

Report of the Director

Presented at the 54th convocation – 2016

School of Crop Improvement

As a flag-ship organization in developing crop varieties and agro-technologies to meet the challenges of food and nutritional security, IARI has developed high yielding varieties with primary focus on developing hybrids with resilience to several biotic and abiotic stresses and enhanced nutritional quality. The Institute released seven varieties of different field crops during 2015, including HD 3118, HI 8737, HS 542 and HW 1098 of wheat, Pusa 1592 and Pusa Basmati 1609 of rice and BG 3022 of chickpea.

In the changing climate scenario, biotic and abiotic stresses have become major production limiting factors. Molecular breeding was employed to incorporate resistance to these stresses in different crops. In wheat, elite genotypes with drought and terminal heat tolerance have been developed. Genes for resistance to bacterial blight, blast, and brown plant hopper, and tolerance to salinity were incorporated in the basmati rice varieties, Pusa Basmati 1, Pusa Basmati 1121, Pusa Basmati 6. Blast resistance genes were also incorporated in an elite medium slender grain high quality rice variety BPT5204. In maize, marker assisted backcross breeding was employed to introgress beta carotene enhancing gene in the parents of hybrids Vivek QPM-9, Vivek Hybrid-27, HM-4, and HM-8. Promising waxy inbreds, sweet corn hybrids (*sh2sh2*-, *su1su1*-, *sh2sh2/su1su1*-) and waterlogging tolerant maize hybrids have been developed. In the case of pearl millet, PPMI 903, PPMI 904 and PPMI 906 have been identified with high Fe (>90 ppm) and Zn (65 ppm) concentrations. The bio-fortified varieties of cereals will contribute to the nutritional security to the ever growing population of the country.

Our national, annual import bill on pulses and edible oils are Rs. 10,000 and 56,000 crores, respectively. Realizing the importance of pulses as a chief source of protein in the vegetarian diet, the United Nations' General Assembly has declared the year 2016 as the 'International Year of Pulses.' At IARI, we are committed to provide improved varieties of pulse crops to the farmers. In pigeon pea, several genotypes with early maturity, determinate growth habit and amenability to mechanical spraying and harvesting have been developed. These include PADT-5, PADT-16 and PADT-25. In mustard, for the first time, a 'double zero' variety PDZ-31 having <2% erucic acid and <30 micro moles of glucosinolate with great health benefits has been released. In soybean, several promising lines have been developed through inter-specific hybridization with enhanced seed storability, resistance to mosaic complex and rust disease.

With an aim to serve the nation through the supply of quality seeds, IARI, and its regional stations produced 5463 q of breeder seeds and 9495 q of truthfully labeled seeds of 64 varieties of 13 field crops; and 112 q seeds of 24 varieties of 16 vegetable and flower crops.

School of Horticulture

Pusa Aushadhi, a bitter gourd variety, was released by the Central Sub Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops for cultivation in Zones VI (Rajasthan, Gujarat, Haryana and Delhi). Pusa Sabzipetha, an ash gourd variety, was identified by the AICRP-Vegetable Crops (VC) for *kharif* cultivation in Zone VIII (Karnataka, Tamil Nadu and Kerala). An early Cauliflower variety, Pusa Ashwini was identified by AICRP-VC for zone IV comprising of Punjab, U.P., Bihar and Jharkhand states. A total of 32 genotypes (22 varieties + 10 F1s) in 11 vegetable crops were advanced to AVT-I & AVT-II of AICRP (VC). Fourteen new

entries (7 each of vegetable varieties and hybrids) were submitted in 2014-15 for IET trials of AICRP (VC). Pusa Kartiki (cauliflower), Pusa Kulfi (carrot), Pusa Pasand (summer squash), Pusa Rasdar & Pusa Purvi (bitter melon), Pusa Shweta (radish), and Pusa Cherry Tomato-1 were released by the Delhi State Variety Release Committee of Govt. of NCT of Delhi. Pusa cauliflower hybrid 1 (KTH-27), the CMS based F₁ hybrid was identified by IARI Variety Release Committee for cultivation in the NCR region. Pusa Snowball Cauliflower Hybrid 1, the snowball cauliflower F₁ hybrid, has been released by the Delhi State Seed Committee for cultivation in the NCR region.

The β -carotene rich desirable elite lines in early (up to 12 ppm) and medium (up to 10 ppm) maturity groups of Indian cauliflower were developed. Elite horticulturally desirable lines with introgressed 'Or' gene were obtained in early (Pusa Meghna, CC14 & DC41-5) and mid (Pusa Sharad, CC35 & DC18-19) maturity Indian cauliflower background. One gynocious line (PVGy-201) in the back ground of Pusa Vishesh was licensed as DBGy-201 to Namdhari Seeds Pvt. Ltd. Bengaluru, through ZTM&BPD Unit of the Institute.

Artificial hybridization was attempted in mango using 13 cross combinations. Amrapali, Mallika and Kesar were used as female parents and Sensation, Tommy Atkins, Janardan Pasand, Pusa Arunima, H-11-2, H-8-11, H-12-5, and Irwin were used as male donors. Improved sweet orange variety Pusa Round (MS-13) has been released and notified by Government of NCT of Delhi in 2015. This variety has a distinct advantage for yield and quality characters over other commercially available sweet orange cultivars; Pusa Round yields 3.5-fold higher than 'Jaffa' and 2.4-fold higher than Valencia. A clonal selection of acid lime Pusa Abhinav (ALC-40)' has been released and notified by Government of NCT of Delhi. It has a dense canopy, fruits are round, medium sized (38 g) with thin peel (1 mm), high acid content (7.7%) and has high yield. It produces fruits round the year with peak harvesting during August-September and March-April under Delhi conditions.

We have generated 60,359,815 and 58,212,961 raw reads from pooled cDNA libraries prepared from leaves tissue using SOLiD sequencing technology for mango varieties Neelum and Dashehari, respectively using the *de-novo* assembly approach. A total of 3,319 SSR loci were identified in 3,208 TSA contigs, representing 9.26% of the total 34,654 unigene TSA contigs.

A new Hybrid Tea rose variety Pusa Mahak, a recurrent flowering, floriferous and highly fragrant variety, is ideal for garden display and floral arrangements. Pusa Deep Marigold is a promising selection (Fr./R-8) suitable for the loose flower production during October-November (festive season). For the first time in India, the interspecific crosses were attempted successfully in lily; a line with precocious flowering ability was developed with reduced juvenile period having no vernalization requirement. Out of 25 acclimated progenies of a cross between *Lilium formosanum* × *Lilium longiflorum*, eight progenies were bolted and reached anthesis within one year. The cultivar Lalit (white), a bright yellow natural bud sprout chrysanthemum, was found to be very promising, and the regeneration protocol was developed from ray florets.

Flavour and color of watermelon can be preserved by irradiation treatment at 0.5 kGy. It maintained lycopene pigments as well as the total color changes of the drink during three months of storage at 4 ± 2 °C. For the shelf stable and the minimal processing of vegetables, citric acid was found to be the most promising pretreatment followed by calcium lactate; it prevented browning in lotus stem when stored at 6 ± 1 °C, and shelf life could be extended by up to six days without any discoloration. The minimally processed baby corn could be stored up to 10 days at 6 ± 1 °C without tip browning and loss in sweetness by the application of citric acid and ascorbic acid.

Pusa Vita was developed through extrusion processing using finger millet-soy. This product which can be consumed by mixing in milk is gluten-free, has high water solubility index and high protein (18%), and is rich in micronutrients. KAD Bioresources Pvt. Ltd. has signed the MOA with IARI for commercialization of this product. Pusa Arunima and Bombay green mango varieties were found to possess the highest phenolics and antioxidant activity [upto 8.7 $\mu\text{mol TE}$ (trolox equivalents) per g] in their dehydrated kernels. High antioxidant potential of the extracts of these kernels can serve as nutraceutical supplements in various functional foods.

School of Basic Sciences

The research programmes in the school of Basic Sciences are chiefly on the identification of donors for crop improvement, understanding the mechanisms of abiotic stress tolerance in crops, and postharvest shelf-life of tomato. Contrasting genotypes for epicuticular wax deposition, stay-green and root traits in wheat, and stem reserve mobilization in rice and wheat have been identified. For gaining a better understanding and improved water use efficiency and drought tolerance of rice, ten genes encoding plant stress hormone Abscisic Acid Receptors (ABARs) were cloned from rice cv. Nagina 22. Rice transgenics overexpressing *OsABAR6* gene under stress inducible *AtRD29A* promoter were developed and confirmed by molecular analysis. Physiological analysis of T2 transgenic lines of rice revealed that ABAR6 conferred drought tolerance through dehydration avoidance and desiccation tolerance mechanisms. Further, transgenic rice lines used about 30-40% less water as compared with non-transgenic plants under greenhouse conditions.

Non-availability of high throughput method is a rate limiting step in large-scale phenotyping of germplasm lines and breeding populations. Hence, the phenomics facilities have been developed at IARI. Studies on the interactive effect of elevated CO_2 and P deficiency in wheat revealed that organic acid exudation from the root is an important mechanism of P acquisition and elevated CO_2 enhances organic acid exudation from the root, and thus helps to mitigate P deficiency stress in wheat. Analysis of post-harvest shelf life of tomato and endogenous salicylic acid (SA) content showed that tomato fruits with high SA content at harvest showed longer shelf life while post-harvest treatment of fruits with SA enhanced the shelf life by one week. Treatment of tomato fruits with ethanol vapour (3.0 ml/ per kg of fruits for 16 h) was found to delay fruit ripening by ten days.

More than 23000 stress-associated unigenes and 32000 SSR were identified in wheat (cv. HD2985 and HD2329) for heat stress tolerance through *de novo* assembly and transcriptome analyses. Six heat-responsive miRNA were also identified from HD2985. Four heat-responsive SSR were validated in 30 different genotypes of wheat which can be used for screening of wheat germplasm for thermo-tolerance. Rubisco activase gene was cloned from HD2985, and site-directed mutagenesis was carried out to enhance thermal stability of the enzyme which may be used for improving thermo-tolerance of elite wheat cultivars.

A transcription factor (AP2/ERF) which confers drought stress tolerance was cloned in pBI121 for *Agrobacterium*-mediated transformation of *Arabidopsis*. Molecular analysis of T₂ transformants by Southern hybridization for gene integration and copy number indicated a marked increase (1.5 fold) in the expression of the gene in transformants after eight days of water deficit stress (WDS) in rice. Towards the development of low-phytate soybean with improved mineral bioavailability, *phytase* gene was over-expressed in cv. DS-9712 under the control of a seed specific promoter. Analyses of T₄ seeds revealed low-phytate soybean seeds showed

improved mineral bioavailability with an increase of 21.2% in iron, 11.7% in zinc and 13.8% in calcium levels due to the decreased phytate content.

School of Crop Protection

A new series of halogenated Schiff bases were synthesized and screened for antifungal activity. All the compounds showed fungicidal activity against two paramount plant pathogenic fungi viz., *Rhizoctonia solani* and *Sclerotium rolfsii*. Triggered release formulations of Thiamethoxam were prepared using biopolymeric clay hydrogels composites, which gave higher release rate of Thiamethoxam at basic pH than the neutral condition.

A method for analysis of 73 pesticide residues (organochlorine, organo phosphorous, synthetic pyrethroids and herbicides) in a single run using Gas Chromatography – Mass Spectroscopy (GC-MS) has been developed and validated in Basmati Rice and Tea. Likewise, a new method has been developed for analysis of four aflatoxins (B1, B2, G1 and G2) in the animal feed using LC-MS-MS with recoveries ranging from 95 to 98% for the bird, fish and tortoise feeds. Various decontamination techniques have been developed for removal of contaminants from water, soil, vegetables and fruits. For removal of pesticides and heavy metals, nZVI-BTBAC modified clay and modified clay embedded porous hydrophobic polymer showed removal efficiency of more than 80% for pesticides and 60% for heavy metals.

The climate change impact on brown planthopper (BPH) population on Pusa Basmati 1401 with elevated CO₂ @ 570 ± 25 ppm in open top chambers (OTCs) during *kharif* season exhibited the positive feedback effect of CO₂ on BPH population; the BPH population (39.9 ± 13.9 hoppers/hill) tripled compared to that under the ambient CO₂ (13.2 ± 4.8 hoppers/hill) during the crop season.

The cauliflower + coriander (square) system recorded lower incidence of aphids and the highest number of predatory coccinellids and syrphids. Weekly monitoring of both melon and peach fruit flies was undertaken at the Pusa Institute Campus at 24 locations for nine years. The peak of fruit fly trap catches of seven years was correlated with weather parameters, and the forecasting model was developed and validated for two years. Evaluation of soybean lines revealed that the lines DS 2705, DS 27060, DS 2806, SI-982, and SI-983 showed multiple resistance to pests. In studies on insect pests of stored products 40 populations of *Tribolium castaneum* and *Rhyzoperthadominica* infesting wheat in storage were collected from FCI godowns of Rajasthan, Haryana, and Punjab and bioassayed with phosphine. Most of the populations showed low to high level of phosphine resistance.

Next generation sequencing techniques have been deployed for identification and isolation of novel gut bacterial isolates viz., *Pseudomonas stutzeri*, *Bacillus safensis*, and *Stenotrophomonas rhizophila* from insect pests including bollworms and whitegrubs which could be exploited for pest management. Fifteen potential *Bacillus thuringiensis* (Bt) strains that showed toxicity against *Tribolium castaneum* were isolated and characterized by their *cry* toxin profiles. A new subgroup of phytoplasma (16Sr I-B) associated with sugarcane leaf yellows disease in India was characterized. A microarray chip that has the potential for simultaneous detection of more than 1100 DNA and RNA viruses and 40 viroids infecting plants has been developed. A PCR-based diagnostic marker developed for detection of *Bipolaris oryzae* and *Fusarium fujikuroi*. Multiplex-PCR protocol was developed for the simultaneous detection of *R. solanacearum* and *E. carotovora* subsp. *carotovora* from potato tubers. Universal Barcode (ITS) and secondary barcode (β -tubulin) for the identification of *Chaetomium* species were confirmed.

In pursuit of identifying potential pathogenicity genes of *Rhizoctonia solani* AG1-IA for exploitation in sheath blight (ShB) management, four putative candidate pathogenicity genes (JF701177, JF701181, HS077645, and HS977578) were isolated and characterized. For the first time, the complete Type 3 Effectors profile of avirulent Indian Xoo strain (race 4) causing bacterial blight of rice has been established. Gene expression profiles of tomato leaf tissues during *Tomato leaf curl New Delhi virus* (ToLCNDV) infection, resulted in 920 differentially expressed genes. The KEGG Pathway analysis of these genes categorizes 652 differentially expressed genes into 77 known pathways, mostly related to increased respiration rate, decreased rate of photosynthesis, accumulation of soluble sugars/starch and coding enzymes for elevated levels of amino acid synthesis. Infection efficiency or generation rate model for leaf blast of rice was developed to explain accurate temperature response on the pathogen and thus are useful for disease forecasting and assessing climate change impact.

The plant endophytic *Pseudomonas putida* BP25 and *Bacillus megaterium* BP17 were found to release antimicrobial volatiles to inhibit a broad range of pathogens and plant parasitic nematode. The transgenic strategy to manage *Papaya ringspot virus* (PRSV) was initiated and two Southern hybridization positive putative transformants were developed having single copy number insertion of the viral transgene. Papaya line Pune Selection-1 has been registered with ICAR, NBPGR, New Delhi as the unique germplasm for tolerance to Papaya ringspot virus (PRSV-P) with yellow pulp. Dioecious lines of papaya selections PS-1, PS-2, PS-3, and PS-5 are being converted into the gynodioecious lines. Severe invasive insect pest known as South American tomato pinworm, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) also known as the tomato leaf miner was observed for the first time infesting tomato crop in Maharashtra, India. This pest has been identified as the most serious threat to tomato production worldwide. The pest alert has been issued in the webpage of IARI and ICAR.

School of Natural Resource Management

IARI has developed an indigenous fermenter for mass production of compost inoculum. These microbial inocula can improve the efficiencies in the *ex-situ* and *in-situ* degradation of paddy and wheat straw. Endophytic bacteria which have the second genome of plants, have been isolated from mustard, chickpea, pearl millet and maize, and characterized for several plant growth promoting traits. The application of biofilmed microbial inoculants was observed to be significantly enhancing the plant photosynthetic pigments in chrysanthemum, carnation, tomato and capsicum.

Pusa STFR (Soil Test and Fertilizer Recommendation Kit) Meter is now available for the analyses of as many as 10 relevant soil parameters *viz.*, pH, EC, OC, available nutrients (P, K, S, Zn, B), and gypsum and lime requirements. It could be connected to the personal computer (PC) through a computer-interface. The commercial production of Pusa STFR has been licensed to eight firms; two of them have already started its marketing. For abating the abysmally low use efficiency of applied Zn (2%), slow-release Zn fertilizers *i.e.* nano clay polymer composites (NCPCs) containing 5 and 10% Zn were synthesised that could enhance the applied Zn use efficiency by 8-10%.

Crop stress characterization based on thermal image processing could evaluate the moisture and temperature stress in wheat crop. A new Crop Status Index (CSI) was derived for wheat, based on a minimum dataset of physiological, biochemical and biophysical parameters. This index indicated that increasing abiotic stress intensity might cause decline in crop vigour due to constraints in soil and environmental resources under future global warming

scenarios. Work on the use of drones in field phenotyping of rice revealed its potential for phenotyping of crops in fields. A Large Aperture Scintillometer (LAS) was installed in the experimental farm of IARI, covering a path length of 990 m over intensively cultivated irrigated cropland. The diurnal pattern of energy fluxes at different growth stages of the crop and their seasonal patterns were analyzed about the crop parameters and soil moisture. Agro-met advisory bulletins are prepared and disseminated on every Tuesday and Friday to the farmers of the National Capital Region of Delhi.

Farm equipment such as paddy straw collector-cum-chopper, precision pneumatic planter, solar powered gadgets like knacksack sprayers, vegetable vending cart, and solar powered refrigerator was developed for use of 'Green Energy.' Fourteen machines for Animal feed block making with different capacities, feed and fodder crusher, feed and fodder mixer, and urea molasses mineral block formation were supplied to the end users for preparing complete feed blocks from the agri-residues.

Sustaining the productivity of rice-wheat system while enhancing soil carbon sequestration and mitigating greenhouse gases (GHGs) emissions is a significant challenge to the conventional transplanted rice (TPR)-conventional till wheat (CTW) system in the IGPs of India. As an important adaptation-led mitigation strategy to climate change the cotton-wheat system under zero till broad bed with residue could be a potential alternative to transplanted rice-conventional till wheat rotation. A System of Wheat Intensification (SWI) revealed that using a narrow spacing (20×10 cm) of crop, could increase wheat yield by 23.2% over conventional practice. Similarly, a system of crop intensification (SCI) in soybean spaced at 45×45 cm and 30×30 cm was found superior to the conventional method.

Intensification in agriculture has indeed led to food and nutritional security in this country. However, it has also invited several environmental problems such as pollution of soil, water, air, and food; depletion of groundwater and the climate change. Inventory of greenhouse gas emission from agriculture was updated by IARI, which was approved and submitted by the Govt. of India to the United Nations. Pusa-mKRISHI, a dynamic two-way communication tool, was developed to communicate with farmers for their field queries through pictures, text SMS, and voice mail. Also, a documentary film on "Adaptation Strategies for Climate Change" of 15 minute duration was prepared to demonstrate the impact of various technological interventions to cope with climate change in different sectors of farming and also to improve their livelihood security.

Short- and long-term effects of sewage water irrigations on agricultural lands and their concomitant opportunities for nutrient savings and threats regarding metal and pathogen loads were investigated. Some land, water, and crop management strategies and low cost treatment technologies for managing these risks were also devised. An innovative eco-friendly wastewater treatment technology, designed by IARI, was highly appreciated and strongly recommended for its promotion across the country by the Second Committee on Agriculture on Demands for Grants (2014-15) of the Ministry of Agriculture (DARE). A perspective plan for the overexploited blocks of the Muzaffarnagar district of Uttar Pradesh was also prepared, in collaboration with the IIWM (Bhubaneswar). Methodologies for achieving enhanced input use efficiencies, devising efficient surface (flood) irrigation guidelines and impact of some diversified cropping systems and INM strategies on the system productivity, irrigation water use efficiency and profitability were also formulated.

School of Social Sciences

IARI Post Office Linkage Extension Model, an innovative Agricultural Extension Model, designed and validated for effective outreach mechanism for frontline extension system, has been expanded in partnership with the Krishi Vigyan Kendras (KVKs) in 55 districts of 14 states covering 110 branch post offices. The model is useful in the dissemination of farm information to the remotely located farmers and is a satisfactory means of making improved agricultural technologies available in the rural areas in relatively lesser time and cost.

Farmers were mobilized to take up commercial *agri* enterprise ventures to maximize Farm Profitability through Entrepreneurship Development and Farmer Led Innovations. Focus Group Discussions for taking up specialty agricultural products and value addition of selected fruits and vegetables were conducted. The farmers showed keen interest in protected cultivation, seed production, floriculture, bio-fertilizers and value addition technologies of IARI for commercial uptake as per micro-screening exercises conducted in the project villages. Under the action research project on mobilizing farmers to take up seed production of high yielding IARI varieties of selected vegetable crops, a Public- Public Partnership Farm Model was developed. The process of connecting a research institute – the developer of hybrids/ varieties (IARI), a rural bank (NABARD) and a commercial seed-producing agency (National Seed Corporation) with the Farmers for turning them into farm entrepreneurs was designed, tested and found effective.

During last year, 3532 field demonstrations of IARI technologies were conducted covering an area of about 1000 ha. Apart from this, two e-agri nutri centers are being set up in Sonapat, Haryana, and Baghpat, U.P. for creating awareness and for the dissemination of agri nutri deliverables by using the multimedia modules. IARI technologies are assessed and disseminated through extension outreach programme at different locations of the country using various approaches to Development of Lighthouse villages through integrated approach, National Extension Programme through Linkages with NARS and Strengthening the Public-Private Partnership in technology dissemination in partnership with 31 Voluntary Organizations.

Scientists and students of this Institute have published more than 750 research papers in peer reviewed journals of national and international repute (224 with IF > 4.0; 83 with IF > 3.0; 133 with IF >1.0 and 337 with IF <1.0). We have received 93 externally funded research projects (34 projects > 50 Lakhs, 59 projects < 50 lakhs) with a funding of about 64 crores. IARI has filed 95 patents and commercialized 135 technologies to 362 industrial partners. Under Agribusiness incubation, we have incubated 15 Startup companies working in Agri sector out of which five Startups have been graduated this year. Through the commercialization of these technologies, we have generated revenue of around Rs, 157 lakhs in this year. As a step towards the mission of Skill India, the Institute has conducted 28 training programmes in which 600 trainees have participated. In addition to these, seven summer institutes / workshops / Symposium were also organized for 289 participants. About 20 Skill Development Training and Exposure Visit of Farmers were conducted and about 1000 farmers and farmwomen were benefitted. Pusa Krishi Vigyan Melawas conducted during March, 10-12, 2015, at IARI, with the theme “IARI Technologies for Inclusive Growth”. In this mela, nearly one lakh farmers across the country participated, and were exposed to different technologies of the Institute.

IARI has tremendous strength and provides a powerful platform for research, education and extension activities. In this Convocation, 242 students (120 M. Sc., 7 M. Tech., and 115 Ph. D) are receiving their degrees. Till now, IARI has awarded degrees to 8153 students (3660 M.Sc., 25 M.Tech. and 4468 Ph.D.), which include 349 international students. Our diaspora of alumni is intensely committed to the farmers' welfare. IARI has a great admiration among the potential students, the job seekers, the job providers, the think-tank, and the society as well. I am

convinced that our students who are bestowed with their degrees today will work to enhance productivity, profitability, and sustainability of 'Farm Families' of our nation. It's a moment of great pride to IARI in conferring these qualified young researchers to the service of our Indian nation and welfare of the world at large.

Jai Hind!