conventional interview using structured interview schedules revealed better acceptance and application of messages by the farmer.

Under another innovative project on strengthening agri-nutri linkages for enhancing nutritional security and gender empowerment, food consumption pattern and nutritional status in ten districts across ten states of India were studied. The rural people had low level of knowledge about nutrition and medium level of dietary diversity. The most consumed food groups were cereals, vegetables, milk and milk products and the majorly missing food groups were pulses, millets and fruits. In project villages of Uttar Pradesh and Haryana, through a series of awareness campaigns, capacity building programmes and nutrition oriented agricultural interventions, agri-nutri smart villages are being established. Macro trend on linkage between agriculture and nutrition across the states was analyzed. Per-capita consumption in cereals has decreased and is stagnant in pulses, and has doubled in edible oils, vegetables, eggs, fish and meat during 1993-94 to 2011-12. It has reflected the nutritional intake wherein calorie and protein intake has declined; fat intake has increased during this period. Simultaneously, a significant growth has been observed in per-capita income and availability of food commodities along with rapid urbanization. The multivariate regression analysis of 28 states has suggested that dietary diversity significantly increases with production diversity and per-capita income and is significantly higher in other states vis-a-vis north-eastern states. A significant non linear relationship has been observed between dietary diversity and literacy. The study has highlighted a significant impact of local production diversity on consumption pattern and therefore, policies should target the diversification of agricultural production, particularly in the north-eastern states to bring out dietary diversity and desired nutritional outcome in India. Sixty two extension personnel (Trainers) involved in organising training as training managers and trainers were interviewed using structured interview schedule. Brostrom training style inventory was used for deciding different instructional orientation approaches in training activities by trainers. Behaviourist and structuralist orientation were dominant in all extension personnel.

The documentation and assessment of innovative extension initiatives for effective dissemination of information and technology as well as capacity building of farmers were carried out through survey in the states of Maharashtra, Karnataka, Uttar Pradesh, Bihar, Rajasthan, Odisha, Jharkhand, Madhya Pradesh and Haryana. The innovative approaches observed included extending the reach of research institutions and convergence of players in farming through *Krishi-mahotsava*; linking farmers to markets through *Dhanyamahotasava*; value chain development, collectivization and empowerment through community organizations; partnership among multiple extension agencies; experiential learning through farm schools and farmers' field schools; technology dissemination through school children. Assessment of Agricultural Technology Management Agency in the states of Maharashtra, Karnataka, Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, Nagaland and Haryana revealed effectiveness in convergence of the line departments, convergence of extension activities, uptake of micro-enterprises, group formation, and sensitizing the farmers about latest developments in agriculture with exposure visits. Survey of KVKs in Uttar Pradesh, Haryana, Rajasthan, Maharashtra, and Gujarat revealed their impact in enhancing crop yield by 1.5 to 2 times with introduction of improved varieties and technological packages and capacity building.

A comparative study of constraints in adoption of improved technologies and yield gap in was carried out in selected pulses and cereals. A total of 450 comparative profitability demonstrations of paddy with pigeon pea and wheat with chickpea were conducted at 18 locations of National Capital region. The micro level yield gap-I and yield gap - II were calculated. Both types of yield gaps were found to be higher in pulses as compared to cereals, though the B: C ratio was higher in case of pulses whereas the absolute profit was higher in case of cereals.The adoption gap in high potential high gap states of chickpea (Rajasthan, Gujarat, UP and MP), Pigeon pea (Maharashtra, UP, AP and Gujarat) were studied for adoption of improved technologies. Largescale block demonstrations with nutrient and plant protection centric approach converged with providing support for construction of rain water harvesting farm ponds for providing protective irrigation have expanded the area and production. The major changes in input use pattern as an impact of NFSM was in application of micronutrients, liming material application, HYV Seed, IPM practices, possession of farm implements and participation in FFS. An increase in productivity by 10-25 per cent was reported by majority of the NFSM beneficiaries.

The strategies chalked out as a result included promotion of pulses in high productivity zones through pilot projects, popularization in new niches, promotion in different cropping systems including replacement of less profitable crops and intercropping, reducing post-harvest losses and institutional support in terms of improved seed replacement ratio, irrigation water, ensuring input availability, mechanization of pulse production, research intervention and policy support for value chain.

A study of 51 cases of achiever agri-preneurs revealed best practices as: opportunity recognition in reference to abundance of available resources, capitalizing on one's own prior knowledge or skills, hygiene and strict adherence to quality standards, unique products having niche market and encashing promotional marketing strategies for brand visibility. The motives of agri-preneurs were earning more from farming, driven by market demand, helping fellow farmers, running farm in a modern way, converting abundant resources into profitable ventures and working for self. The major facilitative factors for agri-preneurship development process were seeking adequate technical knowledge through interaction with experts, entrepreneurial competencies of farmers, available opportunities, optimum utilization of available resources, market demand for quality products and developing effective marketing linkages. The inhibitive factors were lack of entrepreneurial competencies, timely non availability of critical inputs, non-availability of critical technical guidance at the opportune time, lack of information about market, lack of adequate marketing avenues and lack of rural infrastructure.

Identification and prioritisation of IARI technologies for agri-enterprise ventures uptake in a participatory mode were conducted in the selected project villages. Focus group discussions were conducted to create awareness regarding specialty agriculture and value addition for higher farm profitability. Primary and secondary value addition, seed production, protected cultivation of vegetables and flowers, dairying, fruit production and primary processing were prioritised as promising agri ventures based on SWOT and Micro screening exercises. Documentation of farmer led innovations for five cases was done and the characterization in terms of type, strength, communicability and policy suitability of innovation was made. The triggers, catalysts and sparks have been identified. Two Farm Innovators meet were organised to share the experiences of farmers-led innovations and for networking of farm innovators, research institute and other promoter agencies.

Training Modules for skill improvement among SHG women, selected on the basis of Training Needs Assessment of women SHGs members, were tested and validated in the areas critical for sustainability of SHGs viz., managerial skill: conflict management, personal effectiveness, decision making, monitoring and evaluation; financial management skills

: savings, record keeping, linking with banks; operational skills for use of ICTs: computer applications, mobile applications and operating mechanism of internet; and micro-enterprise: mushroom cultivation.

Farmers were educated about Direct Seeded Rice technology for *kharif* and incorporation of pigeon pea in the cropping system on upland areas of the villages. Four demonstrations of zero-till wheat using IARI's varieties were laid out in Mewat. Analysis of climate change adaptation among vulnerable communities was undertaken. Climatic risk analysis of flood prone areas of Maynaguri and Dhupguri of West Bengal revealed that risk to the climate led hazard (especially flood) was very high in terms of its probability, exposure and consequences in the area. Climate smart farmers group MaaKuttam Chandi Krushak Committee, Achutdaspur, Jagatsinghpur (Odisha) was formed and started functioning.

**Pusa Krishi Vigyan Mela**

Every year Institute organizes three days Krishi Vigyan mela on a theme of current importance viz., Agricultural technologies for national prosperity, Farm technologies for enhanced productivity and income, Prosperity through innovative farm technologies, Agricultural technologies for farmers prosperity, Climate resilient agricultural technologies etc., for sustainable production. Thousands of visitors from different parts of the country including farmers, farm women, extension workers, entrepreneurs, students and others visit the m*ela.*

**(B) AGRICULTURAL ECONOMICS**

Research focus was on major issues of national importance particularly, public investment on agriculture, energy use, trade reforms, domestic market reforms, rural non farm sector, smallholder's productivity, total factor productivity, agricultural growth, and impact assessment of agricultural technologies.

***a.*** ***Agricultural research and investment:*** Globally, it is a well-articulated fact that technology, investments, enabling institutions and policies have driven agricultural growth and poverty reduction. India's public expenditure for agriculture & allied sectors has stepped up in the mid 2000 decade following a period of stagnation in the 1990s. Further, the recent trend in public expenditure pattern does not corroborate the notion of neglecting the marginal agro-ecoregions as far as public investment in agricultural research & education (Ag R&E) is concerned. However, the study undertaken shows that higher infrastructure and Ag R&E investment priority should be given to relatively backward states of eastern India, as the region still has poor infrastructure and higher concentration of subsistence producers which make private sector hesitant to invest.

***b.*** ***Prioritization of public expenditure:*** It revealed that rising government spending under revenue account on agri-inputs and farm support services may have a crowding-out effect on private investment. These investments, must, therefore, be treated as composite strategy for rural development and a sustained step-up in investments should be maintained in order to benefit agriculture, given that benefits from these investments tend to materialize after a considerable time lag. The policy shift towards rising capital expenditure in rural infrastructure and irrigation would translate into economic gains only, if it is backed by responsive institutions as they form part of the enabling environment for private investment.

c. ***Energy Requirement for Agriculture:*** The structure of energy consumption in the Indian agriculture has changed substantially, with a huge shift from animal and human labour towards tractor for different farming operations and electricity and diesel for irrigation. In 1970-71, agricultural workers and draught animals contributed 60% to the total energy-use in agriculture (15% and 45%, respectively), while electricity and fossil energy together provided 40 % energy. In a span of four decades, the share of these energy inputs in agriculture has undergone a drastic change and as a sequel, the contribution of electricity and fossil energy together has gone up to 90% and of agricultural workers and draught animals has come down to 10% (5% each) in 2012-13. The consumption pattern of both direct and indirect energy inputs has revealed that the energy consumption per hectare of net as well as gross cropped area has increased over time and therefore, the output per unit of energy use has declined. This underscores that Indian agriculture has become more energy-intensive.

d. ***Impact of Domestic Market and Trade Reforms in Agriculture:*** The Model APMC Act provides for the establishment of private market yards and direct purchases from farmers. The perception survey on domestic market reforms in Himachal Pradesh indicated that market reforms in the line of Model APMC Act is perceived positively by farmers and consumers, in terms of reducing malpractices streamlining market activities, providing opportunities to link with national and international markets, reducing the role of commission agents, deepening of the institutional credits. A survey undertaken in Karnataka indicated that the Special Commodity Market has provided them an assured market and remunerative prices. The analysis of export indicated that India’s agricultural trade has witnessed compositional change over the years in terms of increased share of meat and meat products, cereals, guar gum and resins and cotton (raw and yarns); and a decline in share of fish and fish products, and traditional export commodities (like tea, coffee and plantation based commodities). The export competitiveness analysed through revealed comparative advantage indicated that cashew nuts, coffee, cotton, egg, maize, mangoes, onion, sugar, tea and rice are competitive.With respect to the impact of the bilateral and multilateral trade agreements, it was noted that such trade agreements fosters faster growth of both import and export. The Sectoral Hirchman Index of diversity indicated that the bilateral and multilateral trade agreements tend to favour specialization rather than the diversification. The SAARC region exhibits high potential for increasing agricultural trade.

e. ***Rural Non-Farm (RNF) Sector and Employment pattern :*** The percentage share of agriculture in employment has declined during last two decades, but it was not comparable to the extent of decline in its share in the national GDP. The wage determinant analysis has revealed that agricultural productivity and RNFE have a positive influence on agricultural wages, while labour availability (labour-land ratio) and high dependency on agriculture pull down the wage rates. The analysis has confirmed that the growths of agriculture and RNFE have trickled down to the agricultural labour, indicating an inclusive growth. Though small and marginal farmers are primarily self-employed in agriculture, there is a shift towards casual work. However, as the size of holding decreases, share of self-employed workers in non-agriculture sector increased, indicating the need for alternate employment opportunity for the weaker section of the society.

f. ***Agricultural growth and Total factor productivity:***Along with input usage, the total factor productivity (TFP) continues to be a major contributor to agricultural growth. An analysis has been carried out to estimate the TFP of Indian agriculture, for major crops and states. The analysis has revealed that the TFP for the crops for the overall period has remained positive, except for jowar and arhar. The farm size-productivity relationship was examined for wheat and sugarcane crops in Western Uttar Pradesh and soybean in Madhya Pradesh. The analysis has not revealed a definite pattern of the relationship. However, in case of usage of fertilizer, marginal farmers are using relatively more fertilizer than large farmer in rice crop of southern states.

g. ***Impact assessment of improved agricultural technology :*** The impact assessment studies have been undertaken for major crops of IARI. A study on varietal diversity of rice in North Eastern Plain region of Uttar Pradesh has revealed that the majority of farmers' in the study area have grown Kalanamak variety followed by Swarna Sub1 and Samba Masuri Sub1. The rice varietal diversity indices were estimated which showed that 46 per cent of the farmers had grown only one variety (no rice varietal diversity) and only 11 percent of sample farmers have reported high rice varietal diversity (more than three varieties) in the study area.Another set of study was carried out on adoption and spread of major rice varieties of IARI. It was noted that among non-basmati varieties, Pusa 44 and PR 122/121 are mostly adopted in sample district. Pusa1121 and 1509 are the most adopted basmati variety in sample area of Punjab. Almost 90 percent of varieties of both basmati and non-basmati variety are contributed by IARI.

h. ***Agriculture market reforms :*** Agricultural market reforms indicated that variation existed in progress of agricultural marketing reforms in different states. Tamil Nadu is the state where the APMC act already provides for the reforms and on other extreme is Bihar, Kerala and Manipur, which have not adopted APMC act. Domestic market reform has also attracted the attention of the policy makers. In this context, the operation of the e-mandi system has been gaining importance and increased automation of auction process helped in increasing the transparency, competition, and reduced scope for collusion and cartels, and reduced delay in payment.

## (C) CENTRE FOR AGRICULTURAL TECHNOLOGY ASSESSMENT AND TRANSFER (CATAT)

The project, "Assessment of agricultural technologies and developing market led extension models for different production systems" was taken up in five districts of Haryana, two districts of UP and Najafgarhblock of NCT of Delhi. From *Kharif* 2011 the project has been reoriented with purpose to develop Model Villages in peri-urban areas of NCR for integrated development. Four villages namely Badarpur Said, Pabesara (Later Rajpur) and Kumbawas in Faridabad, Sonipat and Gurgaon districts of Haryana, respectively and Partapur (Later Soodna) in Ghaziabad district of Uttar Pradesh have been identified. In order to disseminate the need based and situation-specific technologies, socio-economic and bio-physical appraisal of the identified villages in participatory mode was conducted. In villages Badarpur Said, Soodana and Rajpur wheat variety HD 2967 outperformed very well and giving an average yield of 70.20 q/ha, 62.5 q/ha and 62.10 q/ha respectively. Mustard varieties *Pusa Bold* and *Pusa Jaikisan* performed well and were new introduction in the area. Pea variety *Pusa Pragati* gave an average yield of 55 q/ha, which was 27.91 percent higher than the local check (43.00 q/ha). Demonstration of use of hydrogel on wheat resulted in saving of one irrigation. The lentil variety L-4076 performed very well in village Soodana resulting in increase of yield to the tune of 39.18 per cent as against local variety (16.00 q/ha). resulting in the B : C ratio of 5.21. The best trait of mustard varieties *Pusa Bold* and *Pusa Vijay* were reported as bold seeded grain. At Soodna, Hapur total area under P. Rudhira through project intervention increased to 90 acres (60%). Carrot variety P. Rudhira has been found superior over best private company hybrid Sungro and gave 25 percent additional income. Due to long size, dark flesh colour, good taste and market friendly quality it fetched net profit of Rs. 2.44 lakh from 1.5 acres. Further, IARI technologies have also been diffused to neighbouring villages.

A National Extension Programme was further strengthened in collaboration with 17 ICAR institutes/ SAUs for faster diffusion of IARI varieties and production technologies to large numbers of farmers in different parts of the country. This programme found to be effective in dissemination of IARI technologies in far off locations. During *kharif* 2010, 643 demonstrations of 13 crops were conducted in different states. During *Rabi* 2011-12, a total of 494 demonstrations were conducted at 16 locations and covering an area of 171.50 ha. on varieties of wheat, mustard, gram, lentil, carrot, onion, bottle-gourd, pumpkin, pea and palak. During *kharif* 2012, a total of 279 demonstrations of paddy PRH 10, Pusa 1121, P 1401, Pusa 2511, P 44, JD 6, JD 13, PNR 519, P 1460 and PB 1; Arhar, P 992 and P 2001; Bottle Guard; *Pusa Naveen*; Cauliflower - *Pusa KartikSankar* and *Pusa Snowball* and four demonstrations of Bhindi; Pusa A 4 were conducted. During Rabi 2012-13 a total of 350 demonstrations were conducted covering an area of 106.91 ha. across 15 locations for wheat, mustard, lentil, pea, palak and onion. Similarly during *Kharif* 2013, 336 demonstrations on 22 varieties of paddy, sorghum, bottlegaurd, cauliflower, carrot, arhar, bajra and bhindi were conducted. During *kharif* 2013, a total of 336 demonstrations of paddy, sorghum, Arhar, Bajra, Bottle guard, and Bhindi were conducted. During Rabi 2013-14 a total number of 306 demonstrations were conducted covering an area of 73.92 ha. across 15 locations for wheat, mustard, lentil, chick pea, pea, palak, carrot and brinjal. During *rabi* 2014-15 a total number of 541 demonstrations were conducted covering an area of 127 ha. across 15 locations for 21 varieties of wheat, mustard, lentil, pea, gram, spinach, carrot, tomato and marigold crops in collaboration with ICAR institutes and SAUs. In collaboration with 25 Voluntary Organizations, during *rabi* 2014-15, a total of 1279 demonstrations covering an area of 429.37 hectares, for 25 varieties of wheat, mustard, lentil, pea, gram, spinach, carrot, tomato, marigold crops and hydrogel were conducted. Overall adverse effect on yield of Rabi crop was observed due to heavy rainfall at the time of maturity and harvesting in all varieties of wheat, lentil and mustard in North India. During Rabi 2015-16, a total number of 268 demonstrations were conducted covering an area of 57.92 ha. across 17 locations for wheat, mustard, lentil, gram, pea and spinach. All demonstrated varieties of IARI showed significantly higher yield in comparison to local varieties at all locations except one or two instances

The project on 'Outscaling agricultural innovations for enhancing farm income and employment' was initiated in Rabi 2014-15 in three villages, namely, Khajurka (Palwal, Haryana), Kuthbi (Muzzafarpur, U.P) and Rajpur, (Aligarh, U.P). The benchmark survey and participatory agroecosystem analysis was conducted to identify the resources and agricultural related problems in the area. To assess crop varieties during Rabi 2014-15, 163 demonstrations on wheat, spinach, pea and lentil were conducted in all the three villages. During *Kharif* 2015, in all 467 assessment trails were conducted on paddy, maize, sorghum, pearl millet, pigeon pea, cowpea, moong, bottlegaurd, bhindi and muskmelon covering an area of 186.18 ha. During *Kharif* 2016, in all 212 assessment trials were conducted on five paddy varieties covering an area of 88 ha.

The externally funded project, "Water Management Technologies for Sustainable Crop Production - An Action Research" was initiated with objectives of the project are to assess and transfer five water management technologies to the end users for enhanced water and nutrient use efficiency and improved soil-health for sustainable agricultural productivity. Use of Biogas technology: Installed 80 biogas plants; SRI Technology: 35 Demonstrations; Bed Planter: 30 Demonstrations; Aqua ferti seed drill : 20 Demonstrations; Laser leveller : 240 acres (45 in *Kharif* 2009 and 195 in Rabi 2009-10) were covered.

DBT funded project on "Biotechnology-Led Socio-economic Empowerment of Farm Women" is being implemented in collaboration with two organizations *viz*DeenDayal Research Institute (DRI), Chitrakoot and PRDF, Gorakhpur, UP as Non-Government Organization with lead centre at IARI. At CATAT, project is under operation in five villages in Tappal Block of District Aligarh having different agro ecological conditions. After conducting the participatory analysis of the area, women of these villages were mobilized to form Self Help Groups (SHGs). During the period 19 SHGs were formed. Interventions on improved cereals, pulses, oil seeds, fodder crop, vegetables, fruits (lemon) and flowers, nutrition garden, soil and water management, protected cultivation and improved implements to reduce drudgery were implanted to address technological need of the women. Besides, training programmes to motivate and mobilize women farmers for group action, scientific cultivation of crops including protected cultivation, grain storage, and processing, baking and nutritional awareness were conducted. Twenty two SHGs were formed under DBT funded project 'Biotechnology Led Socio-economic Empowerment of Farm Women' since July 2014 in five villages of the Aligarh district namely, Baluapur, Haziayapur, Nagar, Karanpur and Kalyanpur. Skill demonstration on preparation and storage of tomato ketchup, mixed pickle, aonla candy and carrot murabba were conducted. Around 73 trainings of 40-50 women participants each were conducted on the preparation of muffins, Rusks, Buns, healthy pizza bases, different types of cookies (*Pista, almond, pinwheel, tutti-fruity, Choco chips and jam*). One bakery unit has been established with necessary baking equipment (Bakery Oven, Dough Kneader) and regular trainings on baking technology are being conducted for skill development of farm women.

## (D) **AGRICULTURAL TECHNOLOGY INFORMATION CENTRE (ATIC)**

ATIC is effectively providing products, services, technologies and information services to the different stakeholders through a 'Single Window Delivery System'. Besides farm advisory services at ATIC, farmers are given farm advice through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), Pusa Agricom (1800-11- 8989), exhibitions, farm literatures and letters. A IInd level of *Kisan Call Centre* (1800-180-1551) has also been established at ATIC to address the problems/queries of farmers of Delhi state. Information & advisory needs of the visitors are also being catered through touch panel *kiosks*, revolving scrollers, laminated posters information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples, bio-fertilizers displayed at the centre.

Laid out live demonstrations of *kharif* Paddy varieties Pusa Basmati -1, P. B. – 1121 Pusa Sugandh -5 (P.S. 2511), Pusa -1401 (P. B. – 6), Pusa Basmati – 1509, maize var. Pusa Composite 3 and Pusa Composite 4 and Moong var. Pusa Vishal. In rabi live demonstrations of wheat varieties: HD -3086, HD -2851, HD-2967, and HD-3059; mustard varieties Pusa Vijay and Pusa Mustard-26, Vegetables: In summer season: Pumpkin var. Pusa Vishwas, Okra (Bhindi) var. Pusa A-4, Lobia (Cowpea) var. *Pusa Sukomal*, Cucumber var. *Japanese long green*, Onion var. *Pusa Red*, Bathua var. *Pusa Bathua -1*, Sponge gourd var. *Pusa Sneha*, Brinjal var. *Pusa Uttam*, Bottle Gourd var. Pusa Naveen, Palak var. Pusa Harit, Chilli Var. Pusa sadabahar, Tomato var. Pusa gaurav, Amaranthus, var. Pusa Kiran. In winter season Cauliflower var. Pusa Hybrid -2, Broccoli var. KTS- 1, Radish var. Hybrid -1, Beet var. Crimson globe, KnolKhol var. W. Vienna, Tomato var. Pusa Rohini, Methi var. PEB, Methi Pusa Kasuri. Among flowers Five varieties of Gladiolus viz., Shabnam, Sinayana, Srijan, Kiran and Cidushi and one variety of Marigold var. Pusa NarangiGaindademonstrations were laid out. Medicinal Garden, nutrition garden and fruit orchard were also maintained.

Drip irrigation system was demonstrated for fruit orchard and nutri-garden were demonstrated in crop cafeteria for the benefit of the visitors. High density fruit trees orchard planted with lemon (Kagzi Kalan), Mango (Amrapali), Guava (Lucknow -49, Allahabad Safeda and Lalit), Ber (Banarasi Karaka and Gola) have been grown in current season. For awareness of farmers herbal block has been developed in crop cafeteria which includes medicinal plants of Aloevera, Ashwagandha, Satavar, Coleus, Giloe, Mushkdana, Sadabahar, Mint, Tulsi (Basil), Lemon grass, Java citronella etc.

New technological additions in ATIC:

- 10 LED illuminated posters with farmer friendly information and success story of IARI Fellow farmers about the IARI technologies have been fixed in the ATIC training hall.
- One POS machine has been fixed in ATIC for cashless transaction on 5.2.2017.

A total number of 38,521 farmers/entrepreneurs, development department officials, students, NGO representatives etc. from 18 states of India visited ATIC during the year for farm advisory, diagnostic services, purchase of technological inputs/ products and trainings. A majority of the farmers (82.5%) visited ATIC to purchase / enquire seeds / varieties and farm publication and others (17.5%) for agro-advisory services. A majority of them were from Uttar Pradesh (29.5%) followed by Haryana (22.5%), Rajasthan (13%), Delhi (11.5%), Punjab (6.5%) and others

(17%). Besides, 11,905 farmers from 18 states were able to get information on various aspects of agriculture through Pusa Agricom(A toll free Help Number-1800-11-8989) Pusa Help-line (011-25841670, 25841039,25846233, 25803600) and Kisan Call Centre 1800-180-1551 (IInd level). Pusa seeds of worth Rs. 88,03,165/- and farm publication for Rs. 1,61,130/- have been sold to the farmers during the year.

Four issues of Hindi farm magazine “PrasarDoot” were published by the centre during the reporting period. Besides, more than 1500 farmers and others got farm advisory services through letters/e-mails during the period. The demands of IARI products, technology and services are increasing day by day in the market. Besides farmers, industry has shown a lot of interest in IARI Research products. ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators. The feedback strengthened the ATIC activities and provides a ground for need based technologies. The ATIC has also developed functional linkages with various agencies working for the farming community to effectively cater the information needs of the different stake holders.

### (E) KRISHI VIGYAN KENDRA, SHIKOHPUR (GURUGRAM)

The KrishiVigyan Kendra of IARI at Shikohpur, Gurgaon plays a vital role incombating unemployment of rural youth through technological empowerment and improving farmers awareness and farm productivity through various TOT programmes.

During the review period, 1489 front line demonstrations (covering 582.18 ha) were laid out in 42 villages of Gurgaon district. Out of 1489 demonstrations, 792 (299.88 ha) on oilseed (Mustard) and pulse crops (arhar, moong and gram) and 457 (201.9 ha) on cereal & millet crops (wheat,paddy, barleyand pearl-millet) and 190 (54.6 ha.) on vegetables (cauliflower, peas, onion, okra, bottle gourd and sponge gourd) and 50 (25.8) on Drudgery & Nutrition garden were conducted in farmers’ fields under the direct supervision of KVK scientists/ subject matter specialists.

Six hundred and thirty six training programmes were organized for different target groups. Out of 636 trainings, 113 vocational courses for unemployed rural youth and girls, 480 day long on/off-campus trainings for practicing farmers and farm women, 43 in-service trainings for agriculture development officers of the state agricultural departments and aganwari works. Through these trainings, 11852 persons were benefited.

### (F) ZTM –BPD unit

ICAR being a public research system wanted to create an eco-system of technology transfer and diffusion, in the light of WTO-TRIPS regime, that research outcomes are properly protected and then transferred to public/farmers through PPP mode of commercialization/ technology transfer. Also through creation of agri business Incubation facility, it was envisaged to create startups and new breed of entrepreneurs by involving Agri-Graduates.

**Fig. 54: IP Spectra Launched**

This Unit works both as IP management, tech transfer office, as a guide for Institute level ITMUs and as well as Incubation facility for nurturing ideas into commercially viable start ups and agri-preneurship development programs, working with an objective of augmenting income of farmers and employment generation by preparing a formidable force of agri-preneurs. ZTM & BPD Unit of IARI has set up its mission as *"Translating Research into Prosperity"* and scaled heights in last three years by putting in place effective and innovative systems, fast tracking the process of transfer of latest technologies ultimately to farmers through agri-preneurs and agri-business by adopting innovative PPP models.

## 1. IP MANAGEMENT

From 2009-2017, the unit has filed 34 Patent applications and among them 17 patents has been granted. Four copyright applications were filed and all are registered/granted during the period. Additionally, 17 Trademark applications have been filed and 2 have been registered during the period. 53 Plant Variety applications have been filed and 26 have been registered from 2009-17. ZTM & BPD Unit has organized more than 40 ITMC meetings to evaluate research outcomes, management of IPR portfolios, make decisions on inventions that need to be protected by patents and to formulate the terms and conditions of offers for commercialization of IPR enabled as well as know-how based IARI technologies from 2009-2017.

a. **IP Auditing:** An IP Audit is a systematic review of the Intellectual Properties owned by the Institute to assess, manage risk and commercialization, remedy problems and implement best practices in IP asset management. The ZTM & BPD Unit has conducted Technical Audit for filed and granted patentapplications of ICAR-IARI, identified the active and inactive IP list along with potential commercialization of protected technologies and initiated the action according.

b. **IP Spectra:** With mission to provide complete IP solution to Agro-based MSMEs, IP Spectra (Fig. 54) was launched on December 17, 2016 at ZTM & BPD Unit, ICAR- Indian Agricultural Research Institute with financial support of MSME, GoI. Under this, the unit provides IP services like drafting and filing applications for patent, copyright, trademark, and advisory services to Agro start up& MSMEs along with IPR awareness programmes.

Dedicated website www.ipspectra.ztmbpd.iari.res.in has been launched to create awareness regarding IP having features like information on IP policies, IP Acts & Rules; Lecture series; downloadable forms for IP Services. These services can be availed by submitting online form/ offline form available on the website.

## 2. TECHNOLOGY COMMERCIALIZATION

In the last seven years, IARI through ZTM& BPD Unit has successfully commercialized around 196 agricultural technologies (Fig. 55) ranging from crop varieties, bio-fertilizers, post-harvest technologies, agri-chemicals, farm implements and diagnostic tools to 366 agro-based companies and generated the revenue of Rs. 654.5 lakhs (Fig. 56).

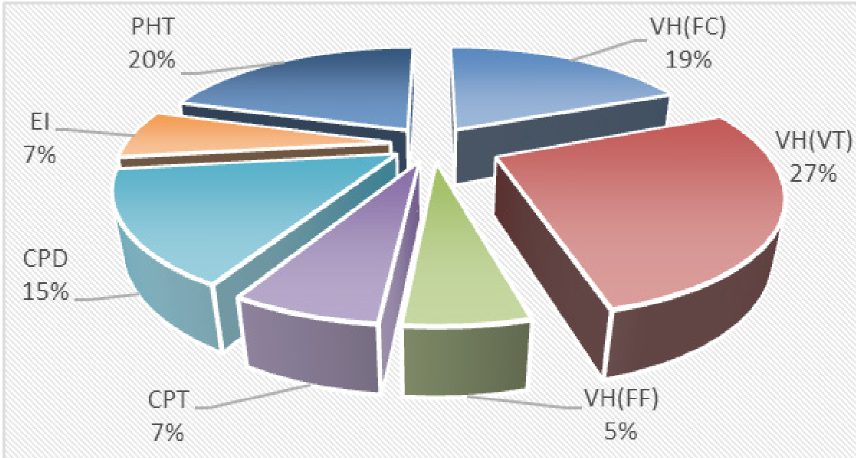


**Fig. 55: Sector wise Technology commercilaization from IARI from 2009 to 2017**

Sixteen IP Protected varieties i.e. Rice variety PB1509, PB 1612, Wheat varieties HD 2967, HI 1563, HI 1544, HD 3086, Mustard varieties 25, 26, 27,28, 29 and 30, floral varieties Chrysanthemum Pusa Anmol and Pusa Centenary and vegetable varieties i.e. tomato variety Pusa Hybrid-8 and cauliflower variety Pusa Kartik Shankar were commercialized to industry partners. Similarly 14-patented technologies were licensed to industry for commercial purposes so that innovative technologies should reach to end-users.

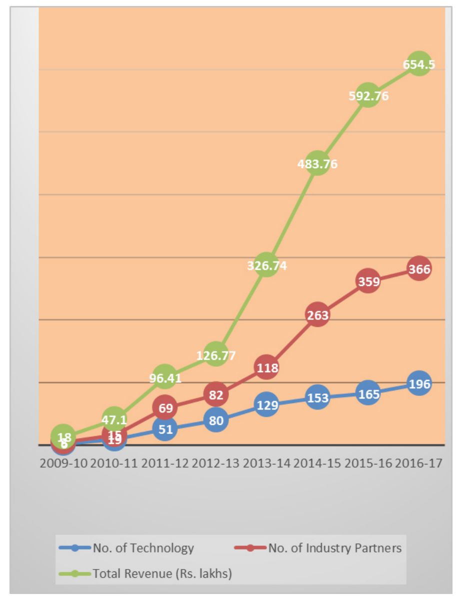


**Fig. 56: Revenue generation**

Innovative Marketing Approaches like B2B meetings, *Timely Response to Queries*, inventor's link, showcasing of technologies at different form, Mass emails and cold calls, News bulletin TAKSAY (*Taknique se Vyavsay*), use of social media like dynamic web portal of ZTM & BPD Unit, Face book page & LinkedIn were used for creating the visibility among the industry for wider reach and dissemination of information for technologies to Industry partners and other stakeholders.

a. ***Pusa gautami*: HD 3086:**The unit has executed licensing agreements with 202 seed companies for its climate resilient wheat variety HD 3086 in the shortest period of 2 years. The wheat variety HD3086 is the fastest adopted crop improved varieties of IARI that has covered an area of approx. 2 million hectares in 2014-15 and contributed approx. Rs. 15,822 Crores to farmer's income within a record 3 years of its release. Out of 200+ seed companies, 57 seed startup companies were supported, guided and nurtured by ZTM & BPD Unit. In a way, this initiative has nurtured the entire seed value chain from LAB TO LAND via industry participation and created around 5000 new employment opportunities in the last two years.

b. **Soil Testing and Fertilizer Recommendation Meter (STFR meter):**A portable STFR meter designed by the institute's inventors, IP protected and then commercialized to fourteen industry partners for providing the soil testing services at the farmer's doorstep.

c. **Zero Erucic Acid Indian Mustard Varieties:** Most of the popular Indian mustard varieties have >40 % of erucic acid which leads to diseases like myocardial fibrosis in adults and lipidosis in children, thereby affecting the human health. The team of scientists at ICAR-IARI has developed Indian mustard variety PUSA 30 with <2% erucic acid using conventional breeding method. Besides, the quantity of other essential fatty acids like Oleic acid has also improved to make the oil healthier with enhanced shelf life. The two other two essential fatty acids viz., Linoleic and Lenolenic acids, which are not synthesisedby human body, hence are supplemented by diet only, are also present in very balanced proportion in this variety.

d. **Launch of Pusa Krishi Mobile App:** Union Agriculture Minister Shri Radha Mohan Singh launched a new Mobile App "Pusa Krishi" during valedictory function of *Krishi Unnati Mela* on 21 March 2016 for farmers in order to take the technology to farm fields. PusaKrishi mobile application has been developed to realize the mission of "Lab to Land" i.e. to disseminate information about these technologies to update its various stakeholders like farmers, industry, entrepreneurs and start ups. Till date the App has been downloaded and used by more than 35,000 people (Fig. 57).

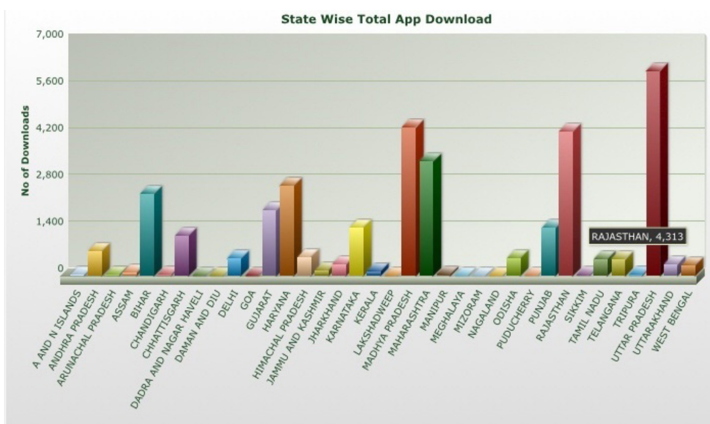


**Fig. 57: Statewise download of mobile app**

e. ***Agri-Biz Incubation:***

- On the line of our national campaign of Start-up India and Stand-up India, to further strengthen the efforts, new dimension of 'agribusiness incubators' has been added to facilitate start up in agri sector that is difficult one in a no. of ways mainly on technical side.
- In 2014 **for the first time,** in agribusiness sector, on-line entrepreneurial ecosystem was created through four months long **"Agribiz Incubation Program"**. Under this platform, next generation agri-business leaders were identified and mentored for developing and setting up viable business models based on their innovative ideas or technologies available with IARI and with other BPD units of North Zone i.e. IVRI, Izatnagar, NDRI, Karnal, CIPHET, Ludhiana and BAU, Ranchi. Seven out of 10 are running their business successfully and graduated from the programme.

- Encouraged by the success of its first Agri Biz Incubation Program,in 2016, the Unit has organized its second **Agri-Biz Accelerator program** - "**Arise 2016, Launch Pad for Agri-Startups"** in association with; nine Agribusiness Incubation Centres of ICAR, two State Agricultural Universities, three knowledge partners (Indigram labs Foundation, CIIE, Ahmedabad, KGS Advisors) two social media partners (Inc 42 and your story) and COWE (Confederation of Woman Entrepreneur) as social partner. ZTM & BPD Unit has received 500+ applications. During 2009-16, five business incubates have successfully graduated, Forty seven other entrepreneurs are under incubation for setting up their enterprises.

**f.** ***Facilitation in establishing Financial Linkages:*** Keeping in view the financial constraints of start-ups, schemes of Ministry of MSME have been linked and sanctioned the project entitled "Support for Entrepreneurial and Management Development of SMEs through Incubators" to ZTM & BPD unit to facilitate much-needed seed funding to start-ups. Under this scheme, nine start-up incubates of the unit got the grant in aid of around Rs 60.03 Lakhs for working in diverse agriculture fields, such as- post harvest management, seed, bio-fertilizer etc.

**g.** **BeejIndia: Farmers Producer Company:** With a mission of *"Utpadak se UdhamiTak"* (from Producer to Entrepreneur) and a motto of transforming farmers to entrepreneurs, ZTM&BPD Unit facilitated the formation of a Producer company named "beejIndia Producers Co. Ltd" which has been registered under Company's Act 1956. This company has 50 farmers with 20 subscribed founding members. It has five-member Executive Board with IARI as Advisory Director in it. Activities have been initiated as Seed Venture from Rabi 2013 covering approximate area of 100 ha.

### 3. CORPORATE MEMBERSHIP

To create strong and meaningful relationship with the industry so that the technologies of ICAR-IARI can reach and benefit the society and farmers, ZTM & BPD Unit welcomes partnership through 'Corporate Membership'. 970 corporate members have been enrolled so far from year 2009-2017, and generated revenue of Rupees Forty Lakhs Thirty Thousand Five Hundred only (Rs.40, 30, 500/-).

### (VII) PG SCHOOL ACHIEVEMENTS:

The Institute offers M.Sc. and Ph.D. programmes in 26 disciplines. During the review period, 1152 M.Sc., 57 M.Tech. and 1373 Ph.D. students including 155 foreign students were admitted to Post Graduate School. The Institute awarded M.Sc.degrees to 878 students, M.Tech. to 110 students and Ph.D. to 739 students, which include 49 M.Sc., 2 M.Tech. and 53 Ph.D. foreign students. IARI has a student Placement Cell, and need based Institute-Industry meets have been arranged for career counseling and placing outgoing students in the jobs of their choice. Most of IARI students because of their skills got selected in ARS or went overseas for higher studies.

**a. Human Resource Development**

- Development of the post graduate school to function as an important international centre for Human Resource Development in the field of agriculture
- Development of need-based basic and advanced courses and hand-on practical experience aimed to produce skilled human resources in the areas of biotechnology, precision agriculture, GIS, etc. Strengthening of trainings on molecular breeding, judicious use of natural resources, plant protection and hybrid seed production technologies
- Development of Centres of Advanced Studies to play leadership role in scientific research and technology generation

**b. Library and Learning Resources**

As a tribute to Prof. M.S. Swaminathan and his dedicated global services to agricultural sciences IARI Library has been renamed as "Prof. M.S. Swaminathan Library" on April 29$^{th}$ 2016. IARI Library is one of the 10 best agro-biological libraries of the world. Library provided the services as lead centre to all ICAR institutes/SAU & International institutes.

The Library today houses over 4 lakhs highly specialized research publications on agriculture and related sciences consisting of books, monographs, reference materials, journals, annual reviews, abstracting and indexing journals, translated periodicals, statistical and data publications, bulletins, reports, post-graduate theses of IARI, and ICAR research fellowship theses. The collection gets enriched annually by 8,000 to 9,000 documents. Now Library subscribes 109 Foreign Journals & 180 Indian Journal which are highly ranking journal in the world & published by Taylor & Francis, Elsevier, John Wiley, Nature & 76 online Journals accessible through Intranet. At present library uses most updated user friendly Open Source Library management software KOHA. The entire library premises are under constant surveillance through network of CCTVs.

The Library provides reference service, bibliographical services, documentation services, CD-Rom database searches, reprography services, etc. The Library has digitized IARI/ICAR RFT, 27 rare books, scanning of abstract/ summary pages of each thesis, making the PDF file and making the database searchable through Doublin Core Method, digitization of Bibliography of Indian Agriculture (BIA) and creation of membership database and preparation of bar-coded library membership cards. The Library provides the following information services to the scientists/research scholars of IARI and other users from all over India: (i) current awareness service, (ii) selective dissemination of information, (iii) document delivery, (iv) bibliographies on demand, and (v) inter-library loan.

Prof. MS Swaminathan Library has a well-equipped Facility Management Unit with ten personal computers attached with internet facilities for M.Sc. and Ph.D. students. The Library also has a well-equipped 'Computer Lab.' with 24 terminals with internet & Wi-Fi connectivity. The two reading halls of the library have been equipped with WI-FI system and computers with intra-net connectivity. Periodic training is given to scientists and students of the Institute for CD ROM search, Web of Science, Digital Resources, E-Journals, On-line information retrieval, etc.

The NAIP supported project Consortium for e-Resources in Agriculture (CeRA) has been initiated, which provides online access to over 2000 scientific journals to 123 libraries of the National Agricultural Research System (NARS).

One compulsory credit course of Library Information System (LIS) for M.Sc. and Ph.D. students was started in 1982. The aim of the course is to acquaint students with Library literature, searching of literature, services rendered by the Library, and information retrieval technology and techniques.

**c. Post Graduate School**

Before IARI became a 'Deemed to be University' in 1958, students numbering 903 were awarded Associateship of IARI which was recognized as equivalent to the M.Sc. degree of Indian universities. The Institute presently offers Master's (M.Sc.) and Doctoral programme in 26 disciplines, namely, Agricultural Chemicals, Agricultural Economics, Agricultural Engineering, Agricultural Extension, Agricultural Physics, Agricultural Statistics, Agronomy, Biochemistry, Bioinformatics, Computer Application, Entomology, Environmental Sciences, Floriculture & Landscape Architecture, Fruit Science, Genetics and Plant Breeding, Microbiology, Molecular Biology & Biotechnology, Nematology, Plant Genetic Resources, Plant Pathology, Plant Physiology, Post-Harvest Technology, Seed Science & Technology, Soil Science & Agricultural Chemistry, Vegetable Science and Water Science & Technology. M.Tech. in Agricultural Engineering and Post Harvest Technology.

During 2014-15 initiated the IARI Ph.D. outreach prgramme at Indian Institute of Horticultural Research, Bengaluru in four disciplines namely, Floriculture & Landscape Architecture, Fruit Science, Vegetable Science and PHT and at Central Institute of Agricultural Engineering, Bhopal in the sub-disciplines of Agricultural Processing & Structure and Farm Power & Equipment. During 2015-16 onwards admitted M.Sc. students for IARI, Jharkhand and Assam in five disciplines, namely Agronomy, Genetics and Plant Breeding, Soil Science and Agricultural Chemistry, Vegetable Science & Water Science & Technology.

PG School in International arena: PG School, IARI is actively involved in establishing:

i) Afghan National University of Agricultural Sciences and Technology (ANASTU), Afghanistan and

ii) Advanced Centre for Agricultural Research and Education. Yezin Agricultural University, Myanmar;

The Institute, at present, admits students to the Post Graduate School under five separate streams, namely, (i) open competition, (ii) foreign students, (iii) in-service candidates of SAUs for faculty up-gradation, (iv) departmental students (scientific and technical), and (v) ICAR in-service nominees. Since the year 2000, M.Sc. entrance test is conducted by ICAR. Entrance test for Ph.D., however, is conducted by IARI. Approximately, 30 foreign students are admitted to the M.Sc. and Ph.D. degree courses.

During the period of 2009-16, 1152 M.Sc., 57 M.Tech. and 1373 Ph.D. students (including 155 foreign students) were admitted to the P.G. School.

**d. Training**

In addition to the regular M.Sc. and Ph.D. programmes, the Institute also organizes short-term training courses and refresher courses in specialized areas for the teachers and scientists of SAUs, NARS and other countries. During the period of review, the Institute organized ??training programmes in which ??scientific staff from SAUs/ Institutes updated their skills in the various fields of agricultural research.

**e. Miscellaneous**

During 2009-2016, 40 faculty members were awarded the Best Teacher Awards for their untiring efforts in improving the teaching in different subjects. Several awards like Rao Bahadur Dr. B.Viswanath award, Dr. A.B.Joshi award, Hooker Award, Dr. B.P. Pal Memorial Award, Hari Kishan Shastri Memorial Award, Sukumar Basu Memorial Award are given by the Institute to promote excellence in agricultural research in the country. During the period under report, the IARI instituted Dr. A.B.Joshi for giving recognition to agricultural scientists for outstanding research and education. These awards are open to all the scientists of the country.

Faculty members of the Institute have been honoured with various awards like Om Prakash Bhasin Award, VASVIK Award, Rafi Ahmed Kidwai Award and Hari Om Ashram Award.

**f. Student Development**

Spacious playgrounds are provided, and necessary facilities exist for outdoor games like cricket, hockey, football, volley ball, basketball, badminton and tennis, besides various athletic events. Well-equipped Gymnasia are available for physical development of the students and staff. The students of the Institute also regularly participate in various literary, cultural and sports competitions organized by the Institute, ICAR, and by other Universities/Institutions in India. A Student Counseling Centre operates to provide regular guidance and support to the needed. IARI Alumni Association serves as an effective bridge between the past and the present students and faculty members. Air – conditioned reading rooms and internet facilities have been provided in the hostels.

The unemployed graduates are less than about 2% in M.Sc. and 4% in Ph.D. The placement pattern of outgoing M.Sc. students in recent years is as follows: agricultural universities and research organizations (2%), Agricultural Research Service (20%), Union Public Service Commission (5%), contractual JRF/SRF (3%), and enrollment for Ph.D. program (70%).

# Publications, Recognitions, Awards and Patents

**Table 17: Awards and Scientific Research publications**

| Year | Awards received by the scientists | Institute | Publications | |
|---|---|---|---|---|
| | | | Research publications | Symposia/ Conference paper |
| 2009-10 | 30 | 2 | 563 | 669 |
| 2010-11 | 33 | - | 632 | 471 |
| 2011-12 | 31 | 3 | 636 | 609 |
| 2012-13 | 18 | 2 | 822 | 484 |
| 2013-14 | 15 | 2 | 545 | 360 |
| 2014-15 | 29 | 1 | 529 | 439 |
| 2015-16 | 07 | 2 | 621 | 493 |
| Total | 163 | 12 | 4348 | 3525 |

A number of publications that came out in National and International journals in different disciplines and papers presented in symposia and conferences are given in Table above. A total of 4348 publications in National and International journals with a NAAS rating > 6 have been published.

The scientists of the Institute have been awarded for their significant contributions in the field of research, teaching and extension work. These include-Rafi Ahmed Kidwai Award, Hari Krishan Shastri Awrad, Ramnath Singh Award, Outsatanding Teacher Award, Outstanding Women Scienst Award, Gram Sanskriti Agri-Technology Award, Dr. R.T. Doshi Award, Jawarharlal Nehru Award, NAAS Award, etc.

From 2009-2017, IARI has filed 34 Patent applications and among them 17 patents has been granted. Four copyright applications were filed and all are registered/granted during the period. Additionally, 17 Trademark applications have been filed and 2 have been registered during the period. 53 Plant Variety applications have been filed and 26 have been registered from 2009-17. ZTM & BPD Unit has organized more than 40 ITMC meetings to evaluate research outcomes, management of IPR portfolios, make decisions on inventions that need to be protected by patents and to formulate the terms and conditions of offers for commercialization of IPR enabled as well as know-how based IARI technologies from 2009-2017.

**Table 18: Details of patents filed**

| S. No. | Title | Date of Patent Application Provisional/Complete |
|---|---|---|
| 1 | Development of SCAR Marker for identification of Chaetomium Globosum-A potential biocontrol agent | 25.3.09 |
| 2 | Invention of Mohan's Infective Juvenile Isolator (MIJI) for isolating infective juveniles of entomopathogenic nematodes from infected insect cadavers | 25.03.09 |
| 3 | A novel formulation of Plant Growth promoting Rhizobacteria with enhanced shelf-life and the method of its preparation | 18.8.09 |
| 4 | Novel naphthyridine based hydrazines as potent agrochemicals | 13.12.2010 |
| 5 | Liquid Bioinoculant of Azotobacter chroococcum and the process thereof | 25.02.2011 |
| 6 | Samfungin: A novel fungicide and the process for making the same | 7.06.2011 |
| 7 | Novel Superabsorbent hydrogel/s and the method of obtaining the same | 29.06.2011 |
| 8 | Development of substituted alkene as a potential nematicide | 21.07.2011 |
| 9 | Nanoencapsulated Hexaconazole: A novel fungicide and the process for making the same | 21.07.2011 |
| 10 | Pigeonpea Pod Stripper | 21.07.2011 |
| 11 | Digital Soil Test Fertilizer Recommendation (STFR) Meter | 24.08.2011 |
| 12 | Development of slow release nano formulations of bioactive molecules and method of preparation thereof | 31.01.2012 |
| 13 | A product and process for the decontamination of pesticide residues from vegetables by using safe reagent | 31.01.2012 |
| 14 | Production of cocktail polyclonal antibodies for broad spectrum ELISA based diagnosis of potyviruses and cucumoviruses using fusion construct derived from coat protein gene sequences from Papaya ringspot and Cucumber mosaic virus | 15.02.2012 |
| 15 | Nanocopper"-a copper based formulation to combat bacterial blight of pomegranate, rice and bean | 15.02.2012 |
| 16 | Heat Stable Anthocyanin Rich Composition and process of its preparation | 8.10.2012 |
| 17 | Anti-oxidant and anti-bacterial di-aryl-indazol-3-ols and their method of preparation thereof | 6.12.2012 |
| 18 | Development of polymeric formulations of bioactive molecules and method of preparation thereof | 6.12.2012 |

| | | |
|---|---|---|
| 19 | Amphiphilic polymers based slow release nano formulations of β-carotene and method of preparation thereof | 6.12.2012 |
| 20 | A cross flow flexible membrane filtration assembly for small processing volume | 7.12.2012 |
| 21 | Carotenoid rich composition and process of its preparation | 26/03/2013 |
| 22 | Pusa Basmati Rice Thresher | 19-06-2013 |
| 23 | Insecticidal Formulation of Novel Strain of Bacillus thuringensis AK 47 | 20-Aug-14 |
| 24 | Rapid Detection of Large Cardamom Chrike Virus | 20-Aug-14 |
| 25 | Process for Obtaining High Purity Phycocyanin from Cyanobacteria | 29-Dec-14 |
| 26 | Nanofabrication process involving clay minerals as receptacles for manufacturing advanced nanomaterials including novel fertilizers | 4/2/2014 PCT filed on April 1, 2015 |
| 27 | Nanofabrication of phosphorus on kaolin mineral receptacles | 4/7/2014 PCT filed on April 2, 2015 |
| 28 | Beneficiation of Phosphate Rock for the segregation of phosphorus containing heavy metal free minerals | 16-04-2014 PCT filed on April 2, 2015 |
| 29 | Device For Recommending A Crop Yield Enhancer | Complete along with request of examination |
| 30 | Plant transformation vector for suppressing MIPS gene expression and method for culturing low phytate soybean | 05 -08-2016 |
| 31 | The Microbial Consortium | 23-10-15 |
| 32 | Digital Soil Test and Fertilizer Recommendation (STFR) Meter | 30-05-2016 |
| 33 | A method for the control of Nemotodes in plants | 14-Dec-12 |
| 34 | A method for the control of Nemotodes in plants | 14-12- 2012 |

**Collaborations:**

- The local ICAR institutes are inbuilt in the project programmes. Collaborations with NBPGR, DMR/IIMR, IASRI and NRCPB apart from inter divisional collaborations have been strengthened.
- National Institutes and Agricultural Universities *viz.*, CIAE, Bhopal, DRMR, Bharatpur, PAU, Ludhiana, CCS HAU, Hisar, CSSRI, Karnal, Delhi University South Campus, ICAR NEH RC, Barapani are part of collaborations.
- Strong collaborations exist in the form of extra mural projects with NIPGR, JNU, DU, BARC, Jadavpur University, Kolkata, and various crop based institutes in all the mandate crops *viz.*, DWR (Karnal), DRR (Hyderabad), CRRI (Cuttack), DSR (Hyderabad), AICRP-PM (Jodhpur), DMR (New Delhi), VPKAS (Almora), IIPR (Kanpur), DMR (Bharatpur)

and CICR (Nagpur). Also strong collaborations exist between various SAU working in various crops with respect to collaborative researches.

- Collaboration exists with various international institutions *viz.*,CIMMYT, GCP, IRRI, ICRISAT, ICARDA and AVRDC
- Extension and development agencies *viz.,* Farmers NGO, Farmers Associations, Agriwatch, DAC, VARDAAN, AGRI Watch and SKF are in active collaboration with IARI.
- Stable and good performance of the material with addition of quality traits has attracted the private seed companies, and five large seed producing companies have come forward to have Memorandum of Understanding (MOU) for seed production of six mustard varieties of IARI. MoU for HD 3086 has also been signed with 100 private companies.
- Collaboration for NEH region: Due to wider adaptability and higher yields all the short duration varieties made their impact in all seven NEH states. More than 5.0 quintals seed of Pusa Mustard 25, Pusa Mustard 26, Pusa Mustard 27 and Pusa Mustard 28, all short duration varieties demonstrated in NEH states during 2013-14, was retained by ICAR Research Complex for NEH Region, its Regional Centres and KVKs. Encouraged with the last year's performance of these varieties, additional 20 quintals seed of above four varieties was supplied to ICAR Research Complex for NEH Region, Umiam and 8 quintals of Pusa Mustard 25 to CAU, Imphal during 2014-15, which has been distributed to all the seven NEH states through the research and extension network for popularization and need based seed production.

**Research – Extension linkages:**

- All the project scientists, technical and supporting staff actively participated in different activities during conductance of Pusa Krishi Vigyan Mela.
- Lectures were delivered in various farmers' trainings organized by CATAT. Hundreds of queries related to crops coming through CATAT or directly from farmers were attended in person or through telephone.
- Doordarshan programmes were shot for telecast at DD national channel for the Krishi Darshan.
- Scientists interacted with Print and Media personnel during Pusa Krishi Vigyan Mela.
- During Pusa Krishi Vigyan Mela, farmers have been informed with newly released varieties and package of practices
- Field days for rice, pearlmillet and Brassica were organized
- With a view to accelerate progress in scientific research and take breeding materials from lab to land, collaborative breeding programme was initiated between ICAR-Indian Institute of Agricultural Research (IARI) and Sipani Krishi Anusandhan Farm (SKAF), Mandsour, MP through signing an MoU. After which, large number of breeding lines of wheat, maize, pigeonpea and soybean have been exchanged and tested at both the locations.

- During the crop season various distinguished visitors *viz.,* Dr. M.S. Swaminathan, RajyaSabha MP; Dr. S. Ayappan, DG, ICAR and Secretary, DARE; Agriculture Minister and Director Agriculture of Sikkim along with their team; Dr. S.K. Datta, DDG (Crop Sciences); ICAR, Dr. Arvind Kumar, DDG (Education), ICAR; Dr. J.S. Sandhu, ADG (Seeds), ICAR; Dr. B.B. Singh ADG (OP), ICAR; Dr. A.K. Dhama, Vice Chancellor, RAU, Bikaner; PadamShri Dr. V.P. Singh, Ex-Rice Breeder, visited the crop breeding programm

**Resource Generation**

**Externally Funded Projects**

Being leaders in all areas of agricultural science, the institute has strong linkages with many international and national institutes. To cite a few, the institute has strong linkage with CGIAR's international agricultural research centre's such as CIMMYT,ICRISAT, IFPRI,IRRI, ICARDA, CABI and many more. Few other international organizations with which IARI has strong linkages are FAO, WMO, UNDP, UNEP etc. During the period under report a number of externally funded projects have been sponsored by various agencies which have been given in the table here under.

**Table 19: Number of Externally funded projects operated at the Institute**

| Sponsoring Agency | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 |
|---|---|---|---|---|---|---|---|
| DST\DBT | 95 | 108 | 110 | 107 | 112 | 118 | 122 |
| ICAR | 26 | 24 | 25 | 21 | 18 | 19 | 47 |
| NFBSRA | 4 | 4 | 3 | - | - | - | - |
| NASF | - | 3 | 4 | 13 | 23 | 23 | 24 |
| NAIP | 17 | 18 | 18 | 18 | 18 | 2 | - |
| Foreign aided | 5 | 5 | 8 | 7 | 8 | 10 | 9 |
| Grand Total | 147 | 162 | 168 | 166 | 179 | 172 | 202 |

**Table 20 : Revenue generation @ ZTM (IN INR)**

| Year | Revenue in INR |
|---|---|
| 2009-10 | 478000/- |
| 2010-11 | 4095557/- |
| 2011-12 | 29621821/- |
| 2012-13 | 17249420/- |
| 2013-14 | 29275901/- |
| 2014-15 | 16444000/- |
| 2015-16 | 12608850/- |
| Total | 109773549/- |

**ATIC centre of IARI generates income by sale of Pusa seed and publications. The details are given in Table 11.**

**Table 21: Resource Generation by Agricultural Technology Information Centre**

| Sr. No. | Year | Sale of Pusa Seed (Rs.) | Sale of Publication (Rs.) | Total Resource generated (Rs.) |
|---|---|---|---|---|
| 1. | 2009-10 | 11,19,011/- | 28770/- | 11,47,781/- |
| 2. | 2010-11 | 1414034/- | 50805/- | 14,64,839/- |
| 3. | 2011-12 | 15,37,232/- | 95,435/- | 16,32,667/- |
| 4. | 2012-13 | 22,81,864/- | 65,345/- | 23,44,209/- |
| 5. | 2013-14 | 22,76,285/- | 2,63,620/- | 25, 39,905/- |
| 6. | 2014-15 | 4651388/- | 419660/- | 5071048/- |
| 7. | 2015-16 | 7324980/- | 198840/- | 7523820/- |

Chapter 7

# Financial Achievements

The budget grants of each financial year from 2009-2016 is given in the table below. During 2009-2011 the XI plan was under consideration and from 2012-2016 XII plan was being taken into account. Hence, during the period from 2009-2016, both XI and XII plans were being followed for all financial matters of the institute. In both these plans the format for allotment and expenditure were different. Hence different tables are given hereunder for the period from 2008-2016 under plans XI and XII. The XI plan followed the old format and the XII plan followed the new format for allotment and expenditure.

**Table 22: Consolidated Statement of *Budget Grants* during 2009-2016 ( in lakhs)**

| | Head of Account | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Non Plan | 15847.08 | 16131.14 | 16806.70 | 18665.78 | 20127.75 | 21096.18 | 23346.65 | 27476.00 |
| 2 | Plan | 2273.00 | 4778.39 | 3873.98 | 4000.00 | 2389.50 | 1901.28 | 2387.00 | 2077.00 |
| 3 | Pension | 9154.91 | 9000.00 | 9000.00 | 9000.00 | 9650.00 | 11200.00 | 14400.00 | 11985.00 |
| 4 | Loans & Advances | 10.56 | 10.50 | 16.00 | 16.00 | 61.00 | 60.00 | 60.00 | 65.00 |
| 5 | Non Plan Schemes (Summer Institute, Ntional Fellow, ICAR Fellowships, National Professor, Professor of Eminence etc.) | 232.79 | 285.05 | 448.91 | 247.79 | 271.83 | 131.00 | 309.84 | 443.39 |
| 6 | Plan Schemes (AICRP, Emeritus Scientist, Hybrid Seed, KVK, Best Teacher Award, Stgrengthening of PG Education, World Bank Schemes, etc.) | 5771.07 | 6043.94 | 5852.76 | 6301.07 | 9433.10 | 5717.34 | 7319.21 | 6880.58 |
| 7 | A.P.Cess Fund | 6.18 | 4.35 | 1.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | R-Deposit Scheme | 1236.34 | 2548.02 | 2112.49 | 2571.93 | 3143.16 | 3016.91 | 2018.05 | 5099.64 |
| 9 | Revolving Fund Scheme | 571.53 | 487.66 | 565.38 | 743.00 | 817.65 | 749.91 | 607.82 | 1147.19 |
| 10 | Other Heads | | | | | | | | |
| | **Total** | **35103.46** | **39289.05** | **38677.35** | **41545.57** | **45893.99** | **43872.62** | **50448.57** | **55173.80** |

**The allocation of funds under Non plan for 2008 to 2016-17 is shown in Table 23a and 23b.**

**Table 23 a: Statement showing Allocation under NON PLAN from 2008-09 to 2011-12 in Lakhs**

| sub head | 2008-09 | 2009-10 | 2010-11 | 2011-12 |
|---|---|---|---|---|
| Estt.Charges | 9975.00 | 13240.00 | 11375.00 | 11849.29 |
| OTA | 4.00 | 3.87 | 3.64 | 4.00 |
| TA | 25.00 | 22.68 | 26.00 | 29.00 |
| Other charges including Equipment | 1644.14 | 2054.72 | 2955.52 | 3660.64 |
| Works | 713.00 | 805.50 | 1429.18 | 1564.33 |
| Other items | 330.00 | 308.80 | 265.00 | 160.00 |
| Total | 12691.14 | 16435.57 | 16054.34 | 17267.26 |

**Table 23 b: Staement showing Allocation under NON-PLAN from 2012-2017 in Lakhs**

| Sl.No. | Name of the Head | Allocation 2012-13 | Allocation 2013-14 | Allocation 2014-15 | Allocation 2015-16 | Allocation 2016-17 |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Grants for creation of Capital Assets (CAPITAL) | | | | | | |
| 1 | Works | | | | | |
| | (A)Land | | | | | |
| | (B)Building | | | | | |
| | i. Office building | | | 32.96 | | 300.00 |
| | ii. Residential building | | | | | |
| | iii. Minors Works | | | | | |
| 2 | Equipments | 315.00 | 95.37 | 49.41 | 80.00 | 69.00 |
| 3 | Information & Technology | | 50.60 | 8.41 | | |
| 4 | Library Books & Journal | 4.00 | 5.00 | 4.95 | 15.00 | 17.00 |
| 5 | Vehicles & Vessels | | 63.57 | 17.33 | | |
| 6 | Livestock | | | | | 1.50 |
| 7 | Furniture & Fixtures | 81.00 | 23.23 | 20.02 | 50.00 | 35.00 |
| 8 | Others | | 7.23 | | | |
| A | Total- CAPITAL (Grants for creation of Capital Assets) | 400.00 | 245.00 | 133.08 | 145.00 | 422.50 |
| | Grants in Aid-Salaries (REVENUE) | | | | | |
| 1 | Establishment Expenses | | | | | |

| Sl.No. | Name of the Head | Allocation 2012-13 | Allocation 2013-14 | Allocation 2014-15 | Allocation 2015-16 | Allocation 2016-17 |
|---|---|---|---|---|---|---|
| | (A)Salary | | | | | |
| | i. Establishment charges | 12775.00 | 13903.00 | 14997.62 | 16022.65 | 16530.00 |
| | ii. Wages | | | | | |
| | iii. Overtime allowance | 4.00 | 4.00 | 4.00 | 2.50 | 2.50 |
| | Total-Establishment Expenses(Grants in Aid-Salaries) | 12779.00 | 13907.00 | 15001.62 | 16025.15 | 16532.50 |
| | Grants in Aid-General (REVENUE) | | | | | |
| 1 | Pension & Other Retirement Benefits | 9000.00 | 9650.00 | 11200.00 | 14400.00 | 11985.00 |
| 2 | Traveling Allowance | | | | | |
| | A. Domestic/Transfer T.A. | 35.00 | 38.00 | 43.00 | 45.00 | 50.00 |
| | B. Foreign T.A | | | | | |
| | Total-Traveling Allowance | 35.00 | 38.00 | 43.00 | 45.00 | 50.00 |
| 3 | Research & Opeational Expenses | | | | | |
| | A. Research Expenses | 230.00 | 220.00 | 255.00 | 264.50 | 350.00 |
| | B. Operational Expenses | 195.00 | 290.00 | 320.00 | 380.50 | 350.00 |
| | Total.Res. & Operational Exp. | 425.00 | 510.00 | 575.00 | 645.00 | 700.00 |
| 4 | Administrative Expenses | | | | | |
| | A Infrastructure | 1675.00 | 1800.00 | 2085.00 | 2000.00 | 5775.00 |
| | B Communication | 37.00 | 43.38 | 47.00 | 36.00 | 60.00 |
| | C Repair & Maintenance | | | | | |
| | i. Equipments, Vehicles & Others | 200.00 | 167.16 | 209.00 | 170.50 | 200.00 |
| | ii. Office building | 1226.10 | 1272.38 | 844.00 | 1217.00 | 900.00 |
| | iii. Residential building | 457.45 | 506.67 | 478.25 | 741.00 | 500.00 |
| | iv. Minor Works | 248.90 | 276.85 | 261.00 | 241.05 | 500.00 |
| | D Others (exc.TA) | 702.55 | 843.56 | 821.65 | 1254.45 | 1000.00 |
| | Total-Administrative Expenses | 4547.00 | 4910.00 | 4745.90 | 5660.00 | 8935.00 |

| Sl.No. | Name of the Head | Allocation 2012-13 | Allocation 2013-14 | Allocation 2014-15 | Allocation 2015-16 | Allocation 2016-17 |
|---|---|---|---|---|---|---|
| 5 | Miscellaneous Expenses | | | | | |
| | A HRD | 2.00 | 2.55 | 6.00 | 6.50 | 6.00 |
| | B Other Items(fellow-ships) | 173.42 | 250.00 | 341.58 | 490.00 | 500.00 |
| | C Publicity & Exhibi-tions | 6.60 | 22.85 | 20.00 | 10.00 | 5.00 |
| | D Guest House-Main-tenance | 53.40 | 43.00 | 50.00 | 52.00 | 75.00 |
| | E Other Miscellaneous. | 244.36 | 199.35 | 180.00 | 268.00 | 250.00 |
| | Total -Miscellaneous Expenses | 479.78 | 517.75 | 597.58 | 826.50 | 836.00 |
| | Total Grants in Aid-General | 14486.78 | 15625.75 | 17161.48 | 21576.50 | 22506.00 |
| B | Total Revenue (Grants in Aid-Salaries + Grants in Aid-General) | 27265.78 | 29532.75 | 32163.10 | 37601.65 | 39038.50 |
| | TOTAL (CAPITAL + REVENUE) | 27665.78 | 29777.75 | 32296.18 | 37746.65 | 39461.00 |
| | (C) Loan & Advances | 16.00 | 61.00 | 60.00 | 60.00 | 65.00 |
| | GRAND TOTAL | 27681.78 | 29838.75 | 32356.18 | 37806.65 | 39526.00 |

**The expenditure statement of NON plan from 2008 -2017 is given in Tables 24a and 24b.**

**Table 24a: Staement showing Expenditure under *NON-PLAN from 2008-2011***

| sub head | 2008-09 | 2009-10 | 2010-11 | 2011-12 |
|---|---|---|---|---|
| Estt.Charges | 9451.88 | 13198.69 | 11374.97 | 11849.30 |
| OTA | 3.98 | 3.80 | 3.64 | 3.60 |
| TA | 25.00 | 22.68 | 25.99 | 28.99 |
| Other charges including Equipment | 1634.06 | 2054.71 | 2975.06 | 3659.18 |
| Works | 709.62 | 805.38 | 1429.15 | 1564.28 |
| Other items | 307.60 | 308.22 | 243.44 | 158.26 |
| **Total** | **12132.14** | **16393.48** | **16052.25** | **17263.61** |

**Table 24b: Statement showing Expenditure under *NON-PLAN from 2012-2017***

| | | | | | | ` in lakhs |
|---|---|---|---|---|---|---|
| Sl. No. | Name of the Head | Expnd. 2012-13 | Expnd. 2013-14 | Expnd. 2014-15 | Expnd. 2015-16 | Expnd. 2016-17 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Grants for creation of Capital Assets (CAPITAL) | | | | | | |
| 1 | Works | | | | | |
| | (A)Land | | | | | |
| | (B)Building | | | | | |
| | i. Office building | | | 32.95 | | 98.58 |
| | ii. Residential building | | | | | |
| | iii. Minors Works | | | | | |
| 2 | Equipments | 283.20 | 95.35 | 49.40 | 69.48 | 62.17 |
| 3 | Information & Technology | 25.45 | 50.59 | 8.41 | 10.13 | 8.88 |
| 4 | Library Books & Journal | 3.85 | 4.89 | 4.87 | 14.27 | 17.01 |
| 5 | Vehicles & Vessels | | 63.57 | 17.33 | | |
| 6 | Livestock | | | | | 1.50 |
| 7 | Furniture & Fixtures | 80.99 | 23.23 | 20.01 | 49.94 | 35.82 |
| 8 | Others | 6.32 | 7.23 | | | |
| A | Total- CAPITAL (Grants for creation of Capital Assets) | 399.81 | 244.86 | 132.97 | 143.82 | 223.96 |
| | Grants in Aid-Salaries (REVENUE) | | | | | |
| 1 | Establishment Expenses | | | | | |
| | (A)Salary | | | | | |
| | i. Establishment charges | 12775.00 | 13898.90 | 14997.62 | 15898.54 | 16519.68 |
| | ii. Wages | | | | | |
| | iii. Overtime allowance | 2.61 | 2.13 | 1.57 | 1.44 | 1.52 |
| | Total-Establishment Expenses(Grants in Aid-Salaries) | 12777.61 | 13901.03 | 14999.19 | 15899.98 | 16521.20 |
| | Grants in Aid-General (REVENUE) | | | | | |
| 1 | Pension & Other Retirement Benefits | 8999.54 | 9649.92 | 11199.92 | 14400.00 | 11518.51 |

| | | | | | | ` in lakhs |
|---|---|---|---|---|---|---|
| **Sl. No.** | **Name of the Head** | **Expnd. 2012-13** | **Expnd. 2013-14** | **Expnd. 2014-15** | **Expnd. 2015-16** | **Expnd. 2016-17** |
| 2 | Traveling Allowance | | | | | |
| | A. Domestic/Transfer T.A. | 32.72 | 35.97 | 43.00 | 43.69 | 49.99 |
| | B. Foreign T.A | 2.28 | 2.03 | 0.00 | 1.02 | |
| | Total-Traveling Allowance | 35.00 | 38.00 | 43.00 | 44.71 | 49.99 |
| 3 | Research & Opeational Expenses | | | | | |
| | A. Research Expenses | 230.00 | 220.00 | 255.00 | 264.50 | 334.22 |
| | B. Operational Expenses | 194.99 | 290.00 | 320.00 | 380.50 | 365.72 |
| | Total.Res. & Operational Exp. | 424.99 | 510.00 | 575.00 | 645.00 | 699.94 |
| 4 | Administrative Expenses | | | | | |
| | A Infrastructure | 1674.98 | 1799.47 | 2085.00 | 2000.00 | 5736.66 |
| | B Communication | 37.00 | 43.38 | 47.00 | 35.81 | 36.10 |
| | C Repair & Maintenance | | | | | |
| | i. Equipments, Vehicles & Others | 200.00 | 167.16 | 209.00 | 170.48 | 137.99 |
| | ii. Office building | 1226.07 | 1272.38 | 843.98 | 1216.91 | 962.86 |
| | iii. Residential building | 457.44 | 506.66 | 478.25 | 740.83 | 577.67 |
| | iv. Minor Works | 248.89 | 276.84 | 261.00 | 241.01 | 407.50 |
| | D Others (exc.TA) | 702.55 | 842.58 | 821.57 | 1250.72 | 1215.76 |
| | Total-Administrative Expenses | 4546.93 | 4908.47 | 4745.80 | 5655.76 | 9074.54 |
| 5 | Miscellaneous Expenses | | | | | |
| | A HRD | 2.00 | 2.53 | 11.49 | 6.45 | 6.05 |
| | B Other Items(fellowships) | 173.36 | 217.74 | 341.56 | 489.95 | 450.00 |
| | C Publicity & Exhibitions | 6.59 | 22.83 | 14.49 | 9.34 | 4.46 |
| | D Guest House-Maintenance | 53.39 | 42.80 | 50.09 | 41.35 | 90.69 |
| | E Other Miscellaneous. | 244.36 | 199.17 | 179.91 | 266.78 | 234.86 |

| | | | | | | ` in lakhs |
|---|---|---|---|---|---|---|
| **Sl. No.** | **Name of the Head** | **Expnd. 2012-13** | **Expnd. 2013-14** | **Expnd. 2014-15** | **Expnd. 2015-16** | **Expnd. 2016-17** |
| | Total -Miscellaneous Expenses | 479.70 | 485.07 | 597.54 | 813.87 | 786.06 |
| | Total Grants in Aid-General | 14486.16 | 15591.46 | 17161.26 | 21559.34 | 22129.04 |
| B | Total Revenue (Grants in Aid-Salaries + Grants in Aid-General) | 27263.77 | 29492.49 | 32160.45 | 37459.32 | 38650.24 |
| | TOTAL (CAPITAL + REVENUE) | 27663.58 | 29737.35 | 32293.42 | 37603.14 | 38874.20 |
| | (C) Loan & Advances | 16.00 | 61.00 | 59.94 | 56.57 | 39.00 |
| | GRAND TOTAL | 27679.58 | 29798.35 | 32353.36 | 37659.71 | 38913.20 |

Expenditure under plan is shown in Table 25a and Table 25b under various heads for the years from 2008 to 2012 under XI plan and 2012 to 2017 under the XII plan.

**Table 25a: Statement showing Expenditure in Lakhs under Plan from 2008-2011**

| **Head** | **2008-09** | **2009-10** | **2010-11** | **2011-12** |
|---|---|---|---|---|
| A. Recurring | | | | |
| Pay & Allowances | - | - | - | - |
| TA | 16.41 | 46.70 | 69.97 | 72.48 |
| Contingencies | 809.83 | 749.97 | 980.00 | 409.89 |
| Total(A) | 826.24 | 796.67 | 1049.97 | 482.37 |
| B. Non Recurring | | | | |
| Equipment | 4.16 | 88.43 | 983.23 | 1308.85 |
| Works | 33.81 | 999.79 | 2020.17 | 1418.93 |
| Library | 124.38 | 175.00 | 200.00 | 155.16 |
| Total(B) | 162.35 | 1263.22 | 3203.40 | 2882.94 |
| Grand Total (A+B) | 988.59 | 2059.89 | 4253.37 | 3365.31 |

**Table 25b: Statement showing Expenditure in Lakhs under Plan from 2012-2017**

| **Sl. No.** | **Name of the Head** | **Expnd. 2012-13** | **Expnd. 2013-14** | **Expnd. 2014-15** | **Expnd. 2015-16** | **Expnd. 2016-17** |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Grants for creation of Capital Assets (CAPITAL) | | | | | |
| 1 | Works | | | | | |

| Sl. No. | Name of the Head | Expnd. 2012-13 | Expnd. 2013-14 | Expnd. 2014-15 | Expnd. 2015-16 | Expnd. 2016-17 |
|---|---|---|---|---|---|---|
| | (A)Land | | | | | |
| | (B)Building | | | | | |
| | i. Office building | 949.62 | | 82.99 | 67.00 | 300.08 |
| | ii. Residential building | | | | | |
| | iii. Minors Works | | | | | |
| 2 | Equipments | 772.33 | 254.92 | 159.57 | 102.70 | 94.42 |
| 3 | Information & Technology | | | 0.09 | 17.30 | 5.47 |
| 4 | Library Books & Journal | 249.82 | 251.40 | 249.98 | 239.99 | |
| 5 | Vehicles & Vessels | | | | | |
| 6 | Livestock | | | | | |
| 7 | Furniture & Fixtures | | | | | |
| 8 | Others | | | | | |
| A | Total- CAPITAL (Grants for creation of Capital Assets) | 1971.77 | 506.32 | 492.63 | 426.99 | 399.97 |
| | Grants in Aid-Salaries (REVENUE) | | | | | |
| 1 | Establishment Expenses | | | | | |
| | (A)Salary | | | | | |
| | i. Establishment charges | | 0.00 | 0.00 | 0.00 | 0.00 |
| | ii. Wages | | | | | |
| | iii. Overtime allowance | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total-Establishment Expenses(Grants in Aid-Salaries) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Grants in Aid-General (REVENUE) | | | | | |
| 1 | Pension & Other Retirement Benefits | | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | Traveling Allowance | | | | | |
| | A. Domestic/Transfer T.A. | 80.40 | 96.82 | 102.00 | 120.90 | 70.00 |
| | B. Foreign T.A | 1.80 | | | | |
| | Total-Traveling Allowance | 82.20 | 96.82 | 102.00 | 120.90 | 70.00 |
| 3 | Research & Opeational Expenses | | | | | |
| | A. Research Expenses | 567.69 | 566.00 | 404.12 | 609.99 | 596.88 |
| | B. Operational Expenses | 227.22 | 331.25 | 400.00 | 541.00 | 342.65 |
| | Total.Res. & Operational Exp. | 794.91 | 897.25 | 804.12 | 1150.99 | 939.53 |
| 4 | Administrative Expenses | | | | | |
| | A Infrastructure | 399.84 | 299.53 | 209.98 | 226.99 | 225.00 |

| Sl. No. | Name of the Head | Expnd. 2012-13 | Expnd. 2013-14 | Expnd. 2014-15 | Expnd. 2015-16 | Expnd. 2016-17 |
|---|---|---|---|---|---|---|
| | B Communication | 4.42 | 0.00 | 0.50 | 3.00 | |
| | C Repair & Maintenance | | | | | |
| | i. Equipments, Vehicles & Others | 146.52 | 159.43 | 100.00 | 167.00 | 99.98 |
| | ii. Office building | 0.00 | 0.00 | 0.00 | 0.00 | |
| | iii. Residential building | 0.00 | 0.00 | 0.00 | 0.00 | |
| | iv. Minor Works | 0.00 | 0.00 | 0.00 | 0.00 | |
| | D Others (exc.TA) | 241.19 | 220.34 | 190.02 | 154.00 | 118.00 |
| | Total-Administrative Expenses | 791.97 | 679.30 | 500.50 | 550.99 | 442.98 |
| 5 | Miscellaneous Expenses | | | | | |
| | A HRD | 10.07 | 1.00 | 2.00 | 35.10 | 59.83 |
| | B Other Items(fellowships) (OBC) | 233.33 | 74.99 | | | |
| | C Publicity & Exhibitions | 0.00 | 0.00 | | | |
| | D Guest House-Maintenance | 0.00 | 0.00 | | | |
| | E Other Miscellaneous. | 62.34 | 65.83 | | | |
| | Total -Miscellaneous Expenses | 305.74 | 141.82 | 2.00 | 35.10 | 59.83 |
| | Total Grants in Aid-General | 1974.82 | 1815.19 | 1408.62 | 1857.98 | 1512.34 |
| B | Total Revenue (Grants in Aid-Salaries + Grants in Aid-General) | 1974.82 | 1815.19 | 1408.62 | 1857.98 | 1512.34 |
| | TOTAL (CAPITAL + REVENUE) | 3946.59 | 2321.51 | 1901.25 | 2284.97 | 1912.31 |
| * | Tribal Sub Plan Expenditure | 19.95 | 5.42 | 0.00 | 102.00 | 148.80 |
| * | NEH Expenditure | 29.95 | 16.35 | 0.00 | 0.00 | 14.98 |
| | GRAND TOTAL | 3996.49 | 2343.28 | 1901.25 | 2386.97 | 2076.09 |

# Recommendations

Based on the review of research, technology development, education and extension activities carried out during the period April 2009 to March 2016 keeping in view the goals of the institute and the needs of the farming community of India, the QRT arrived at a set of recommendations for the Council to consider for implementation.

**1. Research**

It is recommended to focus on issues considering the challenges and limitations faced in Indian agriculture as well as National Agricultural Research System to target its research and technology generation. The following recommendations are made:

a. Strengthen public-public and public-private partnership (PPP) in research, education and extension. The institute needs to explore commercial options to ensure adequate supply, availability of region- and production condition-specific quality seed, seeding materials, protection materials (prophylactic and preventive) and other input resources including eco-friendly, nano and biological resources.

b. Develop crop improvement, production and protection strategies to overcome climate sensitivities and vulnerabilities with high-end basic research for evolution of strategies to manage biotic and abiotic stresses on crops.

c. Strengthen interdisciplinary genomics research with emphasis on horticultural crops, pulses, millets and oilseed crops for their genetic improvement

d. IARI created a Centre for Biotechnology in 1985 to intensify research in using new knowledge in genetic improvement. But, it is noted that IARI does not have any more a dedicated facility to carry out the research related to area of bioinformatics, genomics, genome editing, high-throughput genotyping, genetic engineering etc. as the centre was converted to NRCPB in 1998. There is a need for greater utilization of the resources and their outputs and hence there is a need to integrate the NRCPB with IARI.

e. Technology transfer has to be in integration with innovators to mentor the incubation for Startups /Farmer Producer Organization (FPO)/ Woman or Farmer enterprises/ cooperatives, value chain/processing segments with more emphasis on PPP and capacity building in a consortia/networking mode in linkage with industry for delivery of the technologies to farmer

f. Provision for additional funds for AMC/ CMC of the high value equipment should be made. Upgradation of old items of equipment should be taken up on priority so that the national needs are not left unattended due to want of equipment despite the availability of the know-how and human resource.

### 1.1 Crop Improvement

#### 1.1a. Genetics

A significant achievement is the notification of as many as 51 varieties of wheat, rice, pearl millet, maize, chickpea, lentil, mung bean, soybean and mustard during the period under report. Wheat and mustard varieties by IARI cover more than 40% of the area, which assumes significance when the crops are planted to 30 and 7 million hectares in the country, respectively. In Basmati rice, nearly 85% area is under IARI varieties. In addition, several genes/QTLs for biotic /abiotic stresses, yield and yield components, quality and nutritional traits across crops have been identified and mapped. These achievements need to be sustained and enhanced for the good of Indian agriculture with the following major recommendations:

- To accelerate the breeding cycles, considering the excellent expertise available, it is recommended that an **Accelerated Breeding Centre** (ABC)- a centralized facility including high-throughput genotyping centre, doubled haploid facility, bioinformatics centre, rapid generation advancement facility and transgenic facility should be created**.**
- Several validated new genes need to be fine mapped, functionally validated, dissected and cloned for introgressing through genomics within the crop and transgenic across the crops.
- In order to maintain the active germplasm pool long term seed storage of 20,000 sample capacity is required.
- In view of significant contributions by the Division, it is required to showcase the mega achievements of the excellent research with modern display tools and a museum for the benefit of farmers, students and scientists of the country and abroad.

#### 1.1b. Seed Science and Technology

Division of Seed Science has coordinated with all the regional stations and the main campus for the production of Breeder Seed of crops and vegetables by maintaining high quality brand product "**Pusa**", which is an accepted Gold Standard among the farmers. This commitment requires be furthered and encouraged.

- Large scale seed multiplication and maintenance of the notified and released varieties of field and horticultural crops is an essential activity for dissemination of quality seed to the farmers and seed producer agencies of the country. A large scale seed storage facility (for one year) with temperature and humidity control and processing plants are required to be created.
- To upscale the activities for seed testing and seed biology, state-of-the-art laboratories in the areas of physiology and biochemistry and molecular biology need to be established.

#### 1.1c. Regional Station Indore

During the period, the Regional Station participated in the Wheat Improvement Programme for the objectives related to development of varieties for drought and heat tolerance suited to the Central and Peninsular zones of India and successfully coordinated the wheat improvement trials in both durum and bread wheat and released 2 varieties. The varieties of wheat developed by IARI covered more than 40% of the area in Madhya Pradesh and 32% over central zone. The significance of the outcome has made the regional station a prominent technology backstopper for wheat in the Government of Madhya Pradesh. This role can be further strengthened.

- A large scale seed storage facility with temperature and humidity control and a processing plant are required to be created.
- Physiological parameters are getting increasingly important for wheat improvement strategies to counter abiotic stresses for which one good physiologist has to be located at Indore urgently in addition to one agronomist and another plant breeder
- Introduction of dicoccum wheat for quality wheat production.

**1.1d. Regional Station, Karnal**

The Karnal station functioned practically as the Gateway of IARI wheat and Basmati rice **v**arieties to Punjab and Haryana, in addition to planting material of mango and seeds of mustard, mung bean, cow pea, tomato, bottle gourd, okra. The public-private partnership of production of seed was carried out maintaining a competitive edge over seed company produce with Pusa brand being the most sought after. The station needs to be supported with infrastructure improvement.

- The seed processing equipment is now obsolete and a special onetime grant to replace it with modern higher capacity to be able to process and store 5000 quintals of wheat with sufficient infrastructure and engineering workshop support.
- The horticultural seed materials need protected system for maintenance and multiplication which needs to be created.

**1.1e. Regional Station, Pusa**

Acknowledging its historic importance of being the founding institution for agricultural research on field and horticultural crops and the pivotal role the station can potentially play in augering the technological innovation, demonstration and spread in the eastern plains in synchrony involving multi-disciplinary work, there is an urgent need to refurbish and reinforce this station, with the following recommendations:

- Pusa Bihar station is at the moment in deteriorating conditions**.** No new wheat or pigeonpea varieties have been developed for over two decades and no new project proposal for funding support has been submitted in the recent 5 years.
- It is required to immediately take up appropriate research in wheat, maize, pigeonpea and vegetables pest and diseases specific to the eastern plains.
- For consolidating pigeopea-wheat and pigeonpea-maize system, efforts should be made to introduce 120 days maturity based pigeon pea in kharif followed by wheat or maize in Rabi.

- Extra efforts need to be put in to standardize outreach seed production for TL seed and in-house seed production for breeder seed production of wheat, maize and pigeon pea. Both breeder and TLS of papaya, okra, brinjal, onion, etc., have to be produced to facilitate the regional farmers to enhance their agricultural incomes and cultivation.
- Location of the Central University in the adjoining the campus should be taken as an advantage and the centre should work in a mutually benefitting manner with the University in teaching, research and extension collaboration.

**1.1f. Regional Station Wellington**

Under the Wheat improvement program, the station contributed to release two varieties of wheat in addition to supporting not only the entire country in off-season wheat generation advancement during summer season, it also enabled the multiplication and disease screening of 28,000 germplasm lines of NBPGR to rejuvenate, classify and catalogue the material. Its performance as pre-breeding centre for wheat with alien genome introgression of large number of rust and powdery mildew resistance genes supported by rust race-evolutionary analysis, is acknowledged providing starter materials to the wheat programme and other institutions in the country. In addition, the pulse and oilseed breeding programmes were also benefitted by the off-season generation advancement and disease screening facilitation by the station.

- In order to facilitate the excellent off-season nursery, seed multiplication and full –season rust genetics work, the station needs to be provided with one additional controlled condition glasshouse and two laboratories, one for field based work and another for molecular marker analyses.
- All paraphernalia related to molecular marker analysis other than sequencing systems will be required, along with intense training to two technical staff and one more scientist
- The services of the nematologist who has been posted by the Council cannot be fully utilized without being linked with the programme of Plant Protection School and establishment of a support laboratory for microscopy and nematode culture.

**1.1g. Regional Station Shimla (Wheat & Barley), Tutikandi**

The Tutikandi centre not only carried forward the significant work on genetics of rust resistance, race classification, gene postulation of wheat, but also released two varieties of wheat for northern hills zone. Based on the recommendations of the RAC and QRT, the station also added back the barley improvement work from 2014 onwards. The initiation of work for double haploidy is also acknowledged as a good research of strategic importance in accelerating wheat breeding procedure in India.

- The wheat breeding and geneticist team should be provided with infrastructure for doubled haploidy production including culture room, nethouse and controlled greenhouse for rapid DH production
- A long-term association with the Dhaulakuan station of the HPKVV-Palampur is required for continued screening of yellow rust and powdery mildew infection in wheat,

along with the adoption of a village under extension programme in nearby region for demonstration of new varieties

- Genetic analysis of rusts resistance should be continued along with gene postulation based on seedling screening of all advanced generation materials generated by the wheat programme

### 1.1h. Off-season Rice-Breeding & Genetics Unit, Aduthurai and Pulses and Maize Unit, Dharwad

These centres are integral field and laboratory support for summer and off-season continuum of rice and chickpea breeding activities at the main centre, Delhi. This system should continue with adequate support of infrastructure.

- The irrigation facilities at both Aduthurai and Dharwad have to be fully equipped with microirrigation system to meet the needs of the off-season materials as well as the main season work
- Seed storage systems and equipment required for quality analysis need to be provided.
- There should be no other independent research other than the one to complement the main programmes operating at Headquarter

## 1.2 Basic Sciences

### 1.2a. Plant Physiology

The Division has contributed to our understanding on physiological mechanisms of stress tolerance. Soluble starch synthase (SSS) was identified as highly susceptible enzyme for heat stress in developing wheat grains. Impairment of auxin signalling was found to be a major cause of spikelet sterility under drought and heat stresses in rice. New donors for heat, drought and nitrogen use efficiency were identified in rice; for heat tolerance in wheat and chickpea, nitrogen use efficiency in wheat, phosphorous use efficiency in mungbean. Genes for root traits, salt tolerance and heat tolerance in wheat, water logging tolerance in pulses, nutrient use efficiency in wheat were cloned and characterized. To decipher GxE dynamics and bridge phenotype-genotype gap in crop improvement, a state-of-the art automated plant phenomics facility was established and operationalized.

- Towards identification of germplasm/traits/genes for resource use efficiency and abiotic stress tolerance, the work in automated controlled environment facility needs to be strengthened with establishment of Field phenomics facility including UAV/drone/air-borne phenotyping sensors, metabolite and mineral-nutrient profilers.
- For strengthening and effective use of Plant Phenomics facility, a scientist with specialization in Computer Application (image processing) and two technical officers with engineering background (specialization in mechanical/electrical and computers) are recommended.
- Rhizosphere phenotyping facility to identify donors and genes for better root system architecture for enhancing water and nutrient use efficiency of crop

- Emerging genome editing tools need to be used to identify and validate physiological pathways and processes for resource use efficiency and stress tolerance. For this Genome editing Lab needs to be established.

**1.2b. Biochemistry**

The Division has contributed to the knowledge on quality enhancement and mechanisms of drought tolerance. One of the most significant gains was development of an efficient transformation protocol for soybean transgenics using which soybean with low seed phytate content have been developed. Efficient extraction protocols were developed for extraction of Vit E and anthocyanin from soybean. Transcriptomics and proteomics approaches were employed to identify and clone genes involved in heat tolerance and novel miRNAs in wheat.

- Transformation and genome editing facilities for development of soybean lines with low phytate and higher isoflavons.

- Biochemical metabolite analysis lab: Equipped for metabolic profiling, UPLC, GCMS, ChemiDoc gel imaging system, plate reader etc.

**1.3 Plant Protection**

**1.3a. Agricultural Chemicals**

Improved hydrogels with water absorption capacity in the range 800-1500 g/g coupled with reduced cost developed employing clays and agri residue exhibited superior performance under rainfed and limited irrigation treatments with yield enhancement ranging from 17-37% in various crops.

- A Pilot Reactor for bulk hydrogel/chemical synthesis and for prior art search on novel molecules, a Scifinder facility are needed

- Support for pesticide testing laboratory (NABL accredited) up gradation and scope enhancement from the current 9 pesticides to more than 150 with corresponding infrastructure, so as to utilize the same for high-end research on design and development of bioactive molecules, formulations (characterization and analysis).

**1.3b. Nematology**

Sequencing and analysis of whole genome of two key plant parasitic nematodes and transcriptome of six nematodes accomplished along with development of *in silico* resource databases (HAT-DB and MGT-DB) for public access at IARI website. Approach of RNA interference in *Meloidogyne incognita* has established the potential of 15 genes for its management in brinjal, tomato and tobacco and demonstrated interaction between effector genes and other cell wall-degrading enzymes during parasitism of *M. incognita. Galleria mellonella* cadavers infected with entomopathogenic nematode, *Heterorhabditis indica* has been demonstrated for successful management of white grubs in sugarcane in western UP. The good work needs to be furthered.

- Microscopy facilities need to be strengthened with better equipped microscopes and the scanning electron microscope is needed with cryostat for quick and efficient sample preparation for better results.

- Genes which have been identified for developing resistance to nematodes in crops, should be utilised for developing varieties resistant particularly to *M. incognita*.

**1.3c. Plant Pathology**

Through pathogen race profiling and genetic diversity analyses, diagnostic markers have been developed for different pathogens (*Bipolaris sorokiniana*, *B. oryzae*, *Fusarium fijikuroi*, *Puccinia striiformis tritici, F. oxysporum* f. sp. *ciceris,R. solani, Ralstonia solanacearum, Xanthomonascampestris*pv*campestris* and *X. oryzae*pv*oryzae*, Large cardamom chirke virus (LCCV); Peanut mottle virus (PeMoV); Bean common mosaic virus (BCMV); Garlic common latent virus; Lettuce mosaic virus (LMV); Banana streak MY virus (BSMYV); Rice tungro spherical virus (RTSV); Cardamom bushy dwarf virus and Grapevine leafroll associated virus -3).DNA chip for detection of viruses and viroids has been developed. Good progress has been made in whole genome sequencing of major fungal, bacterial and viral pathogens .

- The whole genome sequencing research should be strengthened for determining diversity in major pathogens.
- The wilt problem of guava needs to be addressed on priority.
- Some facilities and activities which are to be supported are listed :
    - o Climate Chambers and BSL III facilities: The Division needs Climate Chambers to conduct research on rust, blast, mildews, blight, spots and wilt for working throughout the year. BSL III level plant growth facilities are required to conduct research on threatening plant pathogens and exotic diseases.
    - o Create bioinformatics facilities

**1.3d. Regional station, Pune**

Papaya germplasm of Pune Selections (PS-1,2,3& 5), their crosses and few commercial cultivars have been evaluated against *Papaya ringspot virus*(PRSV). Survey and surveillance for viral diseases infecting a number of vegetables and papaya are eing studied for virus transmission. The disease occurrence, distribution and incidence were recorded in many of these crops. Molecular characterization of whitefly transmitted *Geminivirus* was carried out using Rolling Circle Amplification to amplify the full genome. New phytoplasma disease in bottle gourd was reported for the first timefrom India Papaya phytoplasma was reported for the first time from India (GenBank Acc. No. JQ346525). A protocol for papaya tissue culture using immature embryos as explants material has been optimized.

- The station should develop system for providing virus free planting materials for clonally propagated plants like banana and citrus.
- The work on epidemiology of viruses affecting papaya and vegetables should be taken up.
- The greenhouses should be refurbished.

**1.3e. Regional station, Kalimpong**

Survey, collection and maintenance of virus of citrus, large cardamom and identification of disease free pockets and study the distribution viral diseases of citrus and large cardamom has led to preparation of map on distribution of CTV of citrus and chirke and foorkey of large cardamom in Darjeeling and Sikkim.

- Need to emphasize on diseases and pest management, Integrated nutrient management of major crops of the area and other indigenous fruit and flower crops
- There is a requirement of Staff quarters of Type IV and Type II and this should be protected by RCC boundary wall.
- The greenhouses should be refurbished.
- The station should develop system for providing virus free planting materials for clonally propagated plants like large cardamom and citrus.
- The work on epidemiology of viruses affecting large cardamom, mandarin and vegetables should be taken up

**1.3f. Entomology**

A total of 26,241 insect specimens were identified, 815 species of insects were augmented. Division has developed forecasting models for Brown plant hopper and fruit fly. The recommended facilities in the discipline are.

- The laboratory which was destroyed by fire four years ago needs to be refurbished.
- Field level insect screening facility of fine net and rearing system at field environment needs to be created for epidemiological investigations
- Facility for intensifying IPM

**1.4 Social Sciences**

**1.4a. Agricultural Extension**

An innovative IARI Post Office Linkage Extension Model was validated in five locations. This model has connected 130 post offices in 56 districts of 13 states. The model has been found as an effective and successful means for making improved agricultural technologies available in the rural areas in relatively lesser time and cost. A cyber extension model was developed and two cyber extension Centres were established. Mobile based advisory services were analyzed in partnership with CABI under Direct 2 Farm project. Strengthening agri-nutri linkages for enhancing nutritional security and gender empowerment, food consumption pattern and nutritional status in ten districts across ten states of India were studied. Identification and prioritisation of IARI technologies for agrienterprise ventures uptake in a participatory mode were conducted in the selected project villages. Training Modules for skill improvement among SHG women, selected on the basis of Training Needs Assessment of women SHGs members, were tested and validated in the areas critical for sustainability of SHGs.

- Should develop pathways of innovations and evolve strategies for up-scaling promising varieties/technologies and processes. Understanding behaviour (or decision making process) of the farmers and stakeholders in acceptance and rejection of improved varieties/technologies is critical. Therefore, some basic research on better understanding of behavioural changes needs to be undertaken by the researchers in the division.
- Both Economics and Extension division should intensify work on impact analysis of IARI technologies in the country.
- Mobile training vans with multimedia facilities are needed for effective transfer of technology and capacity building of farmers at their doorstep to enhance adoption of improved technology and enhance income.
- Should undertake data collection through Computer Aided Personal Interview (CAPI). This will help researcher to monitor data collection on a real time basis. It will also help to quickly analyse the data. Scientists and technical staff may be given training of using CAPI for data collection.
- Special norms for TA and hiring skilled enumerators for data collection may be made for undertaking pan India surveys for research studies.
- Modernization of Audio-Visual Laboratory.

**1.4b. Agricultural Economics**

- Regular research studies on returns to research investment needs to be taken up. It should develop a mega program on adoption and impact of improved varieties/ technologies in partnership with different division, especially genetics, agronomy, horticulture, extension.
- Should undertake studies on barriers (institutional and policy) in scaling up promising varieties and technologies.
- Scientists should be given training on advances on policy tools, econometric analysis and models for policy analysis.
- It should establish a Marketing Intelligence and Forecasting Cell (Artificial intelligence cell) with (Computers and accessories) to regularly monitor prices of essential food commodities at farm and retail level to provide information to the government for taking informed decision well in advance.
- Empirical work is to be undertaken on emerging and promising regional and bilateral trade of agricultural commodities in view of government's commitments at international levels and treaties.
- Should undertake data collection through Computer Aided Personal Interview (CAPI). This will help researcher to monitor data collection on a real time basis. It will also help to quickly analyse the data. Scientists and technical staff may be given training of using CAPI for data collection.

- Special norms for TA and hiring skilled enumerators for data collection may be made for undertaking pan India surveys for research studies.

**1.4c. Centre for Agricultural Technology Assessment and Transfer (CATAT)**

It is a multidisciplinary Centre with focus on Institute's technology assessment and transfer. This is undertaken in partnership with 17 ICAR institutes/SAUs and 28 Voluntary organisations for faster diffusion of IARI varieties and production technologies. It is being implemented in 15 states of the country. CATAT's role has been in developing indicators of 'Model Villages' which is of national importance. Every year, three days National level Krishi Vigyan Mela is organised on a theme of current importance. Kisan Mall, a market platform for progressive farmers is also run by CATAT. A new Kisan Haat is also coming up at outskirts of the Institute under CATAT. Mera Gaon Mera Gaurav (MGMG) a flagship programme is being implemented in 120 village clusters comprising of 600 villages covering 17 districts of 4 states.

- Developing model villages for demonstrating doubling farmers income needs to be taken up by CATAT.
- An e platform for MGMG programme needs to be developed by CATAT.
- For these activities a Exhibition van equipped with multimedia and projection facilities is required

**1.4d. Zonal Technology Management and Business Promotion & Development Unit**

It's an agri-business incubator facilitating the IP protection of ICAR-IARI innovations through filing patents trademarks, copyrights, applications and supports them from protection to technology commercialization. During this period, the unit has filed 42 Patent applications and among them 17 patents has been granted. Four copyright applications were filed and all are registered/granted during the period. Additionally, 17 Trademark applications have been filed and 2 have been registered during the period. 53 Plant Variety applications have been filed and 26 have been registered from 2009-17. ZTM & BPD Unit has organized more than 40 ITMC meetings to evaluate research outcomes, management of IPR portfolios, make decisions on inventions that need to be protected by patents and to formulate the terms and conditions of offers for commercialization of IPR enabled as well as know-how based IARI technologies. To strengthen the above work, the following are required.

- There is a need to decentralize the Council's power at institute level for decisions on PCT/National phase application filing for patents, collaboration with other marketing agencies, institute situated outside etc.
- Dedicated administrative support for quick decision facilitation is most desired in any public-private dealing on business development that benefits the innovators of the institute and consumer farmers
- Valuation of technologies is a huge challenge as it depends upon a number of production and marketing related factors other than utility of the innovation. ZTM should collaborate with other business schools to develop agri-innovation specific tools for valuation processing

- In view of the eNAM commissioned by the Government of India, adoption and use of ICT tools are going to be key to its success in technology commercialization which needs to be facilitated with virtual marketing options in place.
- Farmer enterprises, whether in the form of FPO, cooperatives or startups, have to be recognized/ hand held/ supported in a very systemic way to address the requirements such as value chain development and promoting the processing part.

**1.5 Natural Resource Management**

**1.5a. Soil Science & Agricultural Chemistry**

Soil organic carbon dynamics and nutrient transformations under conservation agriculture (CA) need to be studied in detail, so as to develop nutrient management protocols for different CA-based cropping systems. The impact of Pusa STFR meter in improving soil health and nutrient use efficiency has to be assessed. The research on development of novel fertilizer products should be intensified to enhance nutrient use efficiency. Protocols for neem oil coating of urea have to be evaluated in order to rationalize the specifications for neem coating. In-depth research on risk assessment and remediation of metal polluted soils should be carried out.

In order to undertake the basic and applied research as recommended, the laboratory facilities have to be strengthened as follows:

- X-Ray Diffractrometer (XRD
- Atomic Absorption Spectrophotometer (AAS)
- Microwave digestion system:
- Nitrogen analysis facility including digestion & distillation systems:

**1.5b. Microbiology**

Microbial liquid formulations of N, P, K, and Zn biofertilizers, Pusa Compost Biofertilizer, Soil-based arbuscular mycorrhizae (AM) biofertilizer and BGA Biofertilizer have been developed, and the technology for mass production has been developed and commercialized.

- Strengthen and focus research in the areas of microbial ecology of soils, metagenomics, microbial genetics/genomics and proteomics under abiotic stresses for nutrient management of the soils
- Scaling up production of Biofertilizers and bioethanol using bioreactor based technologies by setting up a pilot plant and at least 3 bioreactors of 50L capacity.

**1.5c. Agricultural Physics**

A web-enabled decision support system (DSS) was developed for real time crop growth monitoring at district level using multi-temporal satellite remote sensing data received at IARI satellite ground station. The DSS was hosted on public website http://creams.iari.res.in.The potential of thermal imaging as a non-destructive, rapid, less-erroneous technique was established for estimating traits like canopy temperature, NDVI, LAI, ground cover. Etc.

- Explore the potential of drone remote sensing for soil and crop environment parameters. Work should be initiated on sensor based image processing techniques
- Satellite data based products should be developed for crop yield prediction Infrastructure facilities need to be created for the above.

### 1.5d. Agronomy

Integrated crop management modules were developed for important cropping systems. Precision nutrient management using decision support tool "Nutrient Expert" and GreenSeeker underlined possibility of yield enhancement. Protocols for crop establishment and residue retention were developed under conservation agriculture-based rice-wheat, maize-wheat, cotton-wheat and pigeonpea-wheat system for irrigated ecosystems and pearlmillet-wheat/ mustard system for rainfed ecosystems. The main recommendations for enhanced production system visibility in the country are,

- Development of technologies/options for Integrated farming system specifically for rainfed and low-water situations of North-western, Central and North Eastern sectors
- Upscaling of precision agronomy research using affordable tools and its integration on latest farm machinery for wider acceptability.
- Upscaling conservation agriculture research for different ecologies and cropping systems
- Discovery of efficient water and nutrient management protocols for intensified cropping systems
- Focused research on cropping system-specific resource simulation modelling and decision support systems, for the key components of agricultural production technologies
- Complete support system for Precision farming, Integrated farming system and organic farming needs to be provided.
- Complete refurbishing of laboratory and field facilities needs to be done.

### 1.5e. Agricultural Engineering

The Division developed precision and resource conservation machines like rapid composting machines, paddy straw collector-cum-chopper, pneumatic precision planter, integral power equipment for small farm mechanization, urea ammonium nitrate (UAN) applicator, direct paddy seeder, manually operated multi-crop planter for small vegetable seeds, planter for system wheat intensification, pulse planter for raised bed planting, and evaporative cooled storage structure for fruits and vegetables, and have been licensed to companies.

- One time catch up grant for renovation of old workshop and laboratories of Agricultural Engineering Division
- Setting up Technology Park for display of Farm Machines for different stake holders
- Develop options for input management system integrated with modern farm equipment

accessible through custom hiring of farm equipment/implement for location specific needs of farming systems

- Develop technologies and designs for bulk cold-storage, bulk storage, short-term small/medium storage systems at farm-gate or local community level along with low-cost cold-storage transport systems employing solar/wind energy

**1.5f. Centre for Environment Science and Climate Resilient Agriculture**

A decision support system InfoCrop (V2 and V2.1) was developed to assist the environmental impact assessment, optimization of resource use and sustainable land-use management which are extensively used in NARS. The Pusa-mKRISHI service was developed for agriculture in collaboration with Tata Consultancy Services to provide local language based information to farmers through mobile phones. This multidisciplinary centre can play an important role to minimize the negative impact of climate change with the following recommendations:

- Environmental Science division should upscale the crop production technologies throughout the Indo-gangetic plains. The climate resilient technologies in rice-wheat cropping system with vegetables and utilization of mKrishi to be strengthened for wider application.
- The impacts of primary and secondary air pollutants and suspended particulate matter (SPM) on the productivity and quality of important field, vegetable and fruit crops and also the level of food chain contamination especially heavy metals through environmental pollution such as soil and water pollution need to be assessed.
- The crop simulation modeling activities needs to be strengthened at the division

**1.5g. Water Technology Center**

The eco-friendly wastewater treatment technology has been developed by the Centre and has also been established at Farah, Mathura. Integrated water management interventions such as redesigning water harvesting based on landscape in Mewat, Alwar and Dhar region enhanced the yield of wheat and mustard crops by about 25-35 per cent, and improved water productivity while the renovated water harvesting structures led to rise in water table by 65-95 cm.

- Water Technology Centre should undertake the responsibility of managing and maintaining the irrigation/water reservoir and prioritized recharging with precisely assessed distribution of the dwindling water resources for irrigation by quantifying available water in the production system(reservoirs, ground water, water-bodies) with appropriate WUE and microirrigation systems
- While the waste water treatment plant is being highlighted, there are several infrastructural or system linked activities require appropriate positioning in the concept for it to assume a repeatable/predictable Technology package. The system is more biological and ecological in orientation than physics or engineering angle while the research infrastructure is inadequately ad-hoc. Mechanism for remediation of waste water needs to be studied in multidisciplinary mode.

### 1.5h. Agriculture Knowledge Management Unit

- Strengthening of AKMU with respect to latest servers and operating systems is urgently required with adequate training, skill and expertise in field of large data handling, data analytics and web services which can go a long way to fully exploit technical advancement in ICT for the benefit of agricultural sector.
- Facility for tele-teaching needs to be developed.

## 1.6 Horticulture

### 1.6a. Fruits and Horticultural Technology

The Division has released 4 mango hybrids, two each of seedless grape and sweet orange. The post-harvest processing technologies have been developed for preserving or prolonging shelf life.. The significant progress needs to be strengthened through the following:

- Basic processing unit with fruits handling and over-season maintenance systems need to be created either separately or integrated over the School, with proper maintenance in the space vacated by the Directorate of Floriculture
- Strengthening of infrastructure for pre-breeding as well as application of molecular marker technology and *in vitro* methods in crop improvement
- Papaya breeding for gyno-dioecious type with cold & virus tolerance and guava for wilt tolerance and processing type.
- Emphasis on rootstock breeding in mango, citrus and grape for biotic and abiotic stress tolerance.
- Evolving nutritionally rich scion varieties with processing and other economic traits.
- The research laboratories dealing with tissue culture, physiology and molecular breeding need to be modernized.

### 1.6b. Vegetable Science

The Division's main contributions were in crop improvement releasing a variety each of garden pea, brinjal, bitter gourd, bottle gourd and cauliflower, and two of ash gourd respectively for specific zones of the country. One hybrid of brinjal was also released during the period. In addition, 14 varieties in total of onion, bunching onion, broad bean, summer squash, cucumber, ridge gourd, cauliflower, carrot, cherry tomato, radish and bitter gourd were released by the State of Delhi.

- The breeding efforts need to be strengthened to develop more varieties/hybrids for protected environment particularly in high value crops such as tomato, capsicum and cucumber.
- Breeding tomato varieties suitable for processing needs to be addressed.
- Efforts to be made for introgression or recombination breeding of desired genes in

commercial varieties/hybrids and for rich in phyto-nutrients, nutraceuticals and processing

- Diversification of genetic mechanisms like CMS, gynoecism and antisense RNA technology etc. needs to be exploited for facilitating hybrid seed production in vegetable crops.
- There is a serious lack of packaging the varieties with production and protection technologies. The research project on production technologies has to be intensified integrating with the School of Natural Resource Management with the Division of Agronomy.

**1.6c. Floriculture and Landscaping**

Division has continued to provide new varieties of flower crops such as three of marigold, eight of chrysanthemum and seven of gladioli, released by the State of Delhi. The Division also initiated for the first time in the country during the period, research on turf grass breeding and development. Infrastructure and intensified research input would enable the Division to provide more technologies for urban and peri-urban marginal and small farmers for profitable livelihood.

- The research work on pre-breeding for biotic and abiotic stress tolerance in rose, chrysanthemum, marigold and gladiolus needs to be strengthened.
- Infrastructure including expertise in the science related to molecular marker technology and *in vitro* methods in crop improvement needs to be strengthened for success in the marketable products development.
- Landscaping research must be taken up. The Division must prioritize its research objectives on turfgrass research and landscape architecture involving modern systems of vertical and green-wall gardening. A laboratory along with a designer expert for the landscape designing has to be put in place.

**1.6d. Post-Harvest Technology and Food Science**

Developed indigenous clay particles for foliar spray in order to improve the quality and reduce the incidence of pests, fruit cracking, sun burn, in pomegranate and apple fruits. Developed $\beta$-carotene rich pumpkin flour for food fortification, ready to serve water melon drink. Stanadardized the technologies for poped ready-to-eat Green chickpea flakes and soy based product named as 'Pusa Vita'.

- Work should be strengthened on alternative use of non-chemical treatments for ripening and extending the shelf life of major fruit crops (mango, banana papaya, guava) of commercial importance. For this an establishment of Controlled Atmosphere (CA) storage facility is required
- There is a need to utilize horticultural waste in value added products in order to reduce environmental pollution and for this purpose upgradation of Fruit Handling and Food processing laboratory and processing unit are required.

- There is need to emphasize on packaging, transportation and after storage retailing of major fruits and vegetables experiencing higher post harvest losses
- As food science discipline gets into prominence, on priority the division should analyse major food items consumed in the country to know the nutritional composition and work towards identifying the most efficient approach for cooking the same and preserving it for long shelf life at normal conditions

**1.6e. Regional station (Amartara Cottage: Horticulture), Shimla**

The centre represents temperate horticulture situation for fruit crops having standardized kiwi cultivation for different conditions and root stock development in apple and tissue culture based regeneration of planting materials in walnut, peach etc. The protection and production technologies for hills were also major inputs for successful fruit cultivation in the hills. The following recommendations are to be considered for better delivery and development of new technologies in the hills of India:

- Development of rootstock for temperate and stone fruits having wider adaptability for biotic and abiotic stresses
- Selection of superior genotypes for walnut, apricot, peach, pomegranate, strawberry and elite mother plant of apple for virus free planting material for which Modernisation of Tissue culture and Molecular breeding lab is required
- Inter-stock studies in apple to overcome seedling rootstock problem
- Popularize of Russian type pomegranate, apple hybrids, Pusa Khor walnut, Strawberry varieties in north western Himalayan region
- Farm roads, storage & irrigation facilities need to be developed.

**1.6f. Regional station, Katrain**

The snowball type cauliflower and golden-acre type cabbage of better quality and productivity were major outputs of the centre. In addition, the station has been promoting new varieties and hybrids of vegetables and flower crops by producing seed of 26 crops in the form of seed of 58 varieties and 8 hybrids. Thus the presence of the station in the difficult agricultural area has been a boon to the farmers of the region. Strengthening the station further would be helpful for the vegetable and flower crop growers of the region.

- There is need for extension of tissue culture laboratory to expand its capacity.
- Production of high quality European vegetables seed.
- Maintenance of parental lines and development of hybrids/ varieties of vegetables and flowers.
- Germplasm collection, maintenance and evaluation of flower crops.
- Development of double haploids in cole group of vegetables.

- Standardization of seed production and processing of vegetable crops.
- Renovation of tissue culture and molecular laboratories is required along with new equipments like Flow cytometer for Double haploid breeding programme.
- Work should be concentrated to upgrade integrated viral diseases management for vegetables and fruits to cope up with emerging diseases and pests.

**1.6g. Centre for Protected Cultivation and Technologies**

The Centre established as a Demonstration centre has in the recent years embarked on the precision agriculture mode adopting the vertical agriculture phenomenon under protected conditions. Strengthening leadership role capability with vibrancy and dynamism would be helpful in enabling innovations in technology

- Need to emphasize on designing of protected structures for different agro climatic conditions/situations.
- Development of suitable varieties for protected structures
- Multi utility structures for protected cultivation need to be exploited to achive the maximum crop response for higher productivity.
- The use of solar operated poly houses may be explored.

**2. Policy Issues**

a. The original institution's relics and remains of Naulakha building (Phipps Laboratory) is in a corner of the Central Agricultural University. As per the policy of the Government to preserve the historical heritage of the country, it is recommended to consider proper archeological excavation/restoration of this monumental site with a "**National Heritage**" recognition as well as making it an official ***agri-science history spot*** for enabling the agriculture students and researchers of the country to be inspired of the national needs as envisaged in the late 19$^{th}$ century despite lack of any civic facility including approach to the site.

b. The institute has to evolve a transfer policy for scientists between Delhi and its 10 outstations. There has to be a term-transfer at all approved cadres with a ready replacement. A roster of replacement in each discipline should be in place within the ICAR guidel*ines such that Regional St*ation postings are neither construed as punishment postings nor secondary at IARI.

c. The Council may make a special effort to maintain high scientific standards of performance comparable to any of the contemporary institutes of National Importance such as IISc or IITs. To this end, it is most critical to minimize lateral entries by transfer into IARI from other ICAR institutes. Whenever, such a lateral transfer is effected, the Director of the institute has to be consulted by the Council based on merit for appropriateness in the standards and vacancy in the discipline concerned.

d. Provision of special budget for overseas post doc training in emerging areas for young and mid level scientists.

e. Training of technicians for high end equipments and providing highly trained technicians for these equipment will ensure that they are put to efficient and long term use.

f. To inspire the newly joined ARS scientists, one time catch-up grant as is followed in UGC/DST should be provided (within six months of their joining) for creation of lab facility, procurement of equipment and hiring ad-hoc personnel.

g. Currently, Scientist: technical staff ratio is 1:0.8 – which is not adequate. A minimum ratio of 1:1.5 for technical staff is desired, thus provisions for allotment of more technical and supporting staff should be made.

h. IARI has excellent opportunities to harness the solar power. So that the power consumption can be saved and also we can produce enough for providing to the research facilities. With an initial investment this can be functional and serve as a model for other institutes in the country.

i. Institute should be able to use the HRD funds for sending scientists for training abroad, at least to a permissible limit such as 30% of the grant available in a year.

**3. Education**

The Post Graduate School offers M.Sc. and Ph.D. programmes in 26 disciplines and during the review period, 1152 M.Sc., 57 M.Tech. and 1373 Ph.D. students including 155 foreign students were admitted to the Post Graduate School. The Institute awarded M.Sc./M.Tech. degrees to 878, M.Tech. to 40 and Ph.D. to 739 students, which included 49 M.Sc., 2 M.Tech. and 53 Ph.D. foreign students. The Institute received accreditation during 2016 as A+ by the National Assessment and Accreditation Council (NAAC) of UGC for a period of five years (2016-2021). Based on the MHRD ranking 2017, IARI has been ranked 23$^{rd}$ among overall institutions of the country. IARI has also taken on the responsibility of enhancing its outreach efforts for HRD both within and outside the country. IIHR, Bengaluru and IIAE, Bhopal have already joined Recommendations for the continued improvement in the Post Graduate School education are as follows:

**a. Upgradation of academic environment** – Regular financial support to be provided for modernizing & strengthening of academic facilities and course curriculum delivery.

**b. Provision of Post-Doctoral Programme** – To improve quality research, Post-Doctoral programme need to be initiated at IARI. Provision of at least two Post-Doctoral Fellow in each teaching disciplines could be made and separate allocation of funds for Post-Doctoral programme under funds received for PG Strengthening from the Education Division of ICAR needed.

**c. Provision for sandwich Ph.D. programme** – Institute has signed MoUs with several International institutes. In order to develop competent human resource, provision for sandwich Ph.D. programme with these institutions is desirable. Similar programme was in operation earlier at IARI with the International Rice Research Institute, Philippines.

**d. Incentive for the faculty to promote quality teaching** – Provision for faculty participation in international seminar/symposium once in five years should be made to enable the faculty to update his/her knowledge and also in building confidence. Besides, provision of short-term and long-term overseas associateship could be made for the faculty. A minimum of 20 faculty members every year should receive international exposure.

e. IARI needs to introduce a post-graduate course in Agri-business Management

f. The course curriculum on Agricultural processing and food processing needs to be advanced with supporting facilities for practicals extended to all commodities of agricultural produce

**g. Provision for establishing Chair to attract talent** – In order to attract young talent from outside in certain identified areas, the Institute should have freedom to establish Chair (at least one per School) on the similar lines of IITs and traditional universities.

**4. Establishment**

**4.1. Scientific Staff**

At the time of reporting, as in March 2017, the scientific staff approved at IARI stood at 578 of which 506 were in position. Though the number looks healthy, it is critical to fill positions in certain disciplines at both Regional Stations and Divisions so that the continuity is maintained in the experiments for meeting the objectives set out in the research projects and institutional mandates are not left unattended.

**4.2 Position**

The core management positions should be Director assisted by Joint Directors of Research, Education and Extension. The Joint Directors should be the nodal control offices for the execution of research, education and extension programmes through Heads of the Division, Regional Stations, Units and Centres, based on the mandate of each establishment. However, some multi-disciplinary establishments such as the Nuclear Research Laboratory, Water Technology Centre, National Centre on Blue Green Algae were also established with external funding support with Project Investigators designated as Project Director. It is noted that the other two centres namely, Nuclear Research Laboratory and National Centre on Blue Green Algae were merged within the Centre of Environmental Science and Climate Resilient Agriculture (CESCRA) and Division of Microbiology, respectively headed by Head of the Division/Centre, at par with the other Divisions. It is also noted that functionally Head of the Division and Project Director, WTC are identical. There is no difference between the allocation of business and responsibilities of a Head of a Division of IARI and that of a Project Director, WTC. Therefore, the Water Technology Centre should be placed at par with a Division of IARI, and be renamed Division of Water Technology.

**4.3. Renaming CESCRA**

The institute renamed the Division of Environment Sciences as Centre for Environment Science and Climate Resilient Agriculture (CESCRA) in 2009 which could be restored as the Division of Environment Sciences.

**4.4. Renaming Division of Fruits and Horticulture Technologies**

It is recommended to rename the Division as **Division of Fruit Science** in sync with nomenclature of the Divisions of Vegetable Science or Floriculture & Landscaping.

### 4.5. Regional Station/Centre Establishments of IARI

The QRT visited the regional stations at Wellington, Indore, Karnal, Pusa, Katrain and Kalimpong out of the 11 stations/centres. The general observations related to the establishments were as follows:

a. There has to be a policy on keeping the regional station's staffing dynamic, especially the scientific staff so that the integrated research programmes of the Institute are executed smoothly without any gaps or disruptions as was visible at the moment. The lack of a transfer policy was visible at all the stations in both administrative and scientific cadres which were being operated on an ad-hoc basis, so much so that the purpose of the establishment of the station is defeated. Except at Karnal, Wellington, Dharwad and Aduthurai, in all the other centres the scientific staff was below the number or inappropriate in the disciplines of research. The administrative staffs in all the centres were less than adequate showcasing negligence in the administrative governance with respect to the Regional Stations during the last three to four years. The Post-Graduate School should encourage greater participation of students along with the faculty at research stations.

b. **Kalimpong Station**: The Kalimpong Research Station meant primarily for Virology studies of horticultural crops of the hills and foothills of Himalayas and provide solutions to the existing virological problems of the orchards and plantations of tea and mandarins, and vegetables. The scientists manning the station are not of the discipline earmarked for the station to carry on the activities of the centre.

c. **Pusa Bihar**: The condition of the centre in every respect was less than optimal in its research achievements and activities. An urgent review and uplifting of the station is strongly recommended in view of the importance of the region as well as its location being in the priority region for agricultural development of the Government. An immediate staffing and location of a regular Head of the Station is most essential so that the value of the presence of the premier research institute on agriculture becomes visible and available to the millions of farmers in the eastern plains region. The committee noted that a staff quarter was occupied by a bank in an unauthorised manner and this should be got vacated.

d. **Amartara and Tutikandi Stations**: Since the physical location is wide and research mandates are different under technically different divisions they should be demerged as before.

### 4.6. Technical & Supporting Staff:

There is a general shortage of Technical and supporting staff in almost all divisions, Centres/Units, Regional Stations as well as PME section and an acute shortage of technical and supporting staff was particularly noted in the Schools of Horticulture, Crop Improvement and Divisions of Agronomy, Soil Science and Agricultural Engi**n**eering. The required strength is essential in order to keep the experiments and equipment in correct order and functional.

The recommended technical staff and supporting staff is indicated in the Table as Annexure XI which has to be put in place for IARI to function efficiently to meet the agricultural research requirements of the country.

**4.7. Administration & Governance**

a. Tele-conferencing facility with the HoDs and the Regional Station Heads should be established.

**4.8 Finance**

a. Auditing and accounting requires to be decentralized within the GFR 2017 limits for faster processing of proposals for approvals as well as completing the procurement liabilities.

b. The grants on operational and maintenance head should earmark a proportion for AMC, Division-wise, of all items of equipment so that their utilization is always ensured without any break.

**5. GENERAL RECOMMENDATION**

a. One time Catch up Grant for infrastructure

b. Autonomy at par with IISc, IITs or CAUs.

c. Item No. 20, 23 and 29 of the ATR of last QRT from 2000-2008 (Page No. 162) is once again recommended for action.

# Annexure I

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Krishi Bhawan, Dr. Rajendra Prasad Road,
New Delhi 110 001

F.No. CS/16/8/2006-IA.IV

Dated the 27th Nov., 2015

**OFFICE ORDER**

In supersession of Council's Office Order dated 3.11.2015 the Director General, ICA has been pleased to approve the IARI Quinquennial Review Team (QRT) to review the wor done by Indian Agricultural Research Institute, New Delhi during the five years period fro 2009 to 2014. The composition of the QRT will be as under :-

| Sr. No. | Name & Address | Designation |
|---|---|---|
| 1. | Prof. Panjab Singh, Ex-DG, ICAR & President, FAARD | Chairman |
| 2. | Dr. D.P. Ray, Horticulture, Ex-VC, OUAT, Bhubaneshwar | Member |
| 3. | Dr. S.A. Patil, Crop Improvement, Ex-Director, IARI & Former Chairman, KK Mission, Govt. of Karnataka | Member |
| 4. | Dr. Anupam Varma, Crop Protection, Former Dean, IARI INSA Honorary Scientist & IARI Adjunt Professor | Member |
| 5. | Dr. P.K. Joshi, Social Science, Ex-Director, NCAP & NAARM and Director, South Asia, IFPRI, South Asia Regional Office, New Delhi | Member |
| 6. | **Dr. K.V. Prabhu, Joint Director(R)** | **Member-Secretary** |

**FUNCTIONS** :

The QRT shall conduct the review of the work of the IARI, New Delhi, keeping in vie the relevant guidelines thereon and submit its recommendations on future research thrust through its report to the Council within 6 months from the issue of this order for furthe submission to the General Body of ICAR. Terms and references for the QRT is enclosed i Annexure I.

## Annexure II

# Terms of Reference of the QRT

**I. Research Achievements and their Impact**

To examine and identify the research achievements of the Institute, Projects/KVKs, its Regional Station and Sub-stations, AICRPs operated by them *ivs-a-vis* sectoral programs since the previous QRT and critically evaluate them. Commensurate with the objectives, mandates and resources of the organization, the social-economic impact of research on farmers, beneficiaries and transferability of results to farmers through extension should be critically reviewed.

**II. Research Relevance and Budget Allocation**

To examine the objectives, scope and relevance of the research programmes and budget of the Institute for the next 5 year in relation to overall/state/regional/national plans, polices and long and short-terms priorities. The Committee may also draw its attention to the EFC/SFC memo in relation to recommendations of the previous QRT and also the Perspective Plan and Vision – 2025 document of the Institution.

**III. Policies, Priorities and Strategies**

To examine the policies, priorities, strategies and procedures adopted by the Institute and the system in relation to Perspective Plan in arriving at these decisions particularly the effectiveness of working of the Institute Research Committee, Research Advisory Committee and the Institute Management Committee as well as the Consultative Machineries like Grievance Cell and Institute Joint Staff Council.

**IV. Relationship/Collaboration with SAUs and Other Stakeholders**

Whether the research programmes of the past and proposal for future are in harmony with the Vision ICAR (HQ) and the programme of related Centres of research and Agricultural Universities, State Government, Private Sector and IARCs.

**V. Linkages with Clients/End users**

To examine the kinds of linkage established with the clients and end users of research results, i.e., farmers/fishermen and extent of interest displayed in conduction "on farm research", on farmers' fields and in organizing demonstrations/training course o demonstrations/training courses for the transfer of technology to extension agencies.

**VI. Proposed Changes in Organization, Programmes and Budget**

To examine whether any changes in the organizational set-up are called for, to achieve and improved and effective working. The Committee may also examine and draw attention to any imbalances in the staffing pattern consistent with the scientific, technical and administrative needs as well as the allocation of research funds towards capital works, establishment and research contingencies. Further the Committee may also examine the resource generation efforts and assess the problems and prospects of the same. The progress and problems of implementing project Based Budgeting may also be highlighted. While proposing major changes in organization and function their feasibility in relation to ICAR's rules, autonomy, resources, etc. need to be kept in view.

**VII. Organization and Management**

Whether the organization structure of the Institute is conducive to efficient functional/ working autonomy, decentralization and delegation of authority in day-to-day routine working and whether the Director and senior staff are interested in promoting a collegiate and co-operate method of administration is to be assessed. The committee may also critically examine the status of implementation of O & M reforms as introduced by the Council form time to time and suggest ways and means to implement them at the Institute level. They may also suggest further reforms to be considered by the Council. The suggested staff ratio by the Council may have to be kept in view white reviewing the staff position in the Institute.

**VIII. Constraints**

To examine constraints hindering the Institute in achievement of its objectives and implementation of its programme and goals and to recommends ways means of minimizing or eliminating them.

**IX. Looking Forward**

To look into any other points considered relevant by the committee or referred to it by the ICAR, the Institute Director or the Management Committee, in respect of future project development, research prioritization and management changes.

The above terms of reference may be modified at the suggestion of Director of Institute/ Project/Management Committee of Institute/Project/ICAR Headquarters/GB keeping in mind any specific problems of the Institute.

## Annexure III

# Schedule of QRT Meetings and Visits

| Date of Meeting | Place of visit | Name of Members visited |
|---|---|---|
| 4th December, 2015 | IARI, New Delhi, Meeting with Director, IARI and finalization of the programme for visits. | Dr. Panjab Singh, Dr. S.A. Patil |
| 7th January, 2016 | School wise presentations by Coordinators in the board room of Directorate, IARI. | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, Prof. Anupam Varma and Dr. P.K. Joshi (Full QRT) |
| 22nd to 24th February, 2016 | School wise presentations by Coordinators in the IARI Library Conference Hall. | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, Prof. Anupam Varma and Dr. P.K. Joshi (Full QRT) |
| 17th to 18th April, 2016 | Visit to IARI Regional Station Indore | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, |
| 19th April, 2016 | Visit to IARI Regional Station Karnal | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, |
| 20th April, 2016 | Discussion among QRT members and interaction with HoDs/Incharges of different units of IARI in the IARI Library Conference Hall. | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, Prof. Anupam Varma |
| 12th to 14th September, 2016 | Visit to IARI Regional Station, Wellington. | Dr. Panjab Singh, Dr. D.P. Ray |
| 7th to 9th November, 2016 | Visit to Divisions of FHT, Vegetable Sciences, FLS, Microbiology, Biochemistry, CPCT, Plant Physiology, Genetics, Seed Science & Technology, SPU, Agril. Economics, Agril. Extension, CATAT, ATIC, ZTMU, Plant Pathology, Nematology, Agril. Chemicals, CESCRA, Agril. Physics, FOSU/OHLU, Agril. Engineering, Agronomy, SS&AC, WTC, Entomology | Dr. Panjab Singh, Dr. D.P. Ray |
| 20th to 22nd December, 2016 | Visit to IARI Regional Station Kalimpong | Dr. Panjab Singh, Prof. Anupam Varma |

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| 6th to 8th September, 2017 | Visit to IARI Regional Station, Pusa Bihar | Dr. Panjab Singh, Prof. Anupam Varma |
| 5 to7th October, 2017 | Visit to IARI Regional Station, Katrain | Dr. Panjab Singh, Dr. D.P. Ray, Prof. Anupam Varma |
| 22nd to 23rd November, 2017 | Preparation of the draft report | Dr. Panjab Singh, Dr. S.A. Patil, Prof. Anupam Varma |
| 20th to 21st January, 2018 | Approval of the draft | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, Dr. P.K. Joshi and Prof. Anupam Varma |
| 18th May, 2018 | Final meeting of the QRT report | Dr. Panjab Singh, Dr. S.A. Patil, Dr. D.P. Ray, Prof. Anupam Varma and Dr. J.P. Sharma |

# Annexure IV

## Recommendations of QRT in respect of IARI (2000-2008) (as approved by the Governing Body of ICAR)-Present Position regarding Action Taken

| SNo. | Recommendations | Action Taken |
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| **Scientific** | | |
| 1. | Heterosis breeding in rice, pigeonpea, mustard and wheat should be strengthened and research on pulses should focus more on crops like pigeonpea and chickpea. | The Institute has strengthened its projects on heterosis breeding for the crops mentioned. Special focus is being given to pigeon pea, mustard and wheat under challenge programme of the Institute. The programme on pulses has been strengthened by placing new scientist |
| 2. | Molecular breeding should be an integral part of the crop improvement programmmes. | Molecular breeding component has been made an integral part of all the targeted crops for biotic and abiotic stress tolerance. |
| 3. | Research and teaching in the area of biotechnology should be strengthened. In this context, work on isolation and characterization of novel genes and promoters should continue for the development of transgenic crops resistant to biotic and abiotic stresses; nutritional quality improvement and post harvest technology. | Strengthening the research and teaching in the area of biotechnology continues. Development of transgenic crops resistant to biotic and abiotic stresses; nutritional quality improvement and post harvest technology is in progress. |
| 4. | IARI should continue to develop high yielding varieties of crop plants along with appropriate production and protection technologies for different agro ecologies of the country. | Necessary action has already been taken. The project on production and protection technologies for different agro-ecologies have been taken up in IARI and its regional stations. |
| 5. | Studies on the effect of climate change in relation to adaptation and mitigation should be undertaken in an interdisciplinary manner. | In-house research projects aiming to study the effect of climate change in relation to adaptation and mitigation in rice, wheat and chickpea are being undertaken. These are being supported by a Challenge Programme on "Enhancing Resilience of Indian Agriculture to Climate Change" and NICRA Project, in multidisciplinary mode. |
| 6. | A well-equipped screening system for abiotic stress tolerance at different stages of crop growth to be developed at the institute. | The Division of Plant Physiology has taken up one project on wheat screening system for abiotic stress tolerance |

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| 7. | Research programmes on Farm Machinery and Power need to be focused on development of precision farm implements and machinery and utilization of renewable energy resources. | A focused programme undertaken on the application of sensors including bioindicators in the project on "Precision machinery for operational and input use efficiency in crop production". One scientist has been trained in US on above aspect this year.<br>Research project on drying using solar energy (renewable energy) has also been under taken. |
| 8. | The Institute should focus research on remote sensing and simulation modeling approach for better crop planning | Research on remote sensing and simulation modeling approach for better crop planning and prediction, has been undertaken under in-house and externally funded projects in the Division of Agricultural Physics and Unit of Simulation & Informatics, with multi-divisional collaboration respectively |
| 9. | Research on resource conservation technologies be strengthened. | A programme on resource conservation has been undertaken in Agronomy Division in multidisciplinary mode under Institute challenge programme. Under this programme interdisciplinary research studies on characterization of soil physical environment and water availability to crops under conservation tillage practices are in progress. |
| 10. | Research linkage and coordination between the regional stations and the relevant main division of IARI should be strengthened. | The research linkage and coordination between main IARI Divisions such as Genetics, Plant Pathology, Seed Science & Technology, Fruits and Horticulture and Vegetable Science and research stations namely Indore, Pusa, Wellington, Pune Kalimpong, Karnal, Shimla, and Katrain, already exits. Some of the projects in these regional stations have been prepared in consultation with the respective Heads of the divisions in IARI |
| 11. | Analysis of cost: benefit ratio should be an integral part of technology development, especially, for INM, IPM and conservation agriculture. | Calculation of the benefit : cost ratio in various projects has been emphasized. The benefit cost ratios in demonstration trials on water use technologies at farms worked between<br>1.3 - 3. |

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| 12. | Basic research on soil processes involving nutrient fluxes and flows, organic recycling in relation to organic matter formation and its stability, nutrient availability and soil quality for enhanced productivity and environment safety should be emphasized | Focused attention on this aspect has been given in the in-house projects, especially "Ionic sorption and desorption under different chemical environment in soil-plant continuum." |
| 13. | Research on modified fertilizers and technologies for improving fertilizer (nutrient) use efficiency and economics should be strengthened. | In-house sub-projects "Rhizospheric and nano-technological applications to increase nutrient use efficiency" is in place for this purpose. |
| 14. | Considering the possibility of new insect pests and disease causing organisms entering into the country in new WTO regime, emphasis on phytosanitary issues in research programmes is recommended. | Phytosanitary issues are dealt under "Referral Centre for Virus testing of Tissue Culture Raised Plants" |
| 15.. | The Institute should continue studies on plant diseases with greater emphasis on plant microbe interactions. | This activity is already being pursued and would be further strengthened in future. |
| 16. | Presently, the work on pest management is not carried out in a holistic manner. Therefore, QRT recommends interdisciplinary approach for developing IPM technology. | A project has been undertaken in collaboration with NCIPM on this aspect. |
| 17. | Considering the importance of new molecules in plant protection, the Institute should concentrate more on synthesis and development of new molecules of pesticides. | The research on this aspect is already in progress. However, as formulation of new molecule of pesticides involves huge investment, the programme is being taken forward in a limited way. |
| 18. | In view of the importance of processing and value addition in food and horticultural crops, the QRT recommends the establishment of a new Center for Food Science and Post Harvest Technology at IARI with full component of human resource and infra structure. | A Division of Food Science and Post Harvest Technology, is created at IARI and is functioning in this Institute. The request to regularize the post of the Head of Division has been submitted. |
| 19. | Research programmes of the Nuclear research Laboratory (NRL) are no longer viable and, therefore, the QRT re-endorses the recommendations of RAC 2005 for the reorganization of the Nuclear research Laboratory. | The action has already been initiated and the NRL has been re-organized in terms of Lab facilities. |
| 20. | The QRT is of the considered opinion that the names of the Division of Genetics and the Division of Fruits and Horticultural Technology be changes as 'Division of Genetics and Plant Breeding', and 'Division of Fruit Science', respectively. | The action, in this regard has already been taken and the matter is under consideration at Council's level. |

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| 21. | The Seed production unit be made an integral part of Seed Science and Technology. | Appropriate action is being taken to merge SPU with Seed Science & Technology Division. |
| **Human Resource Development** | | |
| 22. | Shortage of faculty in most disciplines is seriously affecting the research and teaching activities of the Institute. In view of this, the QRT recommends that the vacant positions of scientific staff in each discipline be filled on priority over the next three years. | Council is being approached for filling vacant posts.. |
| 23. | The position of Professor in each discipline may be filled by direct recruitment with the designation of Principal Scientist (Professor) | Proposal has been sent to the Council again. |
| 24. | As IARI is a University (Deemed), the posts of Head, Library Services and Registrar, PG School should be filled in the grade Professor/ Principal Scientist. | Proposal will be sent to the Council again. |
| 25. | New PG Courses may be introduced in the disciplines of Food Science and Post Harvest Technology and Bio-informatics. However, such courses may be started only when critical competent faculty and infrastructure are provided. | New course started in Bioinformatics. |
| 26. | IARI may involve scientists working in other ICAR institutes and other reputed institutions in research guidance of the students at the Institute only after due accreditation and commitment to participate in teaching. | Ten Scientists from other ICAR Institutes having very good credentials have been identified. |
| 27. | The Institute should develop a center for Distance Education and have a major responsibility for the development of e-content at PG level. | As per regulations deemed to be Universities may not have distance education system. Efforts are being made to develop e-contents |
| 28. | The Institute should have a career development plan for faculty competence improvement. Advanced trainings in the new and emerging cutting edge areas need to be imparted to young scientists at the best institutions overseas. | Agreed for taking necessary action |
| 29. | The post of the Head of the Division be made RMP | It is a policy issue and Council has to consider. |
| 30. | IARI should institute Adjunct Professor Scheme as per guidelines being adopted by ICAR. | 7 adjunct and 8 guest faculty have been notified as per Council Guidelines |

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| 31. | The students hostels at IARI are very old and require major renovation. In addition, the capacity in hostels is much less than its requirement. The QRT recommends the construction of a new hostel and major renovation of old hostels. ICAR should help the institute to get necessary approvals from Urban Arts Commission and other bodies | Necessary action is being taken for which funds are already sanctioned under XI Five Year Plan for three new hostels. Approval of Master Plan awaited |
| **Extension** | | |
| 32. | IARI Extension Education Programme be implemented on pilot basis in different regions with the involvement of SAUs/ICAR institutes/extension agencies/industry. | An innovative National Extension Programme in partnership with 16 ICAR Institutes / SAUs has been launched by the IARI for speedy transfer of its technology in far-off areas of the country. The partner ICAR Institutes / SAUs are: CIRG Makhdoom; MPUAT Udaipur; IVRI, Izatnagar; UAS Dharwad; UAS Bangalore; Directorate on Rapeseed and Mustard Sewar, Bharatpur; Birsa Agricultural University, Ranchi (Jharkhand); Birsa Agricultural University, Ranchi (Jharkhand); BHU, Varanasi (UP); IIVR, Varanasi; CSKHPKV Palampur; NDRI, Karnal, Haryana; JNKVV Jabalpur, Madhya Pradesh; MPKV Rahuri (Maharashtra); MAU, Parbhani (Maharashtra); NavsariAgriculturasl University, Vijalpore, Navsari (Gujarat) and CIFE, Mumbai.<br>The programme aims at creating location – specific models to assess and refine technology, to promote climate neutral and location specific technologies of the Institute at national level and micro-enterprises development among rural youth for income and employment generation |
| 33. | Senior level extension specialists from disciplines (Agronomy, Soil Science, Genetics, Entomology and Pathology) need to be identified as members of Production Unit to assist the Joint Director (Extension). This is required to keep liaison, ensure easy flow of latest technology and provide linkages for feedback of field problems and issues. | A team of five scientists from Division of Genetics, Agronomy, Soil Sciences, Entomology and Plant Pathology has been identified as members of "Production Unit" to assist the Joint Director (Extension) to ensure effective linkages with farmers and flow of technology. |

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| 34. | The Institute should develop appropriate concepts and methodologies for better agricultural extension and technology transfer at national level. | The Institute is continuing its efforts in developing new extension concepts and methodologies at national level. The following programmes are currently in operation:<br>1. National Extension Programme in partnership with ICAR Institutes and SAUs.<br>2. Assessment of agricultural technologies and developing market led extension models for different production systems has been initiated in which detailed assessment of IARI technologies along with its impact on livelihood of rural farmers are being done in four selected villages in National Capital Region. All relevant farm technologies available with IARI will be transferred in these four villages which will serve as model villages.<br>3. Technology dissemination through partnership with NGOs.<br>4. Dissemination of farm technologies through post offices.<br>5. Development of cyber-extension model. |
| 35. | The Institute should make more efforts in expanding and strengthening the existing public-private partnership and linkages in research, extension and marketing of technologies. Linkage and collaboration should continue to exist with several national and international institutions. | The IARI has initiated an innovative extension programme for technology dissemination in partnership with selected NGOs for feasibility trials and promotion of agricultural technologies in their operational areas. Under this programme, 27 NGOs of repute from 16 states of the country are involved since kharif 2010. The major objective is to assess and disseminate IARI technologies in different parts of the country.<br>The Division of Agricultural Extension and CATAT of IARI have established linkage with different national institutions through their regular training programme and also through other programmes offered through Centre of Advanced Faculty Training. The Division of Agricultural Extension has also completed a project on programme evaluation in collaboration wih Michigam State University, USA. |

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| **Administrative** | | |
| 36. | Historically, Heads of Divisions of IARI occupied a pre-eminent position, However, after the creation of ARS, the Heads of Divisions at IARI were not included in research management position (RMP). As a result, there is a flight of competent scientists to research management positions with equal grade, elsewhere. In order to retain competent scientists and provide leadership at IARI, which has a Deemed University status, the QRT recommends that the Heads of Divisions at IARI be given the status of RMP. | It is a policy matter and ICAR may take decision. |
| 37. | The QRT recommends that the Institute should develop a time bound programme for training of technical and administrative staff. | Action has already been initiated and trainings are being imparted to technical and administrative staff by NAARM, Hyderabad |
| 38. | The Institute should also work on paperless system of governance as far as possible. | The Institute is following this and paper work is reduced considerably. |
| **Financial** | | |
| 39. | IARI should develop a Financial Management package online linking the Divisions to the Directorate. | This has been taken up under NAIP for all ICAR Institute and ICAR Headquarters. The work is in progress. |