Printed: June, 2015

Supervision and Guidance
Dr. Ravinder Kaur
Director (Acting)

Dr. K.V. Prabhu
Joint Director (Research)

Compilation Committee and Editorial Team
Dr. C. Vishwanathan, Dr. Rashmi Aggarwal, Dr. Premlata Singh, Dr. S.K. Singh, Dr. Vinod,
Dr. U.K. Behera, Dr. K.M. Manjaiah, Dr. S.S. Sindhu, Dr. Kehar Singh and Mr. D.K. Parashar

Correct citation: IARI. Annual Report 2014-15, Indian Agricultural Research Institute,
New Delhi - 110 012, India.

Copies printed: 1500

ISSN 0972-6136

IARI website: www.iari.res.in
The Indian Agricultural Research Institute (IARI) with a history of bridging the science to the needs of the country maintained its leadership position in agricultural research, education and extension in India. To address the emerging needs of the farmers and consumers, IARI has developed several economically and environmentally sustainable technologies during this year for enhancing food and nutritional security, agricultural exports and farm profit. During 2014-15, the Institute has developed new crop varieties/hybrids with improved yield, quality and climate resilience, crop and natural resource management technologies and new farm machineries with enhanced input use efficiency and minimal global warming potential.

Genomics aided crop improvement programme of the Institute led to the development and release of eight improved varieties of food crops with enhanced yield, quality, and tolerance to biotic and abiotic stresses. Two high yielding superior quality bread wheat varieties HD 3118 (Pusa Vatsala) and HS 542 (Pusa Kiran) with inbuilt resistance to leaf and stripe rusts were released for cultivation under late-sown irrigated conditions of NEPZ and early-sown rainfed conditions of NHZ, respectively. A high yielding durum wheat variety HI 8737 (Pusa Anmol) rich in β-carotene, iron and zinc was released for timely-sown irrigated conditions of Central Zone. A dicoccum variety HW1098 (Nilgiri Khapli) and a barley variety BHS 400 (Pusa Sheetal) were also released for cultivation. A long slender grain and aromatic rice variety Pusa 1592 resistant to bacterial blight was developed by Marker Assisted Selection (MAS) and released for the Basmati growing Region II (Punjab, Haryana, Delhi and Jammu & Kashmir). MAS-derived blast resistant Basmati rice variety Pusa Basmati 1609 with an average yield of 4.6 t/ha was identified for release in the Basmati growing regions. Since it is short duration (120 days) variety, it will not only save water but will also help timely sowing of ensuing wheat crop. In chickpea, an extra-large seeded Kabuli variety BG 3022 was identified for release in NWPZ. It yields about 1.8 t/ha which is 10.4% higher than the best check. In vegetables and fruits 10 hybrids/varieties were indentified/released during this year. Pusa Swarnika, an early maturing (1st week of June) grape hybrid was identified for release. Two early maturing cauliflower varieties Pusa Ashwini and Pusa Kartiki were identified for cultivation in Punjab, Uttar Pradesh, Bihar and Jharkhand and NCR Delhi region. An ash gourd hybrid Pusa UrmI and a variety Pusa Sabzi Petha were released for Kharif season cultivation in Zones VI and VIII. In bitter gourd, a hybrid Pusa Aushadhi was released and two varieties, namely, Pusa Rasdar and Pusa Purvi were identified. Summer squash variety Pusa Pasand was identified for cultivation in Delhi and NCR region. Pusa Kulfi, a cream coloured self-core tropical carrot variety and Pusa Shweta, a radish variety were identified for cultivation in Delhi and NCR region. Pusa Cherry Tomato 1, the first indigenous cherry tomato variety suitable for greenhouse cultivation was identified for release. These varieties and hybrids have already reached the farmers and expected to benefit farmers and consumers.

Crop Protection technologies and molecular diagnostic protocols have been developed for various fungal and viral diseases diagnosis and management. RNAi technology was developed for management of Meloidogyne incognita by silencing nematode genes coding for FMRFamide-like peptide (FLP) and a pharyngial gland specific gene 16D10. Novel antifungal and nematicidal chemical molecules were identified, and controlled release nano-formulation of Carbendazim was developed. Efficient weed management strategies were developed for rice–wheat cropping system under conservation agriculture.

The basic and strategic research programmes of the Institute has identified genes and mapped QTLs for agronomic and adaptive traits. Functional validation of stress responsive genes in transgenic rice system identified rice ABAR6 gene for improving drought tolerance in rice. New QTLs for drought tolerance were mapped in wheat, and MARS was used to introgress QTLs for drought and heat tolerance in to elite Indian varieties HD 2733 and GW 322. Genomic selection models were standardized in maize which will be useful for predicting performance of hybrids under drought stress. Two novel genes for leaf rust resistance were mapped from the derivatives of Ae. markgrafii (ER9) and T. timopheevii (G12). In mustard, a SSR marker
BRMS006 linked to white rust resistance was identified using F, RILs of Varuna x Bio-YSR cross. Molecular markers linked to black rot resistance gene Xca1bo and downy mildew resistance gene Ppa3 were mapped in cauliflower. A single recessive gene conferring resistance to Bakanae disease was mapped using the cross between susceptible rice cv. Pusa Basmati 1121 and resistant cv. Pusa 1342.

A large number of crop and natural resource management technologies were developed and transferred to the farmers during this year. Conservation agriculture (CA) practices such as direct seeded rice followed by zero tilled wheat can reduce the global warming potential by 53% and improve soil health as compared with conventional rice-wheat system. Inclusion of summer mungbean and its in situ residue recycling enhanced the system productivity by 19.1% in basmati rice–wheat system. Nanoclay polymer composites loaded with phosphorus was developed which reduced the P fertilizer requirement by 50% in wheat, and thus expected to reduce input cost significantly. Innovative eco-friendly wastewater treatment facility integrating native media, microorganisms and emergent wetland plants such as Typha latifolia was engineered at pilot scale. Phragmites and Arundo-based systems were developed for efficient removal of heavy metals from wastewater. BGA based composite liquid inoculants, encapsulated microbial inoculants for phosphorus nutrition, microbe mediated nutrient cycling for soybean-wheat and rice-wheat cropping systems, and low cost technologies for utilization of biomass as feed, value added products and fuel were developed. The Institute has developed a self propelled garlic planter for mechanized planting of garlic cloves which will reduce drudgery and increase the production. Solar power based Solar Powered Refrigerator, Solar Photovoltaic Powered Ventilation and Cooling System of a Greenhouse and Pusa Solar Powered Knapsack Sprayer were developed for minimizing the use of non-renewable energy in agriculture.

Noteworthy progress has been made by the Institute in agricultural extension. The IARI Post Office Linkage Model for frontline extension has been expanded in partnership with Krishi Vigyan Kendras (KVKs) in 55 districts of 14 states of the country. For performance assessment and transfer of IARI technologies, >2200 demonstrations were conducted in collaboration with different agencies. The Annual Pusa Krishi Vigyan Mela of the Institute was organized during March 10-12, 2015 on the theme “IARI Technologies for Inclusive Growth” attracted ~1 lakh visitors including farmers, extension personnel, entrepreneurs, students, etc. from different parts of the country. The Agricultural Technology Information Centre (ATIC) continues to provide products, advisory services, technologies and information to the farmers and other stakeholders through a single window delivery system. To empower rural women, the Institute has organized about 21 vocational trainings specifically for women for capacity building in farm and non-farm occupations.

This year also Institute was ranked as number 1 Institute for agricultural education in India, and contributed to about 40% of the agricultural scientists recruited by ASRB (ICAR) during 2014. The Institute conferred Degree of Doctor of Science (Honoris causa) on Dr. José Graziano da Silva, Director-General, FAO in a special convocation held on September 8, 2014. In the 53rd Convocation of the IARI held on February 20, 2015, a total of 108 M.Sc., 07 M.Tech., and 66 Ph.D. degrees were awarded. I congratulate scientists and students of the Institute who developed technologies and received prestigious awards/recognition and brought laurels to the Institute. The Institute’s achievements during this year will have significant impact on livelihood security of the farmers and food security of the nation.

I appreciate Dr. K.V. Prabhu, Joint Director (Research) and the multidisciplinary editorial team for compiling and bringing out this report in time.

June 30, 2015
New Delhi

(Ravinder Kaur)
Director
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IARI : AN INTRODUCTION

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

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

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

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 and human resources development in agricultural sciences
- To provide national leadership in agricultural research, extension, and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards
- To develop information systems, add value to information, share the information nationally and internationally, and serve as a national agricultural library and database

The present campus of the Institute is a self-contained sylvan complex spread over an area of about 500 hectares. It is located about 8 km west of New Delhi Railway Station, about 7 km west of Krishi Bhavan, which houses the Indian Council of Agricultural Research (ICAR), and about 16 km east of Indira Gandhi International Airport at Palam. The location stands at 28.08° N and 77.12° E, the height above mean sea level being 228.61m. The climate is sub-tropical and semi-arid. The mean maximum daily temperature during the hot weather (May-October) ranges from 32.2 °C to 40 °C and the mean minimum temperature from 12.2 °C to 27.5 °C. June to September are rainy months during which about 500 mm of rainfall is received. Winter sets in from mid-November and is delightful. The mean maximum temperature during winter (November-March) ranges from 20.1 °C to 29.1 °C and the mean minimum temperature from 5.6 °C to 12.7 °C. During winter, a small amount of rainfall (about 63 mm) is received.

The Institute has 19 divisions, 2 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, one krishi vigyan kendra at Shikohpur, 3 all India coordinated research projects with headquarters at IARI, and 18 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3034 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹ 34,257.46 lakh (Plan & Non-Plan) for the year 2014-15.
True to its tradition, the Indian Agricultural Research Institute (IARI) or the Pusa Institute continued to play a leadership role in agricultural research, education and extension in the country. The Institute developed several new technologies for food and nutritional security, and enhancing agricultural exports. Genomics based accelerated crop breeding programmes of the Institute resulted in the release of several varieties/hybrids with improved yield, quality and adaptability to climate change in field and horticultural crops. The Institute has also developed several technologies for crop and natural resource management, plant protection, and post-harvest processing, new farm machineries for enhancing input use efficiency, farm profit and minimization of global warming potential. The scientists of the Institute have published several high impact publications in peer reviewed national and international journals, and technical and popular articles.

The crop improvement programme of the institute resulted in the development and release of eight improved varieties of food crops with enhanced productivity, quality and adaptability to different agro-ecosystems with inbuilt resistance to biotic and abiotic stresses. A superior quality bread wheat variety HD 3118 (Pusa Vatsala) with an average yield of 3.95 t/ha and resistance to leaf and stripe rusts and moderate resistance to foliar blight was released for cultivation under late sown, irrigated conditions of North Eastern Plains Zone. HS 542 (Pusa Kiran), a bread wheat variety with an average yield of 3.29 t/ha, was released for early sown rainfed conditions of Northern Hills Zone. This variety is resistant to leaf and stripe rusts with good chapatti making quality. A *durum* wheat variety HI 8737 (Pusa Anmol) with an average yield of 3.29 t/ha and rich in β-carotene, iron and zinc was released for timely sown irrigated conditions of Central Zone. A *dicoccum* variety HW1098 (Nilgiri Khapli) and a barley variety BHS 400 (Pusa Sheetal) were also released for cultivation in *dicoccum* growing areas and NHZ, respectively.

MAS (marker assisted selection) was employed to introgress bacterial blight resistance genes *xa13* and *Xa21* in Pusa Sugandh 5 to develop a long slender grain and aromatic rice variety Pusa 1592. This variety matures in 120-125 days and yields 4.73 t/ha. It was released for the *Basmati* growing Region II (Punjab, Haryana, Delhi and Jammu & Kashmir). MAS derived blast resistant *Basmati* rice variety Pusa Basmati 1609 having genes *Piz5* and *Pi54* with 120 days duration and average yield of 4.6 t/ha was identified for release in the *Basmati* growing regions of the Uttar Pradesh, National Capital Region (NCR) of Delhi, Uttarakhand and Punjab. This variety has superior grain and cooking quality traits, and resistance to neck blast and moderate resistance to leaf blast. A marker assisted backcross breeding programs was initiated to incorporate multiple genes/QTLs for bacterial blight (*xa13*, *Xa21*, *Xa33* and *Xa38*), blast (*Piz5*, *Pi54* and *Pi9*) and sheath blight (*qSB11-1*) into the *Basmati* rice varieties.

MAS-aided introgression of favourable allele of β-carotene hydroxylase (*crtRB1*) in the parents of selected maize hybrids helped an increase in the mean kernel β-carotene from 2.1 to 17.5 μg g⁻¹. The reconstituted hybrids had an average of 8-fold increase in kernel β-carotene, with a maximum of 10-fold increase in the improved version of Vivek QPM 9. In chickpea, an extra-large seeded Kabuli chickpea variety BG 3022, suitable for the north western plains comprising the states of Rajasthan, UP, Punjab and Haryana was identified for release. It yields about 1.8 t/ha which is 10.4% higher than the best check. Seventeen varieties of mustard released from IARI, New Delhi were registered with PPV&FRA as extant varieties.

The focused research of the School of Horticulture on improvement of disease resistance, quality and yield led to the release/identification of 10 hybrids/varieties in fruits, vegetables and flower crops. Pusa Swarnika, a grape hybrid (Hur x Cardinal) was
identified for release during 54th Convocation of IARI. It matures early (1st week of June) and produces large (5-6 g), round and golden-yellow colored berry with high TSS (20-22°Brix). Development and evaluation of 64 mango hybrids resulted in identification hybrid H 1-11 with high fruit weight (346 g) followed by H 8-11 and H 11-2 (222 g). Three polyembryonic mango rootstocks (13-1, Turpentine and Bappakai) and eight exotic cultivars, i.e. Palmer, Lily, Kensington, Tommy Atkins, Maya, Kent, Keitt and Bajrang were introduced. In a rootstock trial on mango, maximum fruit weight was recorded in Pusa Arunima (192.87 g) on Kurakkan rootstock. In sweet orange, Pusa Sharad, Pusa Round and MS 7 were found to produce a fruit weight (~250g) and MS1 produced significantly higher TSS (13.43°Brix) as compared with checks. In acid lime, clone ALC 2 was identified for highest fruit weight (54.60 g) and ALC 21 for highest juice content (28.70mL). Evaluation of several papaya hybrids led to the identification of Pusa Dwarf x Sinta with early flowering (81 days after planting) and high TSS (10.2°Brix), RCTP-I x Pusa Nanha for maximum fruit yield (39.6 kg plant\(^{-1}\)) and P 9-12 with highest lycopene content (4.30 mg/100 g). In Kinnow mandarin, Sohsarkar rootstock was found suitable for regions with saline water. In grapefruit, Karnakhatta and RLC 4 rootstocks proved most productive for Marsh Seedless and Redblush cultivars. The Kagzikalan lemon trees on RLC 4 rootstock yielded highest fruit weight (53.43 g), while juice recovery was highest on rough lemon (45.09%). Success in propagation of apple and Prunus species was achieved through hardwood cuttings treated with IBA (3000 ppm, 30 seconds) on hot-bed (21°C).

An early maturing cauliflower variety Pusa Ashwini (DC 31) was identified by AICRP-VC for cultivation in Zone IV (Punjab, Uttar Pradesh, Bihar and Jharkhand). Pusa Kartiki (DC 23000), an early maturity cauliflower variety was identified by IARI Variety Identification Committee (IARI-VIC) for cultivation in NCR Delhi region. Three cauliflower inbreds (BR 207, AL 15 and BR 161) and five genetic stocks (BR 207, AL 15, Sarjumaghi, BR 2 and AL 3) were found to be resistant to black rot and downy mildew diseases. An ash gourd hybrid, Pusa Urmii (DAGH 16) was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops (CSCCSNRVHC) for Kharif season cultivation in Zones VI (Rajasthan, Gujarat, Haryana and Delhi) and VIII (Karnataka, Tamil Nadu and Kerala). Ash gourd variety Pusa Sabzi Petha (DAG 12) was identified by AICRP-VC for Kharif cultivation in Zone VIII. A bitter gourd variety Pusa Aushadhi was released by CSCCSNRVHC for cultivation in Zones VI. Bitter gourd varieties Pusa Rasdar and Pusa Purvi were identified by IARI-VIC for cultivation in Delhi and NCR region. Gynoecious cucumber hybrids DGCH 18 and DGCH 15, and a monoecious hybrid DCH 9 which produce significantly higher yield than the check Pant Sankar Khira 1 were developed. Luffa selections DSG 43 (13.5 t/ha), and DSG 33 (13.0 t/ha) were found possess superior fruit quality and produce 11.5 and 7.5% higher yield, respectively, over check Kalyanpur Hari Chikni (12.1 t/ha). Three pumpkin selections, namely, DPU 48, DPU 12 and DPU 37 yielded higher (47.5, 43.5 and 41.16 t/ha, respectively) than the check Pusa Vishwas (34.83 t/ha). Summer squash variety Pusa Pasand was identified by IARI-VIC for cultivation in Delhi and NCR region. Two promising muskmelon selections, namely, DM 159 and DM 154 with high yield, better fruit quality and tolerance to *Fusarium* wilt were identified. In long and round melon, six selections with higher yields were identified.

A long-fruited brinjal hybrid DBHL 211 (51.7 t/ha) was found superior over check Hybrid 704 (44 t/ha). In round fruited brinjal, hybrids DBHR 95 (53.6 t/ha), DBHR 4 (52.8 t/ha) and DBHR 7 (49.9 t/ha) were found superior over check Navkiran (45.4 t/ha). Brinjal genotypes G 26, G 37, G 48, G 81 and G 109 were found to be resistant to *Verticillium* wilt under field conditions. The first indigenous cherry tomato variety suitable for greenhouse, Pusa Cherry Tomato 1, was identified by IARI-VIC for cultivation in Delhi and NCR region. Earliest fruit set under high temperature regime in tomato was recorded in DTH 9 and DTH 10 followed by Pusa Sadabahar and L.p.2 (a selection from cross of *L. pimpinellifolium*). Lines DT-C-10y (orange-yellow colour fruits), Sel. 120, and L.p.2 (red colour fruits) were found promising for low cost polyhouse cultivation. Genotype L.p. 2 recorded high lycopene (4.5 mg/100 g) and DT-C-10y recorded high ß-carotene (1.7 µg/ g). In chilli, five lines (DLS-Sel-10, WBC-Sel-5, PBC 142, PBC 345 and Tiwari) were found
resistant to leaf curl complex. Pusa Kulfi (IPCPm1) a cream coloured self-core tropical carrot variety and Pusa Shweta (IPRWw1), a radish variety were identified by IARI-VIC for cultivation in Delhi and NCR region. Cowpea lines CP 5, CP11, CP 55, CP 56 and Pusa Sukomal recorded high resistance to Cowpea golden mosaic virus. In okra, hybrid DOH 1 recorded 19.1t/ha yield with only 1% YVMV incidence.

In flower crops, Pusa Mahak, a hybrid tea variety of rose, was evolved by selection from open-pollinated population of cv. Century Two. Pusa Deep, an early flowering variety (85-95 days after sowing) of French marigold, was identified. In gladiolus, Melody Open, a selection from the open-pollinated seedlings of variety Melody was registered with NBGPR, New Delhi. A red coloured gladiolus hybrid P-16-1 x Eurovision producing straight and long spikes (93 cm) with >16 florets per spike was identified. At IARI Regional Station, Katrain, several Asiatic lily genotypes and hybrids were evaluated and found that the hybrid PKLH 2 (153.5 days) was earliest flowering followed by PKLH 8 (159.9 days). Similarly, seven Lisianthus genotypes, namely, Echo Double Yellow, Echo Double Champagne, Echo Double Pure White, Echo Double Lavender, Echo Double Pink Picotee, Echo Double Blue and Echo Double Pink were evaluated for their suitability for cut flower production.

The Institute is actively involved in the collection, maintenance and utilization of plant genetic resources including land races, wild relatives of crops, exotic and indigenous genotypes and introgression lines. In rice, Athad Apunnu, C101A51, Chandana, IR 58025B, Panchami, PAU 201, Pusa 1342 and Varun Dhan were found to be highly resistant to bokanee disease caused by Fusarium fujikuroi. In maize, inbreds tolerant to turcicum leaf blight (TLB) and maydis leaf blight (MLB) were identified. Sweet corn inbreds with sh2sh2/su1su1 and waxy inbreds with wx1wx1 genetic constitutions were developed. In chickpea, 177 land races obtained from ICARDA were screened and ILC 0 from Latvia resistant to foc 4 and foc 5 races of Fusarium wilt was identified. Vigna unbellata was identified as a potential donor for Al tolerance. In Brassica, 750 germplasm lines belonging to different Brassica species were maintained. In cauliflower, Ogura CMS system was established in the genetic background of early group (Pusa Meghna and DC 41-5) and mid-late group. In cucumber, 69 germplasm with novel traits such as gynoecious character, high carotene content, resistance to Cucumis hysteis disease, parthenocarp, gherkin type, and multiple pistillate type were imported from USA and China. Over 100 germplasm/advance breeding lines in Luffa were evaluated during spring and summer season for yield and virus resistance. Fifty six and 150 germplasm/ advanced breeding lines in pumpkin and muskmelon, respectively, were evaluated. Two hundred lines of muskmelon, watermelon and related species were introduced from USDA. In brinjal, 155 working germplasm and wild brinjal species viz., S. aethiopicum, S. incanum, S. gilo, S. insanum, S. indicum, S. torvum, S. khasianum and S. integrifolium were evaluated. Several germplasm lines of tomato, chilli, onion and pepper were imported from AVRDC Taiwan, HRI UK, NIAB, Japan and USDA for their utilization in improving yield, quality and disease resistance of these crops.

At the Pusa Indian type culture collection (ITCC), 42 new fungal and 3 bacterial cultures were added. A total of 10,000 specimens belonging to genera such as Absidia, Acremonium, Agaricus, etc. and 25 fungal species were digitized. Under insect biosystematics services, a total of 3,145 insect specimens were identified. Thirty eight important diagnostic characters for identification of Holotrichia species, viz., H. serrata (F.), H. consanguinea Blanchard, Schizonycha ruficollis (F.), Brahminacoriacea (Hope) and Sophrops riricollis belonging to subfamily Melolonthinae were documented. Two new species of Igera, namely, I. shillongensis and I. kolasibensis (Hemiptera: Cicadellidae: Megophtalminae) were described from North-East India. A serious invasive insect pest, the South American tomato pinworm (Tuta absoluta) or tomato leaf miner was identified. Under nematode biosystematics, two new species, i.e. Deladenus albicicus n. sp. and D. processus n. sp. (Nematoda: Hexatylina) of insect parasitic nematodes were described in association with CCSCAU, Hisar. Evaluation of Pratylenchus species populations led to identification of two new species of Pratylenchus spp. viz., P. zeae and P. thornei. Thirty two soil and root samples from pomegranate trees in Maharashtra were found to be infected with root-knot
and reniform nematodes. *Meloidogyne incognita* was the most prominent species.

The School of Crop Protection made significant contributions in pathogen diversity analysis, race profiling, diagnostics and integrated management of important agricultural pests and pathogens. Genetic diversity of important pathogens such as *Phoma* spp., *Fusarium* spp., *Bipolaris* spp., *Ralstonia solanacearum* was analysed. Etiology of two new diseases; leaf and pod spot of lentil (*Alternaria tenuissima*) and panicle blight of rice (*Burkholderia glumae*) was ascertained. Molecular diagnostic protocols have been developed for various fungal and viral diseases which shall help in early diagnosis and better management. Antifungal natural products were identified from endophytic bacteria. Weather parameters related to outbreak of leaf folder and brown plant hopper were analysed. Integrated management of pest infecting vegetables based on intercropping and application of new formulations was validated.

The RNAi technology was used for management of nematode (*Meloidogyne incognita*). Silencing of FMRFamide-like peptide (FLP) genes *flp-14* and *flp-18* and a pharyngial gland specific gene *16D10* were found to reduce the penetration of nematode into host. The T<sub>3</sub> transgenic tomato lines exhibited reduction in nematode multiplication. Transcriptome data of *Heterodera cajani* was generated. Novel antifungal and nematicidal chemical molecules and essential oils were identified and characterized. Hydrogen based micronutrient formulation were developed for addressing boron and phosphate deficiency in crops. Novel encapsulating materials were developed for crops like rice and wheat under conservation agriculture.

The basic and strategic research programmes of the Institute made significant progress in unravelling the physiological and molecular genetic basis of biotic and abiotic stress tolerance of crops, mapping of QTLs for agronomic and adaptive traits, and quality improvement. RNAseq analysis of thermotolerance of wheat cv. HD 2985 resulted in the identification of heat stress regulated microRNA430 (miR430) which targets small heat shock proteins (*HSP17* and *HSP26*) and protein kinases (*CDPK* and *MAPK*) genes, and were confirmed by anticorrelated expression miR430-target genes in wheat under heat stress. Comparative transcriptome and Real-time RT-PCR analyses of heat tolerant wheat cv. HD 2985 and heat susceptible cv. HD 2329 revealed that maintenance of expression of AGPase and soluble starch synthase genes under heat stress is important for heat tolerance. Whole-genome RNAseq assay of waterlogging tolerant maize genotype HKI 1105 identified genes for oxygen sensing and aeranchyma formation including ethylene synthesis, N-end rule pathway and programmed cell death. Transgenic rice lines (T<sub>3</sub>) overexpressing Abscisic acid receptor 6 (*ABAR6*) under stress inducible *RD29A* promoter were evaluated for drought tolerance at vegetative stage in greenhouse conditions. The *ABAR6* transgenic lines maintained better relative water content, membrane stability, chlorophyll content and photosynthesis under drought stress (-90 kPa) as compared with WT plants, and showed better drought tolerance and recovery.

Significant progress has been made in combining QTLs for drought and heat tolerance by using marker assisted recurrent selection (MARS). Four MARS populations consisting of about 750-800 F<sub>5</sub> families were evaluated for physiological traits at multi-location under drought, and elite genotypes were selected. New QTLs were mapped using the F<sub>4</sub> base populations, and single nucleotide polymorphism (SNP) genotyping is being carried out for increasing the resolution of the QTLs. MARS was used to introgress QTLs for drought and heat tolerance in to elite Indian varieties HD 2733 and GW 322 and lines with more than 90% recurrent parent background were recovered and BC<sub>1</sub>F<sub>2</sub> and BC<sub>2</sub>F<sub>2</sub> homozygous lines were advanced. Analysis of variation in root growth of 33 wheat genotypes by trench profile wall method led to the identification of HI 1500, Raj 3765, HD 2687, HUW 468, HD 2932, HI 1531 and WH 730 with higher root density at deep soil zone (31-50 cm). The drought tolerant genotypes viz., N 59, HD 2985, DBW14 and C 306 showed narrow root angles
as compared to the genotypes bread for irrigated conditions. Phenotypic data of 240 maize subtropical lines at three locations under drought stress conditions and 30,000 SNP genotypic data were analyzed using 7 genomic selection models. This study identified 77 SNPs mapped to ten drought-responsive transcription factors in their vicinity, which are useful for predicting hybrid performance under drought stress.

Several QTLs for biotic stress resistance were mapped and introgressed in different crops. A dominant gene for leaf rust resistance at seedling stage was identified from genetic analysis of *Ae. markgrafii* derivative ER9; while a novel recessive gene *LrSel.G12* for leaf rust resistance was mapped in *T. timopheevii* derivative Selection G12. Plants with multiple rust resistance genes were selected in genetic background of elite wheat cvs. HD 2733, HD 2932 and HD 2967. Rust resistance genes *Yr10* and *Yr15* were transferred in genetic background of HD 2851. Leaf rust resistance gene *Lr45* is being transferred in to several genetic backgrounds using molecular markers developed by IARI. In mustard, using a F1 RIL mapping population derived from cross Varuna × Bio-YSR, an SSR marker BRMS006 linked to white rust resistance was mapped. Two flanking SCAR markers linked to black rot resistance gene *Xca1bo* have been developed and validated in cauliflower. Inter-specific crosses were attempted between cauliflower and alien *Brassica* species viz., *B. nigra* (IC56072) and *B. juncea* (Pusa Vijaya) to transfer black rot resistance. The crosses are recovered through embryo rescue. Two SSR markers linked to downy mildew resistance gene *Ppa3* was mapped in cauliflower. In tomato, late blight resistance gene *Ph3* was validated in resistant lines using CAPS and SSR markers. Genetic analysis of the cross between susceptible rice cv. Pusa Basmati 1121 and resistant cv. Pusa 1342 showed that the resistance to *Bakanae* disease is governed by a single recessive gene.

Significant progress has been made in mapping/introgression of genes/QTLs and transgenic development for quality improvement in different crops. In wheat, 286 RILs from a biparental mapping population (*WH542/ T. dicoccom* PI94624/*Ae. squarrosa* (409)/BCN) was phenotyped in six environments for grain micronutrients, and six common QTLs for iron and zinc were mapped. In pearl millet, the effect of pollination on Zn and Fe content was evaluated in 25 genotypes and genotypes with >70mg/kg Fe and >60 mg/kg zinc contents were identified. Association mapping is in progress to identify QTLs associated with grain Fe and Zn concentration in lentil. For introgression of low glucosinolates in to low erucic acid varieties of mustard, 150 single plants of two BC4F3s (LES-39 x EC 597325 and LES-1-27 x EC-597325) and BC3F4 were generated through MABB. For identifying low erucic acid and double low genotypes in mustard, 4885 single plants/bulks were screened for fatty acid profile and glucosinolate content and plants with <2% erucic acid and <30ppm glucosinate were identified. In soybean, efforts are being made to develop trypsin inhibitor free and low phytate soybean. MABB approach was used to introgress the null allele of Kunitz trypsin inhibitors (kti) from PI542044 and four advanced breeding lines free from KTI peptides were developed. To reduce seed phytate content for increasing mineral and protein bioavailability from soybean, transgenics were developed with seed-specific overexpression of *Phytase* and RNAi silencing of *MIPS* genes. Transgenic (T4) soybean showed up to 40% reduction in phytic acid content and improved bioavailability of iron (19.1% increase), zinc (9.9%) and calcium (11.7%). For enhancing β-carotene content in cauliflower, 12 markers linked to *Or* locus were identified, and using these markers β-carotene rich elite events were developed in early (~12ppm) and medium (~10ppm) maturity groups. In carrot, 20 polymorphic SSRs were analyzed in 288 F2 plants of the cross White Pale × IPC-126 and nine SSR markers (SSR-89, SSR-1-12T, DCM-2, GSSR-93, ESSR-58, ESSR-59, GSSR-154, GSSR-134 and GSSR-124) tightly linked to anthocyanin locus were identified.

As non-destructive high throughput phenotyping is crucial for bridging phenotype-genotype gap, digital color image and hyperspectral reflectance based phenotyping methods are being developed. Digital color image was used to estimate vertical gap fraction derived from top-of-canopy digital color photography of wheat canopies. An improved vegetation index, Excess Green minus Excess Red (ExG-ExR) was developed as low cost and high throughput method for assessing LAI and early vigour in wheat. Measurement of relative water content (RWC) of leaf is a major bottleneck in phenotyping for drought tolerance of crop. Hyperspectral reflectance...
based high throughput non-destructive methods were developed to assess RWC in rice.

Crop modeling, remote sensing and GIS technologies were effectively used for crop and resource characterization and management. The MODIS satellite Terra-EVI (Enhanced Vegetation Index) time-series dataset with spatial resolution of 500 m and temporal resolution of 16 days from 2000-2014 were used to predict Kharif rice yield. The zonal regression model was developed and validated with 2010-11 yield data. The district wise prediction was then aggregated into AER level and a yield forecast was made for AER-9 for 2014. Time series MODIS satellite-EVI product of 250m was also used for the agricultural calendar May 2012 to April 2013 to retrieve cropping system based on temporal EVI profile and mapped based on ground survey data from the study region. A prediction model for agricultural drought using long term satellite remote sensing data was developed. Multi-temporal SPOT VGT NDVI data at 10 days interval for Kharif season of 15 years (1998-2012) was used to develop a model for predicting agricultural drought through a remote sensing derived drought index called vegetation condition index (VCI). Prediction model worked very well for rainfed regions like Mewat and Ganjam.

The crop simulation models are vital for characterizing the crop growth and simulating the crop yields to predict the impacts of climate change, abiotic stress and crop management practices. The AquaCrop model was evaluated and found that it could predict grain yield and biomass of wheat satisfactorily. Web-based crop model InfoCrop-Wheat was designed and developed at IARI. Web InfoCrop is a web based crop simulation model that simulates the wheat crop growth on daily basis based on weather, soil, variety and management practices, and facilitates the simulation of wheat crop growth and yield.

The National Phytotron Facility (NPF) was largely used by scientists and students from IARI and other ICAR and non-ICAR Institutes for research on climate change, transgenic crops, gene expression, nutrient use efficiency, plant-pathogen interaction, genetic interventions for crop improvement, etc. During this year, 176 new experiments were accommodated along with a few previous on-going experiments. The NPF and Phenomics facility were visited by a number of domestic and foreign visitors including the delegates from the USA (University of Nebraska, and USDA-ARS), Australia, Tanzania, and Argentina.

The School of Crop and Natural Resource Management developed ecofriendly technologies involving conservation agriculture (CA) and integrated nutrient and other resource management to enhance use efficiencies of resources and improving soil health. Environmentally sound and economically viable technologies were developed on balanced usage of fertilizers, organic manures, crop residues and biofertilizers for sustainable high productivity of cropping systems. In a maize-wheat-mungbean cropping system, CA practices were found beneficial over conventional practices. Zero tillage (ZT) raised bed and ZT-flat bed (ZT-F) planting resulted in higher maize yield as compared to conventional tillage (CT)-bed or CT-F, while in wheat, CT-F or ZT-F planting gave higher yield as compared with bed planting with respective tillage. In mungbean, CT-bed planting resulted in significantly higher grain yield. However, system productivity, system partial factor productivity (NPK), net returns and B:C were significantly higher in ZT-F and ZT-B than in CT-F.

CA practices improved SOC and total N in surface soil and reduced methane emission from rice as compared with conventional transplanted rice – conventional tilled wheat system. Basmati rice–wheat cropping system (BRWCS) is the most remunerative system. Summer mungbean residue recycling and genotypic diversification were found to bring sustainability to this system. Mungbean inclusion in BRWCS and its in situ residue recycling enhanced the system productivity by 19.1% over Basmati rice–wheat–summer fallow system. Pusa Basmati 2511/HD 2967 genotypic combination registered highest system productivity in terms of Basmati rice–equivalent–yield followed by Pusa Basmati1/HD 2733.

Estimated return of carbon in rice-wheat cropping system measured in Inceptisol as a sum of stubble biomass C, root biomass C, rhizodeposition C, and external organic amended C ranged from 4.02 Mg ha⁻¹ yr⁻¹ under unmanured control to 16.49 Mg ha⁻¹
yr⁻¹ in the treatment receiving *Sesbania* green manure + farmyard manure + blue green algae (SGM + FYM + BGA) in rice, and LGLM (*Leucaena* green leaf manure) + FYM + *Azotobacter* in wheat. The C sequestration efficiency across the treatments varied from 6.05% in control to 21.29% in SGM+BGA in rice and LGM+FYM in wheat. Evaluation of P loaded nano-clay polymer composites (NCPC) loaded with oxalic acid, PSB and P in wheat in an alluvial soil revealed that application of half of recommended P through NCPC and full of recommended P through DAP were equally effective in biomass yield of wheat. Application of DAP, oxalic acid @ 40 ppm and PSB through NCPC increased soil available P significantly from 5.2 mg kg⁻¹ (control) to 8.5, 8.0 and 8.07 mg kg⁻¹, respectively. In rice-wheat cropping system, the highest water productivity (8.54 kg/ha.mm) was recorded for direct seeded Pusa Basmati 1509 and HD 2967 system.

Strategies for the management and reuse of wastewater and poor quality irrigation water were developed to enhance agricultural sustainability and reduce environmental problems. Innovative eco-friendly wastewater treatment facility involving emergent wetland plants such as *Typha latifolia* and native media and microorganisms that mimic natural wetlands was engineered at pilot scale. The treated water was safe for irrigation. The overall metal (Ni, Pb and Cr) reduction potential of five test emergent macrophyte species (such as *Typha latifolia*, *Phragmites karka*, *Arundo donax*, *Acorus calamus* and *Vetiveria zizanioides*) in the vertical subsurface flow wastewater treatment systems of IARI was assessed. *Phragmites* and *Arundo*-based systems were found to remove metals with high efficiency (84-86% and 90-92%, respectively) at lower (1 to 1.5 ppm) and highest (5-10 ppm) metal concentrations, respectively.

Protected cultivation technologies were evolved for growing off-season vegetables and flowers. Insect proof net house cultivation method was developed to produce virus free crop in the summer season under north Indian plains. Feasible technologies for cultivation of crops under shade net house during summer and tomato cultivation under insect proof net house during October to May were developed. Parthenocarpic hybrid cucumber and coloured capsicum were profitably produced under different protected structures. Forced ventilated polyhouse was found best for maximum cucumber and coloured capsicum production followed by naturally ventilated polyhouse (NVP) and insect proof net house (IPNH) with mulch. Total crop water requirement (CWR) per plant basis for crops grown inside greenhouse was calculated as 22, 45 and 70 litres for cucumber, capsicum and tomato, respectively. The CWR for chrysanthemum, gerbera and rose was estimated at 4.5, 18 and 27 litres, respectively.

New farm machineries viz., self-propelled garlic planter for mechanized planting of garlic cloves to reduce drudgery and increase the production was designed and developed; an oscillating soil separator for garlic harvester was also designed and developed. Wheel hoe was ergonomically evaluated in field for women farm workers. Renewable energy, i.e. solar power was utilized for developing Solar Powered Refrigerator for Rural Households, Solar Photovoltaic (SPV) Powered Ventilation and Cooling System of a greenhouse and Pusa Solar Powered Knapsack Sprayer. Farm Operation Service Unit (FOSU) in collaboration with other divisions and biomass utilization unit led to an efficient farm management with complete utilization of farm residues and other biomass on the campus and their conversion to the compost/FYM. This has led to self-sufficiency in terms of total compost/FYM requirement of IARI experimental farm as well as resource generation.

Postharvest technologies were evolved for value addition of farm produces. For ethylene based ripening of Dashehari mango, a treatment with 80 ppm ethylene for 16 h was standardized. Composite flour cookies using whole wheat and pearl millet flours were formulated with partial replacement of refined sugar using powdered jaggery. To minimize high browning and respiration rate that limit the shelf life of lotus stem and baby corn, different antibrowning agents were studied. Citric acid @1.5% was found to be the most promising to prevent browning in lotus stem when stored at 10°C and shelf life could be extended up to three days without any discolouration. Apple hard cider was made from fruits having 9 % TSS. The TSS of apple juice was chaptalized to 15 % TSS with pure honey (62 % TSS) and then fermented with active
yeast (Saccharomyces cerevisiae) for 72 h in 500 ml batch volume. Multigrain bread was developed using flour mixtures of whole wheat, sorghum, barley and finger millet. Fermentation of flour mixture was carried out with native microflora as well as with pure cultures for sour dough development.

Significant achievements have been made in bioprospecting of microbes from extreme environments for novel genes, development of biofilms and consortia of inoculants by use of fungal, bacterial and cyanobacterial matrix and microbial degradation of agrowastes. BGA based composite liquid inoculant for sustaining crop productivity and soil health improvement, and encapsulated microbial inoculants for phosphorus nutrition were developed. Suitable bio-control agents and their impact on rhizospheric microbial communities were identified, and microbe mediated nutrient cycling developed for improved productivity of soybean-wheat and rice-wheat cropping systems. Low cost technologies for utilization of biomass as feed, value added products and fuel were developed.

In crop simulation modelling research, InfoCrop Model was upgraded and a DSS for grape was developed. Climate resilient agricultural technologies and mitigation and adaptation strategies to climate change have been evolved. Free air CO₂ enrichment (FACE) study on wheat revealed that elevated CO₂ (550 ppm) markedly enhanced the photosynthesis and grain yield. However, it reduced the nitrogen content in both grain and straw significantly. Studies on interactive effect of elevated temperature with elevated CO₂ revealed that 2 and 3°C rise in temperature reduced the grain yield of wheat cultivars to an extent of 7 and 13%, respectively, while elevated CO₂ (550 ppm) countered the negative effect of elevated temperature and significantly enhanced the grain yield of wheat. This indicates that in future climatic scenario, the rise in atmospheric CO₂ level might help in countering the negative effect of rise in temperature up to a certain level on wheat yield. Mitigation studies on greenhouse gases emission in rice-wheat system revealed that growing of direct seeded rice followed by zero tilled wheat can reduce the global warming potential by 53% as compared with transplanted rice followed by conventional tilled wheat.

The School of Social Sciences and Technology Transfer made strides in research efforts towards the progress of agriculture and rural economy, development of innovative agricultural extension models and approaches including agri-entrepreneurship, and assessment and transfer of agricultural technologies. The analysis of public and private investments at all India level revealed that in spite of consistent increase in the private investment by the farm households and corporate, the total accumulated investment by farmers measured as the value of agricultural capital stock, did not show the commensurate increase. The study on energy use in agriculture showed that the structure and quantum of energy use in Indian agriculture has changed substantially with a significant shift from animal and human power towards machines, electricity and diesel. The analysis of total factor productivity (TFP) indicated an increase in TFP of rice in Haryana, Bihar and West Bengal but not in Punjab and UP during 2001-2010. In case of wheat, growth of TFP was insignificant during the last two decades, i.e. 1990-2000 and 2001-2010. The analysis of use of kisan credit cards (KCC) revealed that lengthy and tedious paper work followed by insufficient credit limit, non-availability of loan on time, and inflexibility in the number of withdrawals are the constraints faced by farmers. The study on rural non-farm employment (RNFE) in India showed that agriculture prosperity leads to development of RNFE in rural areas through provision of better employment environment and other linkages which inter alia seeks to develop rural non-farm sector and economy as a whole.

The IARI Post Office Linkage Model designed and validated for effective outreach mechanism for frontline extension system, has been expanded in partnership with Krishi Vigyan Kendras (KVKs) in 55 districts of 14 states covering 110 branch offices. Capacity Building of branch post masters helped in benefitting the farmers in Sheopur district of Madhya Pradesh and Sirohi district of Rajasthan. The survey of Mewat and Gurgaon district revealed change of variety, agronomic adjustments, multiple cropping, non-farm activities, and crop diversification as the
preferred strategies for climate change adaptation. For catering to the information needs of farmers, the content was developed for paddy var. Pusa Basmati 1121 for mobile agro-advisory to farmers in the form of text SMS. The prioritization of IARI technologies for agri-enterprise ventures in participatory mode revealed that farmers are keenly interested in protected cultivation, seed production, floriculture, bio-fertilisers and value addition of IARI technologies for commercial uptake.

The action research on developing agricultural entrepreneurs in vegetable seed production amply indicated that the enterprise development resulted in enhanced farm income. The replication effect was also observed among the non-adopted farmers and in the neighbouring villages after the success of project farmers. Under the initiatives for climate resilient agriculture, the farmers were convinced that paddy variety Pusa Basmati 1509 under direct seeded rice (DSR) helped in saving 3-4 irrigations. A data base was developed on the comparative study between the IPM and non-IPM practices for rice and vegetable crops as well as the constraints faced by farmers in adoption of IPM technologies.

The intervention on development of market led extension models/model villages through technology integration resulted in enhancing the productivity of different crops and income of farmers significantly through adoption of IARI technologies. For performance assessment of IARI varieties, a total of 163 demonstrations on wheat, palak, pea and lentil were conducted in these villages during Rabi 2014-15. Under the National Extension Programme (NEP) in collaboration with selected ICAR institutes and SAUs, IARI varieties and technologies were disseminated through 306 demonstrations conducted on wheat, mustard, lentil, chickpea, palak, pea, carrot, and brinjal in 15 locations during Rabi 2013-14. During Kharif 2014, a total of 332 demonstrations of paddy, moong, pigeon pea, bajra, bottle gourd, tomato, chillies and okra covering an area of 103.72 ha were conducted. Under IARI-Voluntary organizations collaborative program (32 VO), a total of 1461 demonstrations covering an area of 432 hectares of IARI varieties were conducted in 26 locations for wheat, mustard, lentil, pea, spinach, onion, chickpea, bottle gourd, carrot, cauliflower, brinjal, paddy and marigold during Rabi 2013-14. The productivity and B:C ratio of most of the demonstrated IARI crop varieties were significantly higher than that of local varieties. The Annual Pusa Krishi Vigyan Mela of the Institute was organized during March 10-12, 2015 on the theme “IARI Technologies for Inclusive Growth”. In addition to IARI, a large number of ICAR institutes, SAUs, private organizations, KVKs, CGIAR, NGOs, media agencies, progressive farmers, etc., participated in the mela to demonstrate their technologies/products for display or sale. Around 1 lakh visitors from different parts of the country including farmers, farm women, extension personnel, entrepreneurs, students, etc., visited the mela.

The Agricultural Technology Information Centre (ATIC) is effectively providing products, advisory services, technologies and information to the farmers and other stakeholders through a single window delivery system. The farmers are also given farm advise through Pusa helpline (011-25841670, 25846233, 25841039 and 25806300), Pusa Agricom (1800-11-8989), exhibitions, farm literatures and letters. A second level of kisan call centre (1800-180-1581) has also been established at ATIC to provide solutions to the problems/queries of farmers of Delhi state. Demonstrations were also conducted in crop cafeteria, medicinal garden, nutrition garden and fruit orchard for showcasing the IARI technologies to the farmers.

The Institute’s KVK maintained to play a catalytic role in enhancing farm profitability, combating the problem of unemployment/underemployment and improving income of farmers, rural women and youth. A total of 42 on-farm trials on different field/farm related aspects including animal husbandry were conducted during Kharif 2014. A total of 354 FLDs covering an area of 123.5 ha on oilseeds, pulses, cereals and vegetable crops were conducted during Rabi 2013-14 and Kharif 2014 for dissemination of location specific crop technologies in the area. Extension initiatives such as field days, women in agriculture day, field visits, farm-advisory services, exhibitions, soil and water testing and publication of quarterly newsletters were also undertaken.
The IARI Regional Stations and Centres – Pusa (Bihar), Indore (MP), Shimla & Katrain, (HP), Wellington & Aduthurai (TN), Karnal (Haryana), Pune (Maharashtra) and Dharwad (Karnataka) also significantly contributed to the dissemination of improved IARI varieties and technologies to the farmers through various extension interventions like FLDs/demonstrations, farmers fairs, field days, participatory seed production programme, trainings, etc. The performance of FLDs/demonstrations on IARI varieties showed remarkable results in terms of yields and economic returns as compared with local checks. The results and feedback of the farmers about various extension interventions were also encouraging.

Rural Women play an increasingly important role in household and farm activities, and thus are the cornerstone in overall development of the family and society as a whole. Hence to empower women through capacity building initiatives in farm and non-farm occupations, a number of specific interventions and initiatives were implemented. The study on enhancing nutritional security and gender empowerment identified the training needs of extension professionals for organizing gender empowerment trainings. The analysis of constraints revealed that inadequate transportation, social norms, workload of women, and inadequate budget as major constraints in organization of trainings for women. The participatory analysis of project village areas was conducted and local women were mobilized to form self-help groups. Interventions on improved cereals, pulses, oilseeds, fodder crops, vegetables, fruits (lemon), flowers, nutrition garden, soil and water management, protected cultivation and improved implements to reduce drudgery were implemented to address technological needs of rural women. The Institute through its KVK, Shikohpur (Gurgaon) is taking a lead in empowering rural women by providing need based vocational trainings for self employment and income generating activities. Twenty one vocational trainings and other extension programmes were organized through which, 191 rural women were benefitted. Besides, 75 extension programmes were organized in which 964 rural women and girls participated, which were aimed to help them gain self confidence and understand the values of empowerment.

This year also the Institute was ranked as the best Institute for agricultural education in India, and contributed about 40% of the agricultural scientists recruited by ASRB (ICAR) during 2014. The 53rd Convocation of the Post Graduate School of IARI was held on February 20, 2015. Dr. R. Chidambaram, Principal Scientific Advisor, Government of India and Chairman of the Scientific Advisory Committee to the Cabinet as the Chief Guest delivered the convocation address. At this convocation, a total of 108 M.Sc., 07 M.Tech., and 66 Ph.D. degrees were awarded. A Special Convocation of the IARI was also held on September 8, 2014 to confer the Degree of Doctor of Science (Honoris Causa) on Dr. José Graziano da Silva, Director-General, Food and Agriculture Organization of the United Nations, Rome. The Institute also upgraded student amenities. The Institute initiated tele-teaching of a course on “Principles and Practices of Weed Management” for the M.Sc. students of ANASTU, Kandahar, Afghanistan. The IARI library continued to provide services to the students and the scientific community of IARI and other institutions of the country. The Institute brought out several quality publications in the form of scientific peer reviewed research papers in high impact journals, symposia papers, books/chapters in books, popular articles, technical bulletins, regular and ad-hoc publications, both in English and Hindi, to disseminate the information on the Institute’s mandated activities. With reference to protection of intellectual property, the Institute filed six patents with four renewals of existing patents, applied for protection of two varieties of wheat with PPV&FRA and commercialized 30 innovative technologies from North Zone-1 of ICAR. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions, and brought laurels to the Institute. 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. In addition, some special training courses, and other capacity building programmes were also organized for the benefit of professionals, farmers and extension workers.
The crop improvement programme of the Institute is primarily targeted towards enhancing the productivity and nutritional quality of field crops through judicious use of both conventional and modern molecular breeding tools. Several improved varieties with higher yield, better nutritional quality and tolerance to biotic and abiotic stresses have been developed and released for different agro-ecological conditions during the reporting period. Besides, a large number of genotypes in several crops are under various stages of evaluation in All India Coordinated trials. The crop improvement programme was complemented by quality seed production and progress in other relevant areas of seed science.

1. CROP IMPROVEMENT

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

**HD 3118 (Pusa Vatsala).** A high yielding wheat variety HD 3118, with an average yield of 3.95 t/ha and potential yield of 6.64 t/ha under late sown irrigated conditions of North Eastern Plains Zone (NEPZ), was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. HD 3118 is resistant to stripe and leaf rusts and moderately resistant to foliar blight and foot rot. It has the desirable Glu-1 score (8/10), higher bread loaf volume (cc), bread quality score, protein content, grain appearance and other quality traits. It is also suitable for bread making.

**HI 8737 (Pusa Anmol).** A durum wheat variety HI 8737, with an average yield of 5.34 t/ha and potential yield of 6.7 t/ha, was released for timely sown irrigated conditions of Central Zone (CZ) by Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Agricultural Crops. The variety is rich in β-carotene and micronutrients like iron and zinc and showed good levels of resistance to Karnal bunt also.
**Pusa Kiran (HS 542).** A high yielding bread wheat variety Pusa Kiran, with an average yield of 3.29 t/ha and potential yield of 6.03 t/ha under early sown rainfed conditions of North Hills Zone (NHZ), was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety is resistant to stripe and leaf ruts and also possesses superior *chapatti* making quality.

**Nilgiri Khapli (HW 1098).** A high yielding, disease resistant, semi dwarf *dicoccum* wheat variety Nilgiri Khapli was released for timely sown irrigated conditions for all the *dicoccum* wheat growing areas of the country by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety gave an average yield of 4.55 t/ha with potential yield 4.78 t/ha. It showed high degree of adult plant resistance to all the three ruts. It has high protein (16.5%), thousand kernel weight (46.5 g) and β-carotene (3.39 ppm).

### 1.1.1.2 Promising material under all India coordinated programme testing

Eighty wheat genotypes were evaluated in all India coordinated trials under varying production conditions across the country during *Rabi* 2014-15. *Durum* wheat genotypes, HD 4730, HD 4728 and bread wheat line HD 2932+Lr 19/Sr 25 are under final year of testing.

### 1.1.2 Barley

#### 1.1.2.1 Variety released and notified

A high yielding barley variety Pusa Sheetal (BHS 400) with an average grain yield of 3.27 t/ha under timely sown rainfed condition was released for Northern Hills Zone (NHZ) by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety has shown resistance to stripe rust.

### 1.1.3 Rice

#### 1.1.3.1 Varieties released/ identified

**Pusa 1592.** An isogenic line of Pusa Sugandh 5, Pusa 1592 was developed through marker assisted selection for bacterial blight resistance genes *xa13* and *Xa21*. It has long slender grains and strong aroma. It has an average yield of 4.73 t/ha, matures in 120-125 days and has been released for the *Basmati* growing Region II (Punjab, Haryana, Delhi and Jammu & Kashmir).

**Pusa Basmati 1609.** Pusa Basmati 1609 (Pusa 1609-09-9-4; IET 22778) is a MAS derived blast resistant *Basmati* rice variety having genes *Piz5* and *Pi54* with seed to seed maturity of only 120 days and average yield of 4.6 t/ha. It recorded an average yield advantage of 9%, 52.8% and 13.5% over Pusa Basmati 1121, Taraori Basmati and Pusa Basmati 1, respectively, in the AICRIP trials over three years of testing. It has semi-dwarf stature and non-lodging habit, reduced duration, higher yield and superior grain and cooking quality traits and most importantly it is resistant to
neck blast and moderately resistant to leaf blast. It has been identified for release in the Basmati growing regions of the Uttar Pradesh, National Capital Region of Delhi, Uttarakhand and Punjab.

1.1.3.2 Promising material in all India coordinated programme testing

A total of 26 rice genotypes were nominated for testing in all India coordinated programme during Kharif 2014.

1.1.3.3 Breeding material generated/ evaluated

**Marker assisted improvement for resistance to bacterial blight, blast and sheath blight in Basmati rice varieties.** Despite possessing superior grain and cooking quality characters, improved Basmati varieties viz., Pusa Basmati 1, Pusa Basmati 1121, Pusa Basmati 6, Pusa Sugandh 5, parental lines of Basmati quality rice hybrid Pusa RH10 are highly susceptible to diseases such as bacterial blight, blast and sheath blight. Based on the population dynamics of disease causing pathogens in the Basmati growing areas, the genes *xa13*, *Xa21*, *Xa33* and *Xa38* for bacterial blight, *Pt54*, *Piz5* and *Pi9* for blast and *qSB11-1* for sheath blight were identified to be most effective genes/QTLs. Therefore, a marker assisted backcross breeding programs was initiated to incorporate multiple biotic stress resistance genes/QTLs into the Basmati rice varieties viz., Pusa Basmati 1, Pusa Basmati 1121, Pusa Basmati 6, Pusa Basmati 1509, Pusa Sugandh 5 and parental lines of aromatic rice hybrid Pusa RH10.

A set of 36 monogenic and pyramided NILs carrying blast and blight resistance genes in the genetic background of Pusa Basmati 1121 and Pusa Basmati 6 were evaluated for yield and yield components, grain and cooking quality traits, out of which 8 pyramids carrying bacterial blight and blast resistance genes in the genetic background of PB1121 and Pusa Basmati 6 are being multiplied at RBGRC-Aduthurai for further testing in AICRP trials.

**Development of a set of isogenic lines carrying seven major blast resistance genes in the genetic background of Pusa Basmati 1.** A set of 22 pyramided lines carrying two-gene and three-gene combinations of blast resistance genes in the genetic background of Pusa Basmati 1 were evaluated for agro-morphological, grain and cooking quality traits. In addition, a total of 210 NILs including monogenic, two-gene and three-gene pyramids carrying seven blast resistance genes in the genetic background of Pusa Basmati 1 were evaluated for yield and yield components, grain and cooking quality traits in an augmented-RBD along with four checks in 5 blocks, and 28 promising lines have been identified.

**Marker assisted improvement for salinity stress in Pusa Basmati 1121 and Pusa Basmati 1.** A replicated yield trial of 23 selected salt tolerant superior advanced backcross derived lines along with the recurrent parent, Pusa Basmati 1121 and donor parent FL 478 was carried out at the Institute farm, New Delhi and five promising NILs, namely, Pusa

### Rice genotypes under testing in all India coordinated trials

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the AICRP trial (AVT II/ AVT I/ – zone or IVT)</th>
<th>Number of entries</th>
<th>Name of genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AVT1-BT</td>
<td>20</td>
<td>Pusa 1568-05-6-4-153, Improved Pusa RH 101, Improved Pusa RH 102, Improved Pusa RH 103, Pusa 1718-14-2-150, Pusa 1718-19-8-152, Pusa 1883-28-16-360, Pusa 1883-19-9-408, Pusa 1637-18-7-6-20, Pusa 1637-12-8-20-5, Pusa 1879-6-17, Pusa 1879-3-18, Pusa 1728-23-33-31-56, Pusa 1728-6-25-4-62, Pusa 1884-9-12-14, Pusa 1884-3-9-175, Pusa 1656-10-705, Pusa 1656-10-651, Pusa 1734-8-3-8, Pusa 1734-8-3-26</td>
</tr>
<tr>
<td>2</td>
<td>IVT-BT</td>
<td>1</td>
<td>Pusa 1485-06-8-10-5-15-11</td>
</tr>
<tr>
<td>3</td>
<td>IVT-ASG</td>
<td>1</td>
<td>Pusa 1638-07-3-1-4-91-1-2-4</td>
</tr>
<tr>
<td>4</td>
<td>IVT-ME</td>
<td>2</td>
<td>Pusa 2003-09-79-313-478, Pusa 2004-09-80-315-483</td>
</tr>
<tr>
<td>5</td>
<td>IVT-IM</td>
<td>2</td>
<td>Pusa 5001-1-1-1-1, Pusa 5001-2-1-2</td>
</tr>
</tbody>
</table>
1734-8-3-25, Pusa 1734-8-3-55, Pusa 1734-8-3-85, Pusa 1734-8-3-91 and Pusa 1734-8-3-97 have been identified for further evaluation.

**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, IARI, 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, which will be nominated for evaluation in the national trials.

**Evaluation of newly identified potential hybrids.**
*Basmati* quality hybrids: A station trial consisting of 28 elite hybrids of *Basmati* grain quality was conducted and data on agro-morphological and grain quality traits have been recorded based on which a set of five promising hybrids have been identified. These combinations are being multiplied at RBGRC, Aduthurai for further evaluation in the national trials.

**1.1.4 Maize**

**1.1.4.1 Promising material in all India coordinated trials**
A total of 15 entries including hybrids of different maturity group, MAS derived improved QPM and provitamin A rich versions of commercial hybrids, sweet corn, baby corn and stress tolerant hybrids were evaluated during Kharif 2014 in the national trials and seven promising entries have been promoted to final stage of testing.

**1.1.4.2 Breeding material generated/ evaluated**

**Breeding for abiotic stress tolerance.** A set of 13 hybrids were evaluated at three locations (IARI, New Delhi; Pantnagar, Uttarakhand; and Pusa, Bihar) in replicated trials under waterlogged conditions along with control. Hybrids AWLH1 (CML 425´ MGUD1) and AWLH2 (CML425´ HKI1105) were extremely tolerant under waterlogged conditions and outperformed other hybrids. The grain yield/ha data across-locations of the AWLH1 and AWLH2 trials showed several fold increase in grain yield over the other experimental and released hybrids under stress conditions. Yield advantage of maize experimental hybrids (AWLH 1 and AWLH 2) over released hybrids under waterlogging stress conditions across different environments ranged from 60 to 120%.

**Breeding for higher productivity.** A total of 192 single cross hybrids developed during 2013-14 were evaluated at IARI, New Delhi during Kharif 2014 along with 5 national checks of different maturity groups to identify new hybrid combinations. Out of 192 hybrids,
AH 5022 and AH 5023 were found to be superior and will be nominated to multi-location trials. Hybrids H 253, H 335 and H 371 in early category, H 212, H 242 and H 331 in medium category and H 395, H 389, C 433, H 393, H 327, H 392 in late category were promising with more than 15% superiority over national checks at station trials.

**Evaluation, improvement and multiplication of inbred lines.** A set of 133 inbred lines of different groups received from CIMMYT and DMR were evaluated at IARI during Kharif 2014 and 52 desirable lines were further selected to be used for development of new hybrid combinations. The lines within same group will be used for development of pedigree population for extraction of new inbred lines.

Out of 100 inbreds evaluated over two years, 10 inbreds were promising with estimated yield of >5t/ha. Among them, top 5 inbreds are BM-188, BM-253, BM-202, BM-40, and BM-260. Two inbreds, BM-253 and BM-202 had an estimated yield of more than 4.5t/ha at both Dharwad and Delhi.

### 1.1.4.3 Breeding for nutritional qualities

**Development of provitamin A enriched hybrids through marker-assisted selection.** Marker-assisted selection was employed to introgress favourable allele of \(\beta\)-carotene hydroxylase (\(\text{crtRB1}\)) in the parents of two extra early- \([\text{Vivek QPM 9 and Vivek Hybrid 27]}\) and two medium maturing hybrids \([\text{HM 4 and HM 8]}\). Mean kernel \(\beta\)-carotene among the MAS-derived hybrids was 17.5 \(\mu\)g/g, while the same among the original hybrids was 2.1 \(\mu\)g/g. Across the reconstituted hybrids, an average of 8-fold increase in kernel \(\beta\)-carotene was observed, with a maximum of 10-fold increase in the improved version of Vivek QPM 9. Reconstituted hybrids were similar to their respective original hybrids for grain yield and majority of yield-attributing characters.

**Marker-assisted introgression of \(\text{crtRB1/lcyE in opaque 2 genetic background.}** HKI161, HKI163, HKI 193-1 and HKI 193-2 (parents of HQPM 1, HQPM 4, HQPM 5 and HQPM 7) have been targeted for introgression of \(\text{crtRB1 and lcyE alleles using marker-assisted selection.} BC_2F_1\) generations were genotyped and segregants for \(\text{opaque2, lcyE and \(\text{crtRB1}}\) have been selected. Further, QPM version of HKI 323, HKI 1105 and HKI 1128, parents of a number of popular normal maize hybrids have also been targeted for introgression of \(\text{crtRB1 allele. Segregants with opaque2 and \(\text{crtRB1}}\) in homozygous state were selected using marker-based foreground selection. The newly developed inbreds exhibited high degree of phenotypic resemblance with their respective recurrent parents.

**Further enhancement of lysine and tryptophan in QPM.** HKI 161, HKI 163, HKI 193-1 and HKI 193-2 (parents of HQPM 1, HQPM 4, HQPM 5 and HQPM 7) were targeted for introgression of \(\text{opaque16 allele (from Chinese hybrid donors) using marker-assisted selection.} \ BC_1F_1\) generation having 1052 individuals were genotyped and 13 segregants with \(\text{opaque2 (homozygotes) and opaque16 (heterozygote}}\) selected.

**Evaluation of double recessive \(\text{(sh2sh2/su1su1)}\) sweet corn hybrids.** Promising inbreds with \(\text{sh2sh2/su1su1}\) developed at IARI, New Delhi were used for generation of sweet corn hybrids with improved sweetness. Sixty one hybrids possessing recessive alleles of both the genes were evaluated and promising combinations were identified. Further, 122 cross combinations in the genetic background of \(\text{sh2sh2 and su1su1}\) were also evaluated, and 12 promising hybrids with high kernel sweetness and green cob yield were selected.
1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Promising material in all India coordinated trials

Seven entries of the pearl millet were tested in the all India coordinated trials.

1.2.1.2 Hybrid development and evaluation

A total of 65 hybrid combinations developed during Kharif 2013 and summer 2014 at ICRISAT were evaluated in different station trials. A total of 45 hybrids were tested in different replicated trials along with latest checks including the private hybrids in initial station trials. The outstanding hybrid entries identified were - ICMA 93333 x PPMI 69; ICMA 97111 x PPMI 69; ICMA 02555 x H77/833-2-202; ICMA 05333 x ICMR 07111, ICMA 05333 x PPMI 69 and ICMA 91444 x ICMR 07111. A total of twenty hybrids were evaluated in different replicated trials along with latest checks including the private hybrids in Intermediate station trials. The promising hybrid entries selected were ICMA 843-22 x 15458; ICMA 92777 x IPC 1518; ICMA 92777 x PPMI 834; ICMA 92777 x TT-3 and ICMA 92777 x TPMP 1213.

1.2.1.3 Development of new restorers

Elite restorers with good combining ability were used in hybridization programme to develop new restorers with early days to flowering, good combining ability and good spike characters. For new restorer development program, four three way crosses were advanced to $F_3$ and six crosses were advanced to $F_4$ and 400-500 plants per cross were selected. Progenies of six backcross and six $F_2$ generations were evaluated in three environments viz., IARI, New Delhi (Kharif and summer season) and Dharwad during off-season.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Variety identified

BG 3022. An extra-large seeded Kabuli chickpea var. BG 3022, suitable for NWPZ comprising the states of Rajasthan, UP, Punjab and Haryana, was identified for release. It is a high yielding variety with an average grain yield of 1.8 t / ha which is 10.4 % higher

Pearl millet entries tested

<table>
<thead>
<tr>
<th>Name of trial</th>
<th>Entry name</th>
<th>Zone of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHT (M)</td>
<td>Pusa 1405 (411A x PPMI 1001)</td>
<td>A and B</td>
</tr>
<tr>
<td>Advanced population trial (III year)</td>
<td>Pusa Composite 701 (three years testing completed. Data awaited from coordinating unit)</td>
<td>A and B</td>
</tr>
<tr>
<td></td>
<td>Pusa composite 706 (Two years testing completed. Data awaited from coordinating unit)</td>
<td>B</td>
</tr>
<tr>
<td>Initial population trial</td>
<td>Pusa Composite 709</td>
<td>A and B</td>
</tr>
<tr>
<td></td>
<td>Pusa Composite 710</td>
<td>A and B</td>
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<tr>
<td>Initial population trial</td>
<td>Pusa Composite 707</td>
<td>A and B</td>
</tr>
<tr>
<td></td>
<td>Pusa Composite 708</td>
<td>A and B</td>
</tr>
</tbody>
</table>
than the best check. BG 3022 was derived from the cross BG 1048 x BG 1082 following pedigree breeding method. It consistently out yielded check varieties in all four years and showed stable yield performance over locations. Its duration is about 150 days and has 100-seed weight of 36-40 g. It is moderately resistant to *Fusarium* wilt, dry root rot, *Ascochyta* blight and *Botrytis* gray mold. It has excellent grain quality.

### 1.3.1.2 Promising material in all India coordinated trials

Sixteen entries of the chickpea were tested in the all India coordinated trials.

#### 1.3.1.3 Breeding material generated/evaluated

**Selection of wilt resistant single plants/progenies from the early generation segregating material**. $F_1$ (612) were grown in wilt sick plot during 2013-14 and 215 resistant bulks were carried forward for evaluation in $F_2$ during 2014-15. $F_4$ (309) were evaluated in wilt sick plot and 559 single plants were selected based on wilt reaction (<10% mortality), plant type and seed traits. These are being evaluated in preliminary yield trial during 2014-15 for yield and phenology.

**Evaluation of advanced breeding lines in preliminary yield trials and replicated yield trials**. A total of 926 single plant progenies (including 133 lines selected from MAGIC population) were evaluated in three preliminary yield trials during 2013-14 along with checks. One hundred forty four desi and 36 Kabuli breeding lines were found superior to check in yield and promoted to station trials. Fifty four desi and 72 Kabuli genotypes were evaluated in replicated yield trials (7 station trials) during 2013-14. Among Kabuli entries, 38 were extra-large seeded with 100 seed weight >40g. Total 72 entries (36 desi + 36 Kabuli) out yielded the check and were promoted to advance trials.

**Breeding for herbicide tolerance**. A total of 492 cultivars / breeding lines / germplasm accessions were screened for tolerance to Imazethapyr. Lines with moderate to high level of tolerance to herbicide Imazethapyr identified: BG 364, ICC 1205, ICCV 08312, ICCV 03410, ICCV 95138 and ICCV 03402. TILLING population (M$_j$) of ICC 4958 was screened for tolerance to herbicide Imazethapyr (@ 75g/ha) during 2013-14. Single plants selected (100) were grown in progeny rows during 2014-15 and again screened for tolerance to Imazethapyr.

### 1.3.2 Mungbean and Lentil

#### 1.3.2.1 Material in all India coordinated trials

Seventeen genotypes of mungbean and lentil were tested in all India coordinated trials.

#### 1.3.2.2 Breeding material generated/evaluated

In lentil, lines L 7903, PDL 1, PDL 2 and PSL 9 alongwith checks (L 4147, L 4076, DPL 62) and a large number of germplasm were evaluated for high pH.
tolerance under AICRP for Salt Affected Soils, Agra, CSAUA&T Regional Station, Dilip Nagar, Kanpur Dehat (U.P.) and Central Soil Salinity Research Institute, Regional Station, Lucknow (U.P.). Genotypes viz., PDL 1, PDL 2, PSL 9, L 7903 along with checks (L 4147 and L 4076) were tested in EC 12.0dS/m under AICRP for Salt Affected Soils, Agra (U.P). Aluminium tolerant lines L 4602, L 7903 along with check (L 4076 and VL 507) and 102 wild accessions were evaluated in hydroponics at National Phytotron Facility, IARI, New Delhi, ICAR Research Complex for NEH region, A.P. Centre, Basar, (Arunachal Pradesh) and Central Agricultural University, Imphal (Manipur). These genotypes were tested under the most severe conditions of soil acidity (<pH 5.0). The tolerant accessions of wild relatives such as ILWL 56, ILWL 59(1) and ILWL 185 produced higher root length, shoot length, dry weight of roots and shoots, and low accumulation of Al and callose compared to cultivated lines L 4602 and L 7903.

1.3.3 Pigeonpea

1.3.3.1 Varieties in all India coordinated trials

Based on consistent superior performance in station trial, three entries, namely, Pusa 2014 -1 (Selection from ms Pusa 33 x Sel. 90312), Pusa 2014 -2 (Selection from Sel.141 x Pusa 33 ), Pusa 2014 -3 (Pusa Dwarf x Pusa 2001) were selected for their testing under all India pigeonpea coordinated trial during Kharif 2014-15.

1.3.3.2 Breeding material generated/ evaluated

High yielding promising extra early maturing (< 120 days) lines developed. Thirty advanced lines along with 4 checks were evaluated. Out of these, 5 lines were determinate, semi-dwarf lines with synchronous maturity (viz., PADT 1, PADT 5, PADT 39, PADT 25 and PADT 16). These lines were harvested with the combine harvester. These lines provide easy spraying operation as their height is around 95 cm. The extra early maturing lines, (in 119 and 116 days) PADT 1 and PADT 25 yielded 1.94 and 2.00 t/ha, respectively, with a row to row spacing of 30 x 30 cm.

The extra early maturing indeterminate line viz., PAE II-21 yielded 2.72 t/ha which was significantly higher than the check varieties. This genotype matured in 120 days and is having semi-erect compact plant type with long pod bearing length. The lines PAE II-22 and PAE II-2 yielded 2.43 and 2.41 t/ha, respectively, which was significantly higher than the check varieties. These lines matured in 117 and 114 days, respectively. These genotypes are having compact semi-erect plant type with extra early maturity and are suitable for closer spacing thana row to row spacing of 60 cm. The performance of these genotypes revealed that extra early maturity of less than 120 days can be combined with higher yield per unit area by improving the plant type.

One hundred fifteen extra early maturing (< 120 days) genotypes with complete senescence at maturity have been selected from 116 extra early maturing segregating generations. These genotypes attain complete senescence at maturity.

Development of new restorers. Ninety one new R lines were developed from inter-specific cross (Cajanus scarabaeoides x Pusa 33). Three hundred and thirty four

### Mungbean and lentil genotypes tested

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the AICRP trial (AVT II/ AVT I/ – zone or IVT)</th>
<th>Number of entries</th>
<th>Name of the genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lentil AVTI CZ</td>
<td>2</td>
<td>L 4710 and L 4717</td>
</tr>
<tr>
<td>2</td>
<td>Mungbean AVTI</td>
<td>1</td>
<td>Pusa 143</td>
</tr>
<tr>
<td>3</td>
<td>IVT Lentil</td>
<td>6</td>
<td>L 4726, L 4727, L 4730, L 4731, L 4735, L 4737</td>
</tr>
<tr>
<td>4</td>
<td>IVT Mungbean</td>
<td>8</td>
<td>Pusa 1471, Pusa 1472, Pusa 1331, Pusa 1532, Pusa 1541, Pusa 1542, Pusa EM1501, Pusa EM 1502</td>
</tr>
</tbody>
</table>
A x R derivatives of various generations were also grown and evaluated for male fertile genotypes. F2 generation of 56 crosses between A and R lines were evaluated during Kharif 2014-15, and 78 male fertile superior recombinants were selected. Also evaluated 6 F4 generations of crosses between A lines and the male fertility restorers, and male fertile superior recombinants were selected.

**Development and evaluation of experimental hybrids.** Seventy eight F1s of 39 crosses between A and R lines were evaluated. Heterotic crosses between A and R lines were identified and most of the crosses involving Pusa 2001 A, Pusa 992 A and Pusa 2002 A were heterotic.

### 1.4 OIL SEED CROPS

#### 1.4.1 Brassica

**1.4.1.1 Varieties registered with PPV & FRA**

Seventeen varieties of mustard, namely, released from IARI, New Delhi were registered with PPV&FRA as extant varieties.

**1.4.1.2 Elite entries in coordinated trials**

Sixteen entries of mustard, namely, NPJ 185, NPJ 186, NPJ 187, NPJ 188, NPJ 189, NPJ 190, NPJ 191, NPJ 192, LES 50, LES 51, PDZ 3, PDZ 4, LES 49, PDZ 1, and PDZ 2 were tested in all India coordinated trials. Out of there, genotype NPJ 180 was tested in AVT–I (Timely sown irrigated trial) in zones II and III. Genotypes LES 49 (low erucic acid) and PDZ 1 and PDZ 2 (double low) were tested in AVT–I (Quality mustard trials) in zone–II.

#### 1.4.1.3 Hybridization and pre-breeding

A total of 214 crosses were attempted for various objectives viz., earliness (12), white rust resistance and quality (7), shattering resistance (9), heat and drought tolerance (10), cold and frost tolerance (5), oil content (8) and quality (23). Additionally 108 crosses were attempted for yield and yield improving traits involving homozygous advance lines and elite entries of different durations. Eighteen multiple crosses were also attempted using F1s for creating larger selectable genetic variation and to assemble favourable alleles. In addition 12 inter-specific crosses were also attempted utilizing *B. napus*, *B. carinata*, *B. nigra* and *B. rapa*. Off season nursery facility at IARI Regional Station,Wellington was used for making crosses and screening of parental lines for crosses particularly for white rust resistance breeding component.

#### 1.4.1.4 Hybrid breeding

**Development of CMS lines.** To develop CMS lines, backcrosses were attempted in paired manner to transfer nuclear genome of 26 genotypes to sterile cytoplasm viz., *Moricandia arvensis* (mori), *Diplotaxis erucoides* (eru) and *Diplotaxis berthautii* (ber). Crosses were also attempted for multiplication and evaluation of CMS lines in the next season. These were also used for attempting test hybrids for evaluation in 2015-16 seasons.

**Development of restorers.** Paired crossings were made to transfer fertility restoration in 28 genetic backgrounds which restores fertility in mori/eru/ber sterile cytoplasms. To transfer fertility restorer gene(s) into five genetic backgrounds viz., NPJ 93, NPJ 112, SEJ 8, Pusa Jagannath and Pusa Agarni, 60 paired crosses (BC1/BC2) were attempted in phytotron/IARI Regional Station, Wellington to develop restorers for mori, eru and ber cytoplasms and BC1F1/ BC2F1 were raised and evaluated in the main season.

**Breeding material evaluated and advanced.** During 2014-15, a total of 1508 single plant selections
and 63 bulks were made from early sown (296 single plants and 9 bulks involving 71 crosses), timely sown (503 single plants and 17 bulks involving 174 crosses), late sown (297 single plants and 17 bulks involving 61 crosses), low erucic acid (229 single plants and 18 bulks involving 26 crosses) and double low (183 single plants and two bulks involving 14 crosses) breeding material from \( F_2 \) – \( F_7 \) populations/progenies for further evaluation and advancement. One hundred twenty nine \( F_1 \)s of the crosses attempted for identification of good combiners were also evaluated for 11 morphological traits.

**Evaluation of elite purelines.** One hundred twelve entries, bulked during 2013-14 were evaluated in replicated station trials (six) under early, timely, rainfed and late sown conditions. These entries also include 18 (0/00) genotypes. Best two entries from these groups shall be contributed to AICRP-RM testing.

### 1.4.2 Soybean

#### 1.4.2.1 Material in all India coordinated programme testing

Three entries of soybean were tested in all India coordinated trials.

**Entries tested**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the AICRP trial (AVT II/ AVT I/ – zone or IVT)</th>
<th>Number of entries</th>
<th>Name of the material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AVT II (NPZ) (Kharif 2014)</td>
<td>one</td>
<td>DS 2705</td>
</tr>
<tr>
<td>2</td>
<td>IVT (Kharif 2014)</td>
<td>Two</td>
<td>DS 3101, DS 3102</td>
</tr>
</tbody>
</table>

#### 1.4.2.2 Breeding material generated/ evaluated

Sixty five advanced lines were evaluated in station trials. Twenty one lines were tested in multi-location trials at Indore, Dharwad and Pusa Bihar. Sixty seven fixed lines were tested in station trial and twenty one lines tested in multi-location trials. More than 700 lines in different segregating generations were evaluated. More than 300 RILs developed from the cross *Glycine max x G soja* were grown in replicated trials and analyzed for various agro-morphological traits. The lines exhibited enormous variability for different traits including pods/plant which ranged from 700 to 1200 pods/plant. A few selected plants were crossed back to the *G. max* parent.

### 1.5 FIBRE CROP

#### 1.5.1 Cotton

**1.5.1.1 Material in all India coordinated programme testing**

Three entries of cotton were tested in all India coordinated trials.

**Entries tested**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the AICRP trial (AVT II/ AVT I/ – zone or IVT)</th>
<th>Number of entries</th>
<th>Name of the material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AICCRIP Br 03(a) in Central Zone under irrigated conditions</td>
<td>Three</td>
<td>P.5430, P.5760, P.2151</td>
</tr>
</tbody>
</table>

**1.5.1.2 Breeding material generated/ evaluated**

In AICCRIP trials, P 5430 ranked 2\(^{nd}\) in national trial Br 03(a) and promoted to final year i.e., Br 04(a) in Central Zone under irrigated conditions with 32% higher cotton seed yield over zonal check. It had highest oil content i.e., 18% among all the entries evaluated in this group. This entry has good span length (27.1) and micronaire value (4.5). In 3 station trials, a total of 47 promising genotypes were evaluated. The highest cotton seed yield of 1341 kg/ha was also recorded in P 5634, followed by P 5630 (1320 kg/ha) as against 1211 kg/ha in local check. Two hundred germplasm lines of *G. hirsutum* and *G. arboreum* were maintained through selfing for future breeding program. Two hundred and seventy recombinant inbred lines (RILs) in \( F_9 \) generation, developed from the intra hirsutum cross ‘P 56-4 x RS 2013’ were evaluated for seed cotton yield and other important traits. Five lines were selected for earliness, fibre strength and good cotton yield. The same will be evaluated in the station trial in the next year. About two hundred RILs developed from the intra hirsutum cross ‘MCU 5 x TCH 1218’ were also evaluated. These intra hirsutum cross lines were found susceptible to jassid and cotton leaf curl virus
disease. Two hundred germplasm lines of *G. hirsutum* and *G. arboreum* were maintained and evaluated for important traits. Wide variation has been observed for yield and yield components.

### 1.6 SEED SCIENCE AND TECHNOLOGY

#### 1.6.1 Seed Vigour Traits in Wheat and Rice

Establishing healthy crop stand, especially under rain-dependent condition was investigated in wheat and rice. In case of wheat, recombinant inbred lines (RILs) developed for drought tolerance were studied and 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 shoot, higher leaf area index and number of tillers are the traits associated with seed yield. In 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. For example, in Pusa Sugandha 5 carbon assimilation was traced ($^{14}\text{CO}_2$) under normal and water-deficit conditions in pot culture. This indicated that 27-35% is remobilised from stem reserve to panicle during grain filling. In addition, six genotypes were evaluated for remobilization of NSC under both normal irrigation and water-deficit conditions in the field. 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.

#### 1.6.2 Test for Storage Potential of Indian Mustard Genotypes

Low vigour seed having poor field emergence may not necessarily be detected by standard germination test. Differences in field emergence of varieties with high laboratory germination or in germination after storage are referred to as seed vigour. Vigour test, thus, provides additional information on relative emergence potential and longevity of seed. Controlled deterioration (CD) is one of the vigour test which allows seeds to increase their initial moisture content followed by exposure to high temperature (45 °C) for 24 h to determine storage potential. The initial germination percentage in mustard varieties was higher than minimum seed certification standard in all the varieties. Subsequently, the germination percentage decreased progressively in all the cultivars after Controlled Deterioration. An increased time and temperature in the CD test reduced germination but increased the mean germination time (MGT). The genotypes with yellow seed coat showed more reduction in germination than the black seed coat ones. The germination percentages of the yellow seeded cultivars had dropped from over 91 to 15% in genotype LES 48 and 62% in genotype Pusa Karishma; the black seeded cultivars showed less reduction, with final germination above 80%. The detrimental effect of CD was more prominent in yellow seeded quality genotypes indicating that they were low in vigour compared to the black seeded. The varieties which showed decrease in germination percentage had increased MGT and, thus, have decreased seed quality. Therefore, both high and low quality mustard genotypes could be accurately identified by the CD test.

#### 1.6.3 Machine Vision – A New Tool for Distinguishing among Crop Varieties

Voluminous database of more than 15,000 images of various plant parts was created using image set-up and flatbed scanner in rice, mustard and chickpea. All captured images were named as per the image nomenclature software. Based on DUS database generated for the three crops, most similar varieties in each crop were identified. The main strategy was to distinguish among the difficult to distinguish varieties by machine vision studies. Additional morphological characters, which aid in differentiating crop varieties, were identified for all the three crops. A hierarchy of traits worked out in rice with more emphasis on seed morphology; in combination with grouping and essential characters for establishing varietal distinctness. Certain additional characters suggested
for establishing varietal distinctness in mustard are anthocyanin colouration of hypocotyls, leaf blade shape (Ovate, Oblanceolate, Wide Elliptic, Narrow Elliptic) and leaf venation pattern. In chickpea, additional morphological characters identified for further studies are trichomes on all the aerial parts, petal colour intensity and petal venation.

**1.6.4 Development of Seed Enhancement Treatments for Assured Plant Stand**

**Wheat.** Twenty treatments were given to the seeds of HD 2967 variety and 100 seeds of each were sown with control in 5m length plot on October 31, 2014 and November 15, 2014 in three replications. Highest plant stand establishment was observed in seeds treated with Quick Roots (QR), a biological to colonize the roots followed by a chemical treatment; Cruiser FS 7.5 ml/kg +Metalaxyl 2.5 g/kg which was at par with haloprimed (ZnSO$_4$ + MnSO$_4$ - 0.05%) seeds. The haloprimed seeds resulted in enhancement of other parameters; plant height and panicle length. While, the treatments (@10g/kg with biological like; Azotobactor + Phosphatica and *T. viride* were found effective for panicle initiation and number of tillers.

**Chickpea.** Twenty seed treatments including control were evaluated in two chickpea varieties viz., Pusa 256 (*desi*) and Pusa 1108 (*Kabuli*) for their effect on plant stand. The seeds treated with Thiram and *Rhizobium* exhibited highest plant stand establishment in *desi* and *Kabuli* varieties, respectively. However, the treatment, SMP (sand) was at par in both types of chickpeas which also resulted in higher numbers of branches. Other biological seed treatments (Biopriming); Azotobacter + phosphatica, *T. viride* and QR showed promising results with respect to various yield attributing traits. Seed treatment with turmeric extract @2.5 g/kg seed and HYT D @ 4.5 ml/kg seed was also found to be effective in enhancing plant stand establishment in chickpea.

**Mustard.** Twenty seed treatments were evaluated in Indian mustard variety Pusa Vijay for their effect on plant stand and yield traits. Osmopriming (PEG1000 @ 100 ppm) gave the highest plant stand establishment which was at par with chemical seed treatment with Metalaxyl @ 2.5 g/kg and Halopriming with KNO$_3$ (0.3%). KNO$_3$ treated seeds also resulted in highest numbers of secondary branches. The seed treatments with Thiram, Halopriming (ZnSO$_4$ + MnSO$_4$ -0.05%; KNO$_3$) and Biopriming (*T harzianum*, Azotobacter + Phosphatica; Microphos) showed improvement in other yield attributing traits; plant height, main shoot length, numbers of primary and secondary branches, no. of siliquae on main shoot and total siliquae/plant.

**Green gram.** The seeds of three varieties of green gram (Pusa Vishal, Pusa 9531 and Pusa 672) were subjected to eight seed treatments during *Spring-summer* and *Kharif*, 2014 for successful plant establishment. The treated seeds were also kept under ambient storage for period of one year and observations on seed quality parameters were taken at every three months interval. Among the non-chemical treatments, HYT D and botanicals (turmeric / garlic extract) were found effective in promoting better plant stand establishment and subsequent seedling growth. These seeds also exhibited better storage potential in terms of germination percentage, vigour indices and seed health.

![Untreated seeds](image1)

![HYT D treated seeds](image2)
1.6.5 Standardization of Seed Testing Protocols of Underutilized Plants

1.6.5.1 Seed testing protocols for anise (*Pimpinella anisum* L.)

Optimum germination of anise was obtained by pre-washing seeds in running water for 48-72 h and testing under 20°-30°C (16 h dark/8 h light) on Top of paper (TP).

1.6.5.2 Seed development and maturation studies in anise (*Pimpinella anisum* L.) and celery (*Apium graveolens* L.)

Based on seed quality parameters viz., fruit fresh weight, fruit dry weight, seed moisture content, onset of seed germination and physiological maturity following inference is drawn:

<table>
<thead>
<tr>
<th>Experimental system</th>
<th>On-set of germination (Days from anthesis)</th>
<th>Physiological maturity (DFA)</th>
<th>Harvest maturity (DFA)</th>
<th>Seed maturity indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anise (NRCSS-Ani-1)</td>
<td>26-28</td>
<td>41-45</td>
<td>44-48</td>
<td>Grey-brown</td>
</tr>
<tr>
<td>Celery (A-Cel-11)</td>
<td>22-24</td>
<td>44-48</td>
<td>52-56</td>
<td>Grey-brown</td>
</tr>
</tbody>
</table>

Germination of celery seeds of different maturation stages

Based on various plant growth promoting and broad spectrum pathogen inhibiting traits coupled with rhizosphere competence for root colonization and uniform results in field performance, *Bacillus pumilus* and *Pseudomonas putida* were considered to be most effective PGPR isolates in all target crops. Further *Bacillus pumilus* and *Pseudomonas putida* isolates were more amicable to be delivered on seeds through biopriming and also in combination with thin-film polymer coating in cabbage, cauliflower and tomato. Scanning microscope studies revealed the recovery of PGPR cells from the dried back seeds and seedlings of tomato, cabbage and cauliflower.

1.6.6 Beneficial Bacteria for Management of Seed-borne Fungal Pathogens and Seedling Growth

Eight elite species viz., *Bacillus methylotrohpicus*, *Bacillus amyloliquefaciens*, *Bacillus subtilis*, *Bacillus sp*, *Paenibacillus sp*, *Bacillus pumilus*, *Ochrobactrum intermedium* and *Pseudomonas putida* isolated from roots and rhizosphere soil of vegetable growing regions in Arunachal Pradesh based on morphological, biochemical traits and 16S rDNA sequences were used in this study. Systematic studies on anti-pathogenic potential of PGPR indicated the higher efficacy of *P. putida*, *B. subtilis* and *B. amyloliquefaciens* against *A. brassicicola* of cabbage and cauliflower. *B. pumilus* suppressed chilli anthracnose pathogen (*C. capsici*). *B. pumilus* and *P. putida* were efficient to reduce damping-off pathogens in all the four target crops. The present work established delivery of adequate cell densities (3x10⁶ CFUg⁻¹ ‘seed’⁻¹) for increasing the efficacy of PGPR isolates through clay based bioformulation with Kaolin, Fuller’s earth, Guar gum) without affecting the seed quality parameters. Mass multiplication of these beneficial bacterial through talc based bioformulation was standardized for seed, seedling and soil application.

1.6.7 Suitability Study of New Late Sown Wheat Variety HD 3059 under Very Late Sown Condition

A study was conducted at the Institute’s Seed Production Unit to find suitability of new wheat variety HD 3059 under very late sown condition in comparison with old variety WR 544. Result showed
that HD 3059 has better yield under late as well as very late sown conditions in comparison with WR 544. Low reduction in yield of HD 3059 under very late sown condition was mainly attributed to consistency in tiller number, number of grain per ear head and kernel weight.

### 1.6.8 Seed Production of Field Crops

The Seed Production Unit (New Delhi) and regional stations of IARI at Karnal, Indore, Pusa (Bihar) were involved in the seed production of different varieties which include breeder and as well as truthfully labelled seed.

#### Seed production (Tonnes)

<table>
<thead>
<tr>
<th>Crop Group</th>
<th>Nucleus Seed</th>
<th>Breeder Seed</th>
<th>IARI Seed</th>
<th>Total Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed Production Unit, New Delhi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>63.736</td>
<td>391.378</td>
<td>455.114</td>
<td></td>
</tr>
<tr>
<td>Pulses</td>
<td>2.311</td>
<td>5.436</td>
<td>9.947</td>
<td></td>
</tr>
<tr>
<td>Oilseeds</td>
<td>0.712</td>
<td>10.661</td>
<td>11.373</td>
<td></td>
</tr>
<tr>
<td>Regional Station, Karnal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>2.697</td>
<td>152.901</td>
<td>325.034</td>
<td>480.632</td>
</tr>
<tr>
<td>Pulses</td>
<td>0.035</td>
<td>5.411</td>
<td>1.181</td>
<td>6.627</td>
</tr>
<tr>
<td>Forages</td>
<td>0.040</td>
<td>2.120</td>
<td>0.620</td>
<td>2.780</td>
</tr>
<tr>
<td>Oil seeds</td>
<td>0</td>
<td>0.552</td>
<td>0.671</td>
<td>1.223</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>0</td>
<td>0.413</td>
<td>0.413</td>
</tr>
<tr>
<td>Regional Station, Indore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>-</td>
<td>162.25</td>
<td>-</td>
<td>162.25</td>
</tr>
<tr>
<td>Regional Station, Pusa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>-</td>
<td>50.024</td>
<td>67.67</td>
<td>117.694</td>
</tr>
<tr>
<td>Pulses</td>
<td>-</td>
<td>0.547</td>
<td>0.602</td>
<td>1.149</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>-</td>
<td>-</td>
<td>1.888</td>
<td>1.888</td>
</tr>
<tr>
<td>Others</td>
<td>-</td>
<td>-</td>
<td>0.6697</td>
<td>0.6697</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5.083</td>
<td>440.453</td>
<td>806.2237</td>
<td>1251.7597</td>
</tr>
</tbody>
</table>
2. HORTICULTURAL SCIENCE

There has been record increase in production of horticultural crops during 2014. This event emerges as a healthy sign in country’s nutritional security besides its role in food, health and economic growth of agriculture sector. The School of Horticultural Science was created in 2013 by reorganizing the School of Crop Improvement. The focused attention is now being made to technological innovations in the form of genetic enhancement, efficient production and resource management strategies. A number of improved varieties/rootstocks in different horticultural crops having not only yield gains but also having added traits to economize production cost like biotic and or abiotic stress tolerance, better nutraceutical properties and processing attributes were developed. Several genotypes were identified in different crops for their release at AICRP, Delhi state and Institute levels. Technologies for quality planting material and seed production have also been developed. Efforts have been made to integrate conventional strategies with molecular technologies in achieving precision in breeding. Besides, novel genotypes have also been developed.

2.1 VEGETABLE CROPS

2.1.1 Cole Crops

2.1.1.1 Cauliflower

*Varieties identified.* Two early maturity group varieties of cauliflower, namely, Pusa Ashwini (DC 31) and Pusa Kartiki (DC 23000) were identified.

Pusa Ashwini identified by AICRP-VC for Zone IV comprising states of Punjab, Uttar Pradesh, Bihar and Jharkhand. Its curd initiation and development takes place at an average temperature range of 22-27°C. It is ready for transplanting during July and reaches marketable maturity during first fortnight of October. Its curds is compact with retentive white colour. The average curd weight is 500-600 g with a yield potential of 16-18 t/ha.

Pusa Kartiki was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is characterized by open frame horizontal green leaves. The optimum temperature requirement for curd initiation and development ranges between 22-27°C. The curds are of retentive white colour and compact with net weight of 500-600 g with an approximately average yield of 18 t/ha. It is suitable for early sown conditions beginning June under north Indian plains and gets ready for harvesting during second fortnight of October.
**Development of new material.** In early group, out of 26 SI and 15 CMS based hybrids evaluated along with 20 hybrids from private seed companies, 17 SI and 10 CMS hybrids were found promising having optimal marketable (up to 40 t/ha) and curd weight and quality. Of the 22 CMS F₁ hybrids evaluated in mid-early group along with 44 from private seed companies, 7 were found promising. In mid-late group, 40 CMS hybrids and 9 SI hybrids were evaluated of which 14 CMS and 4 SI found promising. In resistance breeding, out of 11 hybrids evaluated, 5 were found promising in resistance, curding ability and nutritional quality.

**Breeding for black rot and downy mildew disease resistance.** In cauliflower, 19 inbred lines and 9 breeding lines (source: HRIGRU, UK) were evaluated for resistance to black rot disease by inoculating with Xcc race 1 and 4. Three inbreds, namely, BR 207, AL 15 and BR 161 were found to be resistant, whereas, BR 1 and BR 202-2 were partially resistant to Xcc race 1. The breeding line DJ 8012 was found to be partially resistant to Xcc race 4. For downy mildew, five genetic stocks, namely, BR 207, AL 15, Sarjumaghi, BR 2 and AL 3 were found highly resistant. A total of 108 lines (F₄ generation) of Pusa Sharad x BR 207 were advanced to F₅ generation. One hundred ten RILs of F₄ generations (Pusa Himjyoti x BR 2) were advanced to F₅ generation.

**Phenotypic evaluation of RILs and hybrids for yield and disease resistance.** A total of 39 RILs and 35 F₁ hybrids were evaluated in replicated trial. Thirteen RILs emerging from a cross of DC-309 x BR-2 were found promising. All the RILs were highly resistant to downy mildew disease. Among the hybrids evaluated, six were found superior and were resistant to downy mildew disease. A total of 37 hybrids were evaluated for yield and disease resistance. Among these, Hybrid 6 (PHJ BR-2 x PHJ BR-2) was found superior followed by Hybrid 10 (35114663511 x 309BR-2), Hybrid 4 (PHJBR-2 x PHJBR-2PHJ), Hybrid 33 (309BR-2 x PHJBR-2), Hybrid 14 (35114663511 x 309BR-2), Hybrid 13 (35114663511 x 309BR-2). All these hybrids were found to be resistant to downy mildew disease.

### 2.1.2 Cucurbitaceous Crops

#### 2.1.2.1 Ash gourd

**Variety released.** The hybrid, Pusa Urmi (DAGH 16) was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops for Kharif season cultivation in Zones VI (Rajasthan, Gujarat, Haryana and Delhi) and VIII (Karnataka, Tamil Nadu and Kerala).

**Variety identified.** Ash gourd variety, Pusa Sabzi Petha (DAG 12) was identified by AICRP-VC for Kharif cultivation in Zone VIII (Karnataka, Tamil Nadu and Kerala). Its vines are medium long (av. length 7.0 m) and fruits are cylindrical and easy for long distance transportation. It requires 100-110 days for first fruit maturity. Its fruit has greenish white rind and white flesh with an average flesh thickness of 6.40 cm. Its average yield in national level is 36.5 t/ha and average fruit weight is 3.5 kg. It is suitable for culinary purpose.

#### 2.1.2.2 Bitter gourd

**Variety released.** A bitter gourd var. Pusa Aushadhi (Sel-1) was released by Central Sub Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops for cultivation in Zones VI (Rajasthan, Gujarat, Haryana and Delhi).

**Varieties identified.** A bitter gourd var. Pusa Rasdar was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region.
It is the first extra-early (41-45 days for first fruit harvest) improved variety suitable for cultivation in protected condition. Fruits are smooth, non-prickled with tender skin and fleshy, which will be highly acceptable to the growers. The average fruit weight is 110 g with average yield of 450 kg under 100 sqm insect proof net-houses and 400 kg under 100 sqm poly-house.

Another variety Pusa Purvi was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is the first improved variety of short fruited bitter gourd (*balsamum* type) in the country suitable for making stuffed vegetable. Fruits are attractive dark green colour, small in size (4-5 cm long and 3-4 cm dia.) with pointed tubercles, prickled, and crispy flesh with high dry matter. The fruits contain more minerals and anti-oxidants than commercial varieties. Average yield is 9.0 t/ha.

**Promising genotypes:** The gynoecious line PDMGy-201 in the back ground of Pusa Do Mausami has 100% female flower; reaches edible stage in 45 days from sowing; fruits are light green, 12-15 cm long, 4.5-5.5 cm diameter, continuous ridges, club shaped and individual fruit weight of 85-90 g.

Sixty six hybrid combinations were made and evaluated and among these the combinations, PVGy201× PDMGy201, PVGy201 × DBGS-57 (DBGH 157) and S-2 × DBGS 34 (DBGH 234) were found promising and produced fruit yield of 27.46, 24.70 and 23.10 t/ha, respectively. Two hybrids DBGH 157 and DBGH 234 were included in IET trial under AICRP-VC. Three hybrids, namely, Pusa Do Mausami × DBGS 59 (PH-3), PVGy201 × DBGS 59 (DBGH 159) and Pusa Rasdar × S-2 (DBGH 542) were found promising with respect to yield. One selection, DBGS 32 having light green, cylindrical fruits with smooth surface showed best performance under protected cultivation.

### 2.1.2.3 Cucumber

**Promising genotypes.** During spring-summer season of 2014, 106 germplasm /advance breeding lines including 20 new collections were evaluated and promising lines maintained. Lines DC 83 and DC 22 yielded 20.4 and 18.9 t/ha showing an increase of 17.3 and 9.2% over check variety Pusa Uday (17.3 t/ha), respectively. These selections were entered in AICRP (VC) trial.

Out of 28 F₁ hybrids evaluated, gynoecious hybrids DGCH 18, DGCH 15 and monoecious hybrid DCH 9 yielded 28.4, 25.9 and 24.4 t/ha, which were 33.3, 21.5 and 14.6% higher than that of check Pant Sankar Khira 1 (21.3 t/ha), respectively.

During Kharif season, 143 lines were screened for downy mildew resistance. DC 70 and DC 77 showed highly tolerant disease reaction to downy mildew under challenge inoculation besides having high yield and other desirable horticultural traits. Out of 19 F₁ hybrids evaluated, DCH 16 (21.1 t/ha)
and DCH 19 (19.2 t/ha) were promising with high yield and were tolerant to downy mildew disease. During spring summer and Kharif season 2014, large scale seed multiplication of promising gynoecious parthenocarpic lines DPaC 6, DPaC 9, gherkin lines DG 5, DG 8 and DG 11 and tropical gynoecious lines DGC 102 and DGC 103 were carried out under insect proof nethouse. During winter season of 2014-15, station trial for evaluation of gynoecious parthenocarpic lines DPaC 6 and DPaC 9 were carried out under low cost polyhouse. The promising parthenocarpic line DPaC 6 showed an estimated yield 1474.2 kg per 100 m$^2$ as compared to private company check Asma (1161 kg/100 m$^2$ polyhouse). The seeds of DPaC 6 were sent to CPCT, New Delhi, IARI regional station, Karnal and KVK Shikohpur for conducting multilocational trial.

2.1.2.4 Luffa

**Promising genotypes.** In sponge gourd, out of 28 selections evaluated during spring summer season, DSG-43 (13.5 t/ha), and DSG-33 (13.0 t/ha) were found to be promising and apart from superior fruit quality showed an increase of yield of 11.5 and 7.5%, respectively, over check Kalyanpur Hari Chikni (12.1 t/ha). Out of 36 sponge gourd F$_1$ hybrids evaluated, DSGH-52 (14.5 t/ha) and DSGH-34 (15.24 t/ha) were found to be very promising and showed an increase of 19.9 and 26.0 %, respectively, over check Kalyanpur Hari Chikni (12.1 t/ha). These selections and F$_1$ hybrids were entered in AICRP (VC) trial. The genetics of seed coat colour of sponge gourd was studied where in it was found that black seed coat colour was dominant over white seed coat and it was governed by single dominant gene. This is the first conclusive report on inheritance of seed coat colour in sponge gourd. Ridge gourd selections DRG 74 and F$_1$ hybrid DRGH 4 were found promising with an average yield of 15.4 and 18.3 t/ha, respectively.

2.1.2.5 Pumpkin

**Promising genotypes.** Three selections, namely, DPU 48, DPU 12 and DPU 37 significantly yielded better with productivity of 47.5, 43.5 and 41.16 t/
ha with an increase of 36.38, 24.89 and 18.17 % over check Pusa Vishwas (34.83 t/ha), respectively. Mature fruit flesh colour of DPU 48, DPU 12 and DPU 37 was orange, orange, yellowish-orange with flesh thickness of 4.25, 3.51 and 3.40 cm, respectively.

2.1.2.6 Summer squash

Variety identified. A summer squash variety Pusa Pasand was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is first early improved flattish round variety for spring summer season cultivation under open and off-season winter cultivation under protected conditions. The fruits are attractive light green, shiny, uniform, flattish round, 70-80 g with tender flesh. First harvesting period is 45-50 days after sowing in spring summer season. Average fruit yields were 16.3, 24.1 and 22.9 t/ha during spring summer season under open field conditions, naturally ventilated polyhouse and plastic low tunnel during winter season, respectively.

Promising selections of Sarda melon. Four promising selections were developed which can be successfully grown under net house in north Indian plains. The yield potential of DHM 159 in 100 m² area is 500-505 kg with high TSS (13.8-14.5°Brix). The fruit rind colour of DHM-159 is white-creamish, which makes it a novel genotype with negligible seed cavity. The other promising genotypes were DHM 56 (400-450 kg/100 m², 15.1-15.7°Brix), DHM 145 (480-520 kg/100 m², 13.5-14.1°Brix) and DHM 163 (520-550 kg/100 m², 12.1-12.7°Brix).

2.1.2.7 Muskmelon

Promising genotypes. During summer 2014, promising muskmelon selections for high yield coupled with better fruit quality and tolerance to Fusarium wilt were DM 159 (22.6 t/ha, 12.1°Brix) and DM 154 (22.1 t/ha, 11.8°Brix).

Technoogy for growing sarda melon in north Indian plains. Sarda melon requires moderate range of temperature during its growing period. With the use of net and polythene houses, it can be successfully grown three times a year in north Indian plains. First crop can be successfully obtained under net house during February-March to April-June. Second crop
can be transplanted in August-September and fruits can be harvested in October-November, which is also an off-season. Third crop can be grown during off-season by raising nursery under protected condition in December and transplanting in January under temporary protection from polythene so that fruits can be harvested in the March which can fetch higher prices. Hand pollination was practiced for fruit set under protected conditions.

2.1.2.8 Other cucurbits

Long melon. Long melon selections, DLM 27, DLM 34 and DLM 8 yielded 31.95, 26.48 and 24.66 t/ha, showing an increase of 71.50, 42.14 and 32.37% over check Punjab Long melon (18.63 t/ha), respectively. The seeds of DLM 27 were sent to IARI Regional Station, Karnal; KVK, Ujjawa and KVK, Shikohpur for conducting multi-location trials.

Round melon. Round melon selections, DRM 26, DRM 44 and DRM 3 yielded 8.36, 6.72 and 5.73 t/ha, showing an increase of 79.78, 44.52 and 23.23% over check Punjab Tinda (4.65 t/ha), respectively. The seeds of DRM-26 were sent to IARI Regional Station, Karnal; KVK, Ujjawa and KVK, Shikohpur for conducting multi-location trials.

2.1.3 Solanaceous Crops

2.1.3.1 Brinjal

A total of 197 genotypes/ breeding lines were evaluated, of which G 185 (oblong pink), DBL 6 (long purple), DBGL 164 (long green), DBR 23 (round purple) and DBR 43 (round purple) were found promising with an average yield of 38, 32, 41, 39 and 42 t/ha, respectively. In long fruited hybrid, DBHL 211 (long purple, 51.7 t/ha) was found superior over check Hybrid-704 (44 t/ha). In round fruited hybrid trial, DBHR 95 (53.6 t/ha), DBHR 4 (52.8 t/ha) and DBHR 7 (49.9 t/ha) were found superior over check Navkiran (45.4 t/ha). In resistance breeding, genotypes G 26, G 37, G 48, G 81 and G 109 were found resistant to Verticillium wilt under field conditions. A total of 20 inter-specific hybrids were evaluated for fruit and shoot borer resistance, and hybrids PK x S. incanum, G-190 x S. incanum, PS x S. sisymbrifolium were free from borer infestation under field conditions.

2.1.3.2 Tomato

Variety identified. Pusa Cherry Tomato 1 was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is first indigenous cherry tomato variety suitable for green house environment. It is characterized by indeterminate growth habit, light green leaf, moderate pubescence over stem and leaf. It attains average vine length varying from 9-12 m. Its fruit berries are round shaped with uniform ripening pattern and deep red colour. It has 18.5 average flower trusses per plant. The average fruit weight is 13 g with fruit yield of 22 kg/plant and a yield potential of 4-5 tonnes/1,000 m². The fruits get ready for first harvest in about 70-75 days and crop lasts for about 9-10 months. It is suitable for growing in North Indian plains under naturally ventilated and environment controlled greenhouse conditions having tolerance to root-knot nematode. Its fruits contain 5.4 mg/100 g FW lycopene, 20.7 mg/100 g FW ascorbic acid, 0.43% acidity and 10.4°Brix TSS.

Promising hybrids. Forty-three F₁ combinations were evaluated for yield attributes, fruit characters, pericarp thickness, firmness and quality attributes. No
significant differences in fruit weight were observed among F$_1$ combinations and Pusa Hybrid-8. A total of 84 F$_1$ combinations were made including various high yielding varieties with IARI varieties. A total of 102 entries of 11 AICRP (VC) trials were also evaluated for fruit and yield characters. During 2014-15, a total of 61 entries from eight AICRP (VC) trails were grown for evaluation.

**Screening for ToLCV resistance.** In a station trial on screening of tomato against ToLCV, 265 genotypes including parental lines, 56 accessions of wild species (*Solanum peruvianum* and *S. pimpinellifolium*) and 55 F$_1$'s were screened during Kharif 2014. A total of 12 genotypes including DT-P1-P8, DT-3-7, DT-1-1, DT-4-1, DT 348-4-5 and DT348-4-5R were found promising for resistance against ToLCVNDV. To transfer Ty genes for resistance against ToLCV, crosses were made between EC687094 and Pusa Sadabahar and Pusa Rohini. A total of 15 breeding lines carrying genes for resistance against ToLCV, late blight and *Fusarium* wilt were grown for seed enhancement. Molecular marker analysis using Ty genes linked markers was done using breeding lines from AVRDC. The F$_1$ crosses were attempted between these tolerant lines and high yielding varieties including Pusa Rohini, Pusa Ruby, Pusa Sadabahar, Pusa 120. A total of 15 entries of two AICRP (VC) ToLCV trials were also screened for resistance.

**Genotypes for high temperature tolerance.** Sixty genotypes were evaluated for the tolerance to high temperature during March to June, 2014. Earliest fruit set under high temperature regime was recorded in DTH 9; DTH 10 followed by Pusa Sadabahar, LP 2 (a selection from cross of *L. pimpinellifolium*), PSH × PS, PSH 2 and FEB 2. DT-C-10y (orange-yellow colour fruits), SEL 120, and LP 2 (red colour fruits) were found promising for low cost polyhouse. LP 2 recorded high lycopene (4.5 mg/100 g) and DT-C-10y recorded high β-carotene (1.7 µg/ g) with average fruit weight of 77 and 80 g, good TSS (5.6 and 5.3°Brix) and average yield/plant of 4.8 and 6.3 kg, respectively.

**Interspecific and intergeneric crosses.** Interspecific crosses of *S. lycopersicum* with *S. pimpinellifolium*, *S. peruvianum*, and *S. habrochaites* were attempted for transfer traits for earliness and thermo-adaptability. There was no seed viability in interspecific crosses of *S. lycopersicum* with *S. peruvianum*. Inter-generic crosses of tomato with *S. sisymbriifolium* were attempted for inducing haploidy in tomato.
2.1.3.3 Chilli

Promising leaf curl complex resistance genotypes. Four season trial for evaluation of chilli lines for resistance to leaf curl complex caused by begomoviruses completed this year. Out of the 62 chilli lines assessed for resistance to the disease under natural disease epiphytotic conditions, five lines (DLS-Sel-10, WBC-Sel-5, PBC 142, PBC 345 and Tiwari) showed resistance. Evaluation of disease resistance lines for the next three consecutive seasons (Kharif 2013, summer 2014 and Kharif 2014) resulted in breakdown of resistance of 2 lines, namely, Tiwari and PBC 345 with the remaining three showing resistance (DLS-Sel-10-resistance, WBC-Sel-5-resistance, PBC 142-moderate resistance). Two year DUS trials in chilli, sweet pepper and paprika was completed.

2.1.4 Root and Bulbous Crops

2.1.4.1 Carrot

Variety identified. Pusa Kulfi (IPCPm,) was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is the first cream coloured, self-core tropical carrot variety. Its foliage is characterized by green intermediate leaf dissection with normal leaf type. Its roots are of obtriangular shape with slight green purplish splash on shoulders. It is suitable for normal sowing beginning mid-September under north Indian plains. It attains marketable maturity in 90-100 days. The average root weight is 100-125 g with about 25 t/ha root yield. Its roots contain 216 µg/100g FW carotenoids; 8.80°Brix TSS; 121 µg/100 g FW lutein; 50 µg/100g FW thiamine and 730 µg/100g FW niacin.

Development of promising genotypes. In early group, out of 21 hybrids evaluated, 6 were most promising, viz., IPC7 x IPC 75 (48.4 t/ha), IPC Ht2 x IPC116 (42.70 t/ha), IPC Ht2 x IPC 96 (42.20 t/ha), IPC7 x IPC39 (41.8 t/ha), IPC7 x IPC122 (40.2 t/ha) and IPC Ht2 x IPC 4 (38.90 t/ha) from the point of view of yield potential and quality. Twelve inbred lines were maintained and utilised in hybrid development.

In normal season carrot, out of 64 hybrids evaluated, 41 were red coloured, 15 black/ purple and 8 orange. The most promising of these with high yield potential were IPC 100 x IPC 126 (56.66 t/ha), IPC 98 x IPC 13 (49.75 t/ha), IPC 53 x IPC 104 (49.63 t/ha), IPC 126 x IPC 16 (49 t/ha), IPC 55 x IPC 35 (47.62 t/ha), etc.

2.1.4.2 Radish

Variety identified. Pusa Shweta (IPRWw,) was identified by IARI Variety Identification Committee for cultivation in Delhi and NCR region. It is characterized by light green leaves colour with serrated margins. Its roots are medium long, extra white, cylindrical with blunt ends. It takes 50-55 days to reach marketable maturity. It is suitable for sowing from September to November in North Indian plains. The average root weight is 200 g with about 40 t/ha root yield. Its roots contain 34.84 mg/100 g FW ascorbic acid, 4.20°Brix TSS, 424.8 ppm phosphorus, 8.48 ppm calcium, 497.86 ppm sodium and 1.94 ppm zinc.

Pusa Shweta

2.1.4.3 Onion

Hybridization of short day tropical types with temperate type. Crossing of temperate onion var. Brown Spanish was accomplished with short day tropical onion, viz., Pusa Riddhi, Pusa Red and Sel. 106. Seeds obtained from the crosses have been planted during Rabi season (2014-15) to evaluate their morphological and yield related traits.
2.1.5 Leguminous Crops

2.1.5.1 Garden pea

*New genetic material developed.* Among 13 newly developed early maturing genotypes, GP 904 (11.32 t/ha), GP 912 (13.65 t/ha) and GP 1101 (13.32 t/ha) were found promising. Whereas, GPE 1 (6.34 t/ha), GPE 3 (7.22 t/ha) and GPE 4 (8.33 t/ha) were found promising for fresh pods and were highly resistant to powdery mildew. Two snap pea lines GPE 1 (medium sized) & GPE 4 (long and bold) and GPE 3 (snow pea) were found promising for fresh consumption and also highly resistant to powdery mildew. A total of 22 genotypes and 65 crosses including F<sub>1</sub> to F<sub>3</sub> populations were sown during first week of October in *Fusarium* wilt sick plot. Based on screening against *Fusarium* wilt, the genotypes GP 17, GP 6, GP 55, GP 48, GP 18, EC 677213 and GP 492 showed high degree of resistance. Based on screening for powdery mildew disease under field conditions, genotypes GP 6, GP 473, VP 233, GP 901, GP 912, GPE 1, GPE 3 and GPE 4 were highly resistant. Besides, 20 F<sub>1</sub> and 172 crosses (28 F<sub>2</sub>, 125 F<sub>3</sub>, 10 F<sub>4</sub>, 9 F<sub>6</sub>) were retained for further selection/evaluation.

2.1.5.2 Other legumes

Two promising dolichos bean genotypes (DB 10 and DB 15) and a cowpea bush type (GP 55) were under testing in AICRP (IET). Cowpea lines CP 5, CP 11, CP 55, CP 56 and Pusa Sukomal were found highly resistant to Cowpea Golden Mosaic Virus.

2.1.6 Malvaceous Crop

2.1.6.1 Okra

*New genetic material developed.* About 165 genotypes including parental lines, F<sub>1</sub>s (82 F<sub>1</sub> cross combinations) and advance lines (15) were evaluated for yield, fruit quality and YVMV resistance during *Kharif* 2014 season. DOV 66 and DOV 12 were 100% free from YVMV up to 90 days after sowing and recorded average yield of 18.5 and 17.8 t/ha having dark green attractive pods. However, Pusa Sawani (SC) and Arka Anamika (RC) recorded 100 and 6% YVMV incidence, respectively, during this period under field conditions. Pusa A-4 yielded 14.5 t/ha with 35% YVMV incidence. Hybrid DOH-1 recorded 19.1 t/ha yield with 1% YVMV incidence. Three okra lines, namely, DOV 66 and DOV 12 and hybrid DOH 1 are under AICRP trials (IET, 2014). Five AICRP trials (3 hybrid and 2 YVMV trials) with 63 entries were conducted during *Kharif* 2014 and data on nine traits including YVMV incidence were recorded.

Thirty diverse okra genotypes were evaluated for 19 quality traits during the *Kharif* season (rainy season). Mucilage content was found maximum in genotype, Punjab Padamini (5.73 %) and least mucilage recorded in genotype DOV 26 (3.35%). Genotypes with high mucilage also recorded high sugar content. Protein content was found maximum in USD0 2546 (2.75%) and minimum in DOV 26 (1.37%) with mean value of 1.78%. Genotypes, Arka Abhay and USD0 2546 recorded the maximum dietary fibre content (0.09 g/g). Among minerals, maximum content of calcium, iron, magnesium and copper was recorded in Arka Abhay (6.75 ppm), DOV 27 (1.6 ppm), DOV 29 (2.84 ppm), and P-8 (0.69 ppm), respectively. Flavonoids were recorded maximum in Parbhani Kranti (4.15 mg/g) followed by Punjab Padamini (3.86 mg/g). Genotypes USD0 2546, Punjab Padamini and Arka Abhay were found suitable for utilizing in future breeding programme for developing variety with high nutritional quality.

*Promising genotypes for YVMV resistance.* Seventy nine IC & EC lines of wild okra were evaluated for YVMV resistance. Ten accessions of two promising genotypes for YVMV resistance.
2.2 FRUIT CROPS

2.2.1 Mango Breeding

Artificial hybridization was attempted using 13 cross combinations on 441 panicles having 3,435 flowers. Amrapali, Mallika and Kesar were used as female parents, while Sensation, Tommy Atkins, Janardan Pasand, Erwin, Pusa Arunima, H 11-2, H 8-11 and H 12-5 as male parents. Selfing in Amrapali (50 panicles having 463 flowers) was also attempted. Total 58 hybrid stones were obtained and planted in the hybrid evaluation block. Out of 58 stones from different cross combinations recovered, 41 germinated and 36 hybrid plants are surviving and transferred in the field.

Total 64 mango hybrids were evaluated for different physico-chemical parameters. Hybrids, H-1-11, H 8-11, H 1-5, H 13-4 and H 11-2 had more than 200 g fruit weight. The maximum fruit weight (346 g) was noted in H 1-11 followed by H 8-11 and H 11-2 (222 g). Pulp: stone ratio was maximum in H 1-5 (5.78) followed by H 1-11 (5.26). The fruits of hybrid H 12-5 and H 11-2 had intense red pigmentation on the fruits.

2.2.2 Citrus Breeding

Sweet orange. Sixteen sweet orange variants were evaluated for growth, yield and yield attributing traits and compared with Jaffa and Valencia late, standard sweet orange cultivars. The larger size fruits (79.03 x 81.86 mm) with maximum weight (254.93 g) were found in Pusa Sharad, which had non-significant differences with Pusa Round (253.37 g) and MS 7 (247.87 g) as compared to Jaffa (158.13 g) and Valencia (118.97 g). Higher juice recovery was measured in MS 9 (54.48%), which did not differ significantly with MS 8, MS 14, MS 17 and Jaffa. The significantly higher TSS was found in MS 1 (13.43°Brix), which did not differ significantly with Pusa Round (12.77°Brix), MS 3 (12.50°Brix) and MS 8 (12.43°Brix). Ascorbic acid was found to be the highest in MS 16 (52.40 mg/100 ml juice) as compared to Jaffa (30.06 mg/100 ml juice). The highest yield per plant was recorded in Pusa Sharad (23.33 kg) followed by Pusa Round (20.90 kg), which were at par with MS 7 (20.20 kg). Based on overall performance, Pusa Sharad, Pusa Round and MS 7 had consistent performance than those of the rest variants.

Out of 8 Mosambi variants evaluated, MOS-3 was found relatively dwarf (35.68 m³ canopy volume) with high yield (48.16 kg/tree) and yield efficiency (1.35 kg/m³ canopy volume). For fruit weight, MOS-2 (200.33 g) and MOS-5 (200.00 g) were found maximum. Juice recovery was highest in MOS-2 (50.29%) followed by MOS-8 (45.92%), while MOS-3 had the lowest seeds/fruit (15.00). Juice TSS was found maximum in MOS-6 (10.53°Brix), which was non-significant in MOS-5 (10.43°Brix), while titratable acidity was lowest in MOS-5 (0.29%).

Acid lime. Yield and quality parameters were assessed in 10 acid lime clones. Clone ALC-2 had significantly the higher fruit weight (54.60 g), which was at par with ALC-21 (51.80 g). However, the highest juice content was estimated in ALC-21 (28.70 ml) followed by Pusa Abhinav (20.98 ml), which was
non-significant in ALC 2 (19.17 ml). Juice recovery was recorded highest (56.77%) in ALC 21 followed by Pusa Abhinav (47.41%) and ALC 22 (47.27%). Seed number was lowest (5.67 / fruit) in ALC 22. Total soluble solids were recorded highest in ALC 40 (9.37°Brix) followed by ALC 22 (9.33°Brix). Acidity was measured higher in ALC 22 (7.87%). The number of fruits/tree was found to be the highest in ALC 40 (365) followed by ALC 2 (363.3) and ALC 12 (205.3). Clones Pusa Udit, Pusa Abhinav, ALC 21 and ALC 45 flowered round the year and were found promising as they had two good harvests in a year.

Lemon. Five genotypes were evaluated for physico-chemical parameters. Among different accessions, LS 1 excelled over others in respect of fruit weight (53.27 g) and ascorbic acid content (132.60 mg /100 ml juice).

Grapefruit. Foster proved most vigorous cultivar having higher canopy volume (48.90 m³), while Redblush proved most productive with highest yield (51.52 kg / tree) and yield efficiency (1.79 kg / m³ canopy volume). Imperial cultivar produced the heaviest fruits (428.80 g / fruit) followed by Rubi Red (422.73 g). Marsh Seedless and Redblush had low acid content (1.03-1.06%) and seed number (3.67-6.00/fruit). The lowest peel thickness of fruit (3.43 mm) was recorded in Marsh Seedless. Except Rubi Red in case of juice content and Redblush for TSS content, all the cultivars were statistically superior in juice (48.65-54.21%) and TSS (9.23-10.17°Brix) contents.

Tangerine. Three cultivars differed significantly with respect to yield and fruit quality. Dancy proved to be the most productive (48.25 kg/tree) cultivar, while, the highest fruit weight (229.67 g/fruit) was recorded in Murcott. Itaburai had the lowest number of seeds per fruit (8.33). Murcott proved statistically similar with Itaburai for thin peel and high juice content and Dancy for high TSS content. All the cultivars had almost similar acid content.

Hybridization. From 2014 crosses, in rootstock improvement programme, total 1431 seeds were obtained from 10 different cross combinations. The maximum seeds were recovered from cross between Pummelo x Troyer citrange, while minimum were in Pummelo x Sacaton (6 seeds). From these seeds, total 552 seedlings germinated with maximum in Pummelo x Troyer citrange cross. Out of these seedlings, 55 seedlings in four cross combination had trifoliate leaf characters and proved to be of the hybrid origin. However, in scion improvement, total 679 seeds were recovered of which 180 seeds germinated with maximum in cross Pummelo x Mosambi.

During March 2015, for rootstock improvement crosses were made between Cleopatra mandarin, Rangpur lime, Attani, RLC-6, Pummelo, Yama Mikan and small fruited mandarin as female parent and Troyer, Morton, trifoliate orange and pummelo as pollen parents and total 815 flowers were crossed. In scion improvement, two cross combinations in lime improvement, i.e., Kagzi kalan x acid lime and Konkan Seedless x acid lime and three combinations in sweet orange improvement, i.e., Malta x Redblush, Mosambi x Pummelo and Pummelo x Mosambi were attempted. Total 387 flowers have been crossed in all combinations. Maximum fruit set was recorded in Konkan Seedless x acid lime (95.12%) and minimum in Malta x Redblush (57.14%).

Molecular characterization of Kinnow mandarin clones and mutants. Genetic diversity among Kinnow clones and mutants including the parent was studied using SSR markers. Out of 87 primers tested, 11 primers showed polymorphism and amplified 14 alleles. These polymorphic primer pairs could amplify 1-2 alleles /primer pair giving average 1.27 amplicons / primer pair. The PIC value ranged from 0.14 to 0.99 and indicated that markers used were quite informative. Dendrogram based on Jaccard’s similarity coefficients were generated based on an average linkage algorithm (UPGMA) using marker data showed that genetic similarity between lines ranged from 0 to 0.9. Genotypes (mother plant, mutants and superior clones) were grouped into two clusters based on genetic distances.

Physiological and biochemical characterization of Kinnow mutants. The impact of gamma irradiation
and ethyl methanesulfonate (EMS) on physio-
biological parameters and antioxidant enzymes was
studied in pre-bearing Kinnow mutants irradiated
with gamma rays (5, 10, 15 and 20 Gray) or EMS
(0.05, 0.1, 0.2, 0.5%). Results demonstrated significant
decrease in leaf area (17.64%), membrane injury index
(MII) (62.06%), chlorophyll \textit{a} (101.21%), chlorophyll
\textit{b} (47.61%) and total chlorophyll (67.52%) contents in
the mutants treated with 20 gray. Leaf fresh and dry
mass were recorded minimum in the mutant treated
with 0.5% EMS. Biochemicals like proline and phenol
content increased due to exposure to increasing
doses of mutagens. Maximum leaf protein content
was recorded at 20 gray (27.67%) and 0.5% EMS
(21.11%) treatments. Irradiation treatments upregulated
superoxide dismutase activity being maximum at 20
gray, while the differences were insignificant with other
doses. As compared to control, 1.85 and 1.63% increase
in the catalase activity was observed at 20 gray and
0.5% EMS, respectively. Peroxidase activity exhibited
an ascended increase as compared to control (1.81-fold
increase) at 20 gray. Contrary to this, 1.20-fold decrease
was recorded in the mutants after treatment with 0.5%
EMS.

2.2.3 Grape Breeding

\textit{Identification new hybrids}. A total of 48 hybrids/
varieties were evaluated under subtropical conditions
of Delhi for earliness in maturity, self-thinning type,
sweetness and yield traits. Three hybrids, viz.,
Hyb. R1P9 (Banqui Abyad x Perlette), Hyb. R1P14
(Cardinal x Beauty Seedless) and ER-R2P36 (Pearl
of Csaba x Beauty Seedless) were found extremely
promising in terms of early maturity, total soluble
solids content, self thinning type, bold berries and
vine productivity.

\textbf{Physico-chemical properties of promising grape hybrids}

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Bunch wt. (g)</th>
<th>Bunch length (cm)</th>
<th>Bunch width (cm)</th>
<th>Berry wt. (g)</th>
<th>Berry dia. (mm)</th>
<th>Berry length (mm)</th>
<th>Seedlessness</th>
<th>No. of seeds/ berry</th>
<th>TSS (°Brix)</th>
<th>Acidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1P9</td>
<td>340</td>
<td>24</td>
<td>10</td>
<td>2.8</td>
<td>17.5</td>
<td>16.90</td>
<td>Seeded</td>
<td>Soft, 3-4</td>
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of June). It has large (5-6 g; 15 mm dia), round golden-yellow colour berry with firm pulp. Berries are very sweet having high TSS (20-22°Brix) in loose bunches. The clusters are medium big in weight (409 g) and bunch length 20 cm. The fruits are ready for harvest from 75-80 days after full bloom. Fruit yield from the mature vineyard of 6-8 year-old is 8-10 tonnes per hectare on ‘Head system’ of training. The hybrid is tolerant to anthracnose and powdery mildew. The hybrid has desired traits for table purpose, juice making and munnakka (seeded raisin) preparation.

2.2.4 Guava Breeding

Molecular characterization. Genetic diversity among 24 guava genotypes (22 varieties/collections belonging to Psidium guajava and 2 other Psidium species) were characterized using RAPD markers. Out of 29 RAPD primers screened, 10 were found to be monomorphic and 19 showed polymorphism among guava genotypes. Number of alleles detected using polymorphic RAPD primer ranged between 2 (OPA13A) to 11 (OPF02A) with an average of 6 amplicons/primer. High rate of polymorphism was observed for primers OPF02A, OPH19A, OPF13A, OPA13A and OPB13A.

Six guava genotypes (Pant Prabhat, Arka Mridula, Lalit, Allahabad Safeda, Hisar Surkha and Hisar Safeda) were evaluated for morphological, yield and physico-chemical attributes under high density planting. Significant variations were observed in different traits like plant height, total number of fruits/plant, fruit weight, yield/plant, TSS, acidity and ascorbic acid. Although number of fruits in both the seasons (rainy & winter) were higher in Lalit (269.18) but the highest yield (kg/tree) were recorded in Pant Prabhat (40.82). Highest TSS were recorded in Allahabad Safeda (12.61°Brix) followed by Hisar Surkha (12.41°Brix) and Lalit (12.12°Brix). Among all genotypes, maximum ascorbic acid was estimated in Pant Prabhat (149.70 mg/100 g) followed by Allahabad Safeda (146.40 mg/100 g).

2.2.5 Papaya Breeding

Hybridization. The eight hybrids of different cross combinations [(Pusa Dwarf x Sinta), (Pusa Nanha x Sinta), (Pusa Nanha x TGP-7), (Pusa Dwarf x Pusa Nanha), (Pusa Nanha x Pusa Dwarf), (Pusa Nanha x RCTP-I), (RCTP-I x Pusa Nanha), and (Pusa Dwarf x Tripura Local)] were evaluated for growth, flowering and yield attributes. The earliest flowering was recorded in Pusa Dwarf x Sinta at 81 days after planting (DAP) followed by Pusa Dwarf x Pusa Nanha, whereas, late flowering was noted in RCTP-I x Pusa Nanha. The least plant height coupled with the lowest fruiting zone was in Pusa Nanha x Pusa Dwarf, which is not a desirable trait for achieving higher yield. The data further revealed that lower level of total soluble solids was estimated in some hybrids. Although, it was 10.2°Brix in Pusa Dwarf x Sinta and lowest 7.6°Brix in Pusa Nanha x Pusa Dwarf. Maximum per plant fruit yield (39.6 kg) was recorded in RCTP-I x Pusa Nanha followed by (35.2 kg) in Pusa Dwarf x Tripura Local and Pusa Nanha x TGP-7 (33.2 kg), whereas minimum fruit yield (28.2 kg) was in Pusa Nanha x Sinta. Out of these hybrids, Pusa Nanha x Sinta was dwarf, early flowering and with desired fruiting zone. However, maximum fruit yield was recorded in Pusa Nanha x RCTP-I.

At Regional Station, Pusa (Bihar), 26 papaya germplasm were evaluated for yield, quality and tolerance to ring spot virus disease. The maximum plant height (163.00 cm) was observed in L 13/21, whereas the lowest height (75.00 cm) was found in Pusa Dwarf. However, the highest stem girth (31.33 cm) was found in P 13/93-H, while lowest (15.21 cm) was in BR 13/2 at first flowering stage. Maximum number of fruits (42) was found in Red 13x1 and minimum (24) in P 13/93-H. Highest fruiting zone was found in R,13 (96.33 cm), while lowest was in Pusa Dwarf (47.00 cm). Maximum fruit weight (2.81 kg in R,13 followed by P13/93H (2.72 kg) and F 13/26H (2.38 kg), while minimum (1.18 kg) was in Pusa Dwarf. Maximum fruit yield/plant (68.37 kg) was observed in R,13 followed by P13/93H (65.28 kg) and F 13/26H (65.04 kg), while lowest was found in Pusa Dwarf (43.66 kg). Flesh thickness was highest in P13/93H (3.53 cm) followed
by R8/13 (3.32 cm), while minimum was observed in F 13/27 (2.52 cm). Minimum fruit cavity (6.60 cm) was observed in BR 13/2, while maximum (11.71 cm) was found in P13/93H. Highest TSS (12.5° Brix) was obtained in BR 13/2 followed by R8/13 (12.2° Brix), while lowest was found in Pusa Dwarf (8.5° Brix). BR 13/2 and R8/13 showed tolerance to the ring spot virus disease in first year trial, while the highest infection was noticed in Pusa Dwarf (72.19%). Flesh coloured varied from yellow, orange and pink red.

In dioecious papaya, identification of desirable male is very important in breeding programmes. Male flower colour was found to have correlation with flesh colour of ripe fruits. We have observed that the intensity of whiteness of male flower colour is responsible for flesh colour (yellow to pink) of fruits.

**Mutation breeding.** The seeds of the papaya P 7-2 were treated with gamma rays 0.1, 0.15, 0.2, 0.25 and 0.3 kGy. Control recorded the maximum germination (68%) followed by 64.25% at 0.1 kGy. The germination was least (45%) at 0.3 kGy. Minimum seedling length (8.5 cm) and stem diameter (3.92 mm) were recorded in treatment 0.1 kGy, while maximum length (19.2 cm) and diameter (6.26 mm) were recorded in treatment 0.3 kGy after 30 days of sowing. Minimum plant height (79.24 cm) was recorded in treatment 0.1 kGy, while maximum (112.20 cm) in control. Minimum height at first flower bud initiation (55.28 cm), days to flower initiation (78.28) and petiole length (60.45 cm) were noted in treatment 0.1 kGy, while maximum height at first flower initiation (78.2 cm), days to flower initiation (87.46) and petiole length (68.24 cm) recorded in control. Among irradiation treatments, maximum number of fruits (18) was recorded in 0.3 kGy treatment, while maximum fruit weight (750 g) recorded in control. Maximum TSS (10.6° Brix) in fruit pulp was estimated in treatment 0.1 kGy. The dwarf and precocious lines were selected and selfed for raising M2 population.

**Quality evaluation of genotypes under protected conditions.** Sixteen genotypes including five advance gynodioecious papaya lines (P 7-2, P 9-5, P 7-15, P 7-9, P 9-12, Goa 1, Goa 2, Goa 3, Goa 6, Pusa Nanha, Pusa Dwarf, Red Lady, Pune Selection, Tripura Local, Sinta and CO 5) along with some commercial varieties/hybrids were grown under net-house. The moisture content in the fruit ranged from 85.66 to 88.68%, with maximum in Tripura Local and Sinta followed by P-9-12 and Red Lady. Fibre content ranged from 3.81-6.73% on dry weight basis, which was highest in Goa 2 genotype (6.73%) followed by Sinta (6.34%). The nitrogen content was found to be significantly high in Goa 3, P 9-12, CO 5 and P 7-2 followed by P 7-9 and Sinta (0.896 to 1.585%). Protein content varied from 5.687 to 9.910%. Maximum total carotenoids content was estimated in red pulped genotype (P 9-12) followed by Pusa Nanha (6.34 mg/100 g) and Goa 3 (5.96 mg/100 g). Genotype P 9-12 showed the highest lycopene content (4.30 mg/100 g) followed by Pusa Nanha and P 7-9. The values of β-carotene ranged from 0.25-3.38 ppm (on fresh weight basis), maximum being observed in red pulped genotype P-7-9, which was followed by P 9-12 (2.49 ppm) and Red Lady (2.14...
ppm), all belonging to red-fleshed papaya group. The radical scavenging capacity was assessed by using DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. \( IC_{50} \) values are expressed as µmol TE/g and represent the concentration of extracts that is required for 50% of free radicals inhibition. The DPPH activity was found significantly higher in P 9-5 (0.0454 µmol TE/g) followed by Goa 3 (0.0403 µmol TE/g). CUPRAC values ranged from 2.0609 to 5.1144 µmol TE/g being significantly higher in P 9-5 followed by Goa 1, P 7-15 and Goa 3, which were statistically at par with each other.

2.2.6 Temperate Fruits

Under Shimla conditions, pomegranate varieties, viz., Ichakdana, Ganesh, Kandhari Hansi, Kandhari Kabul, Jodhpur Red, P 23 and P 26 performed well under temperate conditions. The highest fruit weight was recorded in Ichakdana (426 g) with 14.8% TSS. Anar butterfly could effectively managed applying neem-based pesticide, covering of plant by shadenet, and covering of individual fruit with butter paper envelope after fertilization. These treatments resulted in getting 85-90% fruits devoid of infestation.

Study on the bearing habit in paper-shelled Pusa Khor walnut revealed that it bore 60.91% laterally and 39.09% fruits terminally; while all the fruits borne by the other three clones were terminal. It is semi-vigorous in nature. The bio-chemical analysis of kernels was estimated and the organoleptic test revealed that its astringency was significantly lower than market samples. The oil per cent as well as shelling per cent were 55.4 and 49.8, respectively.

2.2.7 Orchard Management

2.2.7.1 Rootstock research

Dwarfing and salt tolerance in mango. Growth, yield and quality performance of four mango varieties released from IARI and commercial variety Dashehari were assessed on three polyembryonic rootstocks, i.e., K 5, Kurakkhan and Oulour. Fruit weight was maximum (192.87 g) in Pusa Arunima on Kurakkhan rootstock. Maximum fruit weight in Pusa Surya (211.80 g), Amrapali (143.13 g) and Dashehari (191.17 g) was recorded on K 5 rootstock, which was non-significant on Oulour. Mallika on Kurakkhan had the highest fruit weight, which was statistically at par with K 5 rootstock. Pulp content in Pusa Surya (152.55 g) was found to be the highest on K 5 rootstock, which was non-significant with Kurakkhan. Similarly, maximum pulp in Mallika (144.77 g) was also recorded on K 5, while, Amrapali had the higher pulp content on Oulour, which was at par with Kurakkhan. Pulp TSS was not much influenced due to rootstocks, however, the maximum TSS was recorded in Mallika when Kurakkhan was used as rootstock. Significantly lower acidity in Pusa Arunima was estimated on K-5 rootstock, which was non-significant with other rootstocks. In Pusa Surya, significantly higher acidity was found on Oulour rootstock and lowest on K-5, which did not have significant difference with fruits on Kurrakan rootstock. Moreover, the highest acidity was recorded in Pusa Arunima on Kurakkhan and lowest in Mallika on Oulour. Total carotenoids content was also influenced by the rootstocks. In Pusa Arunima and Amrapali, the higher TCSA was recorded on Oulour, while in Pusa Surya and Mallika, it was maximum on Kurakkhan and K 5 rootstocks, respectively. The highest yield efficiency was found in Amrapali on Kurakkhan rootstock, while minimum in Dashehari on the same rootstock.

Dwarfing and salt tolerance in citrus. One-year-old Kinnow plants budded on three rootstocks were irrigated with water containing 50, 75 and 100 mM NaCl or tap water (control, 0.0 mM NaCl). At 75 and 100 mM NaCl, higher reduction in the total chlorophyll content (12.43 and 15.85%) was recorded on the Jatti khatti compared to the Soh sarkar rootstock. Kinnow on Jatti khatti rootstock accumulated 13.63 and 11.85% more Na\(^+\) and Cl\(^-\) at 75 and 100 mM NaCl stress than on Sohsarkar rootstock, which accumulated lesser leaf Na\(^+\) and Cl\(^-\) ions. The increasing NaCl concentrations inhibited the accumulation of N, P, K, and Mg in Kinnow leaves budded on Jatti Khatti rootstock, while reduction of K and Ca was more in Kinnow budded on Sohsarkar rootstock at higher NaCl concentrations. The results show that rootstocks were potential for
growing Kinnow mandarin where irrigation water salinity is ≤ 50 mM NaCl; the Soh sarkar rootstock should be adopted where NaCl concentration of irrigation water is higher (≤ 75 mM).

**Grapefruit.** Karna khatta and RLC-4 rootstocks proved most productive for Marsh Seedless and Redblush cultivars, respectively. In Marsh Seedless, the plants budded on Troyer produced the heaviest fruits (441.70 g/fruit), while highest ascorbic acid (157.90 mg/100 ml juice), total phenols (128.43 mg GAE100 mg−1), and CUPRAC (3.25 µmol trolox g−1) activity and lowest acidity were observed in plants budded on Attani-2 rootstock. Attani-1, Attani-2 and Billikhichli proved similar statistically in respect of TSS contents of the fruits. Lowest peel thickness (4.32 mm) and highest juice content (51.83%) were observed on sour orange and RLC-4 rootstocks, respectively. In Redblush, Attani-1 produced the heaviest fruits (393.93 g/fruit). Billikhichli rootstock tended to produce the lowest seeds per fruit (1.00) with highest TSS (13.33°Brix), total phenols (92.80 mg GAE100 mg−1), and CUPRAC (3.70 µmol trolox g−1) activity. The fruits of Redblush cultivar had the lowest peel thickness (4.85 mm) and highest juice content (51.91%) when budded on Troyer rootstock. The fruits produced on RLC-4 and Attani-2 was least acidic (0.89%) with high ascorbic acid (105.17 mg/100 ml juice) content.

**Kagzi kalan lemon.** This cultivar was evaluated on eight rootstocks for growth, quality, physiological attributes and nutrients accumulation. Trees on RLC-4 had the highest fruit weight (53.43 g), which was non-significant with those on Attani-2 (50.73 g) and sour orange (48.27 g), while juice recovery was found to be the highest on rough lemon (45.09%) and minimum on Troyer citrange (33.22%). Furthermore, juice acidity was highest on Troyer (6.02%), which was at par with trees on Karna khatta (5.58%). Transpiration (E), stomatal conductance (g s) and photosynthetic rate (A) also varied significantly due to rootstock. The significantly maximum E and g s were recorded when RLC-4 used as rootstock, while A was recorded maximum on Attani-1, which was non-significant with trees on Attani-2, Billikhichli, RLC-4, Karna khatta and Troyer citrange. Data on nutrients accumulation clearly indicates significant effect of rootstocks. The maximum K (0.69%) was recorded on rough lemon, which was not-significant with trees on RLC-4 (0.68%). While Ca (1.74%) and Zn (87.00 ppm) accumulation was found higher on sour orange. Iron and manganese were recorded the highest on rough lemon but Fe was found non-significant in most of the rootstocks.

**Guava.** Rootstocks of different Psidium species, namely, P. fridrichthalianum, P. molle, and P. chinensis (red), P. quadrangularis were raised and maintained at phytotron for selecting wilt tolerant genotypes.

### 2.2.7.2 Effect of Zn and B on quality improvement in Kinnow

To improve the fruit quality of Kinnow, two micronutrients (Zn and B) were used as foliar application in the form of zinc sulphate (0.4, 0.6 and 0.8%) and boric acid (0.3, 0.6, and 0.9%). There were seven treatment combinations T1 (Control), T2 (Zn sulphate (0.4%), T3 (Zn sulphate (0.6%), T4 (Zn sulphate (0.8%), T5 (boric acid (0.3%), T6 (boric acid (0.6%) and T7 (boric acid (0.9%). A uniform standard doze of farm yard manures (40 kg) and fertilizers (400 g N, 200 g P and 150 g P) were applied in 4-year trees. Foliar application with zinc sulphate and boric acid did not affect significantly the size of fruits in terms of diameter. However, qualitative traits were found affected significantly in terms of peel thickness, total soluble solids, juice content, ascorbic acid, peel chlorophyll and total carotenoids of peel as well as juice. The photosynthetic rate was not significantly affected by foliar application of zinc sulphate or boric acid. The maximum peel colour development was recorded in treatment T7 (boric acid 0.9%) followed by T4, T6 with high positive ‘a’ value. It clearly indicated from the data that 0.9% boric acid and 0.8% zinc sulphate favours orange colour. The value of ‘b’, which indicates yellowness of the fruit, the maximum yellowness was recorded in treatment with 0.9% boric acid. Foliar application of zinc sulphate (0.8%) and boric acid (0.9%) at colour break stage significantly improved the quality parameters.
2.2.7.3 Nutrient studies on papaya cv. Pusa Dwarf

Under Samastipur (Bihar) conditions, the maximum plant height (124.87 cm) was observed with treatment T5 (N + P + Zn + B + S). However, the highest stem girth (34.74 cm) was found in treatment T6 (N + P + K + B + S), while lowest (24.97 cm) was in treatment T7 (N + P + K + Zn + S) at first flowering stage. Maximum number of fruits (36.96) was found in treatment T8 (N + P + K + Zn + B) followed by treatment T2 (N + P + K + Zn + B + S) (27.64). Maximum fruit yield/plant (45.71 kg) was observed in treatment T8 (N + P + K + Zn + B) followed by treatment T2 (N + P + K + Zn + B + S) (37.82 kg). No bumpiness and latex exclusion were observed in T8, while maximum B deficiency symptom was found in T1 (control). NPK along with B application is necessary for better yield and quality of fruits in sandy loam soils of NEPZ.

2.2.7.4 Temperate fruits

Propagation of the difficult-to-root species of apple and Prunus species was attempted through hardwood cuttings by initiation of rooting in the hot-bed (21°C) after giving IBA (3,000 ppm) treatment for 30 second. Very good callusing and root initiation was obtained in the hot-bed designed at the IARI Regional Station, Shimla. This resulted in very good success in kiwi fruit and pomegranate also.

In kiwi fruit, foliar application of calcium and boron (0.4%) resulted in 20% higher yield over control in cv. Allison with improvement in fruit weight (57.2 g). The application of 10 ppm CPPU by dipping fruits for ten seconds at petal fall and 30 days after petal fall stage increased fruit size by 20-70 g over the control. Summer pruning along with the CPPU application proved more effective in obtaining fruits of higher grades with increased fruit weight (95.37 g/fruit) and better quality. Summer pruning when done by pinching at 1/5th at petal fall stage + CPPU dipping (10 ml/l) and pinching 1/5th continued till harvest at one month interval resulted in increased fruit yield (54.80 kg/vine), high TSS (17.6°Brix), high total sugars (9.85%), advanced ripening by one week and reduced pulp firmness.

Foliar spray of nutrient mixture (NPK 15:15:15) at monthly interval in kiwi fruit and pomegranate stem cuttings enhanced sprout initiation and also better field establishment (85%) after one year of rooting.

2.2.7.5 Management of mango malformation

Liquid formulation prepared by using bacterial bio-agent was found promising to minimize mango malformation at IARI experimental orchard, for the last three years. This experiment was repeated at other locations in Saharanpur and at FRS, Gangian, PAU, Ludhiana to see its effect on reducing mango malformation.

2.2.7.6 Management of root rot in papaya

In papaya cv. Pusa Dwarf, maximum number of fruits (28.27) was found in treatment T6 (soil mounding with organic mulch) followed by treatment T4 (plastic mulch with soil mounding) (27.87). Maximum fruit yield/plant (26.17 kg) was observed in treatment T8 (N + P + K + Zn + B) followed by treatment T2 (N + P + K + Zn + B + S) (37.82 kg). No root rot disease was observed in T5 (organic mulch), while maximum disease (43.33%) was found in T1. Organic mulch was found most effective in reducing root rot disease incidence.

2.2.7.7 Apple canker

Based on survey related to apple canker conducted in the different parts of Himachal Pradesh, it was observed that smoky blight and pink canker dominated in most of the orchards in Mandi, Shimla, Kullu and Simaur districts, while nail head canker dominated in dry and temperate areas of Kinnaur and Lahaul Spiti. However, all three types of canker were naturally prevalent in all districts of Himachal Pradesh. Smoky blight and pink canker were observed to prevail in 75% cases in districts of Mandi, Shimla, Kullu and Simaur, while nail head canker existed up to 25% cases. Similarly, 90% cases of canker in Kinnaur and Lahaul Spiti district was represented by nail head canker and only 10% cases belonged to the rest two cankers types.
2.3 ORNAMENTAL CROPS

2.3.1 Rose

*Variety released.* A Hybrid Tea variety of rose, Pusa Mahak evolved by selection from open-pollinated population of cv. Century Two. The plants are tall and vigorous with a height of 100-120 cm. The flowers are dark pinkish in colour and have outstanding fragrance. The flowering starts in 40-45 days after pruning. Flowers are large and semi-double with 22-23 petals. It is a recurrent flowering and floriferous variety and each plant produces on an average 50-60 flowering shoots in a season. The variety is ideal for garden display and the fragrant flowers can be used for floral arrangements.

2.3.2 Marigold

*Variety identified.* Pusa Deep is an early flowering variety of French marigold, which flowers in 85-95 days after sowing. The variety produces medium statured spreading plants having 55-65 cm plant height and 50-55 cm plant spread. It produces compact and medium sized maroon colour flowers. The variety is very floriferous and produces on an average 80-90 flowers per plant resulting in flower yield of 18-20 t/ha. In Northern plains, it flowers during October-November. It is suitable for loose flower production and profitable as it flowers during festive season.

2.3.3 Gladiolus

*Registration of promising hybrids/lines with NBPGR.* Melody Open is a selection among the open pollinated seedlings of the variety “Melody”. The hybrid/ line is very early and flowers in about 74 days. The outer florets are in red group (50C, RHS colour chart) and inner tepals (49B, RHS colour chart), with red spots on the centre of two tepals and white stripes on all tepals. Spikes are straight and long with good rachis length and close arrangement of florets on spikes. It has good spike length (> 100 cm); rachis length more than 62.00 cm and number of florets per spike are 18.44. It is a good multiplier and produces more than 2.00 corms and 42.55 cormels from each mother corm.

Hybrid P 16-1 x Eurovision produces straight and long spikes (93 cm) with more than16 florets per spike. It is an early flowering variety and flowers in 76-80 days after planting. The spikes are straight and long with good rachis length (48-59 cm). At a time 5-6 florets remain open with close arrangement of florets on spike. Florets colour in red group (41 C, RHS colour chart) with dark stripes on inner two tepals (42 A, RHS colour chart) and red spots on outer throat which makes them more attractive. It produces more than 2.00 corms per mother corm.
2.3.4 Lilium

Among the different types of lilies, the Asiatic hybrid, Oriental hybrid and LA lilies are very popular. Performance of three LA lily varieties, viz. Brindisi (pink), Pavia (yellow) and Ercocana (white) under shadenet conditions in Northern plains. Pavia produced the maximum flower shoot length (122 cm) and number of florets per shoot (6.16) under Delhi conditions.

At IARI Regional Station, Katrain, Himachal Pradesh, inter-specific crosses of Lilium were evaluated for their precocious flowering ability. Out of 25 acclimated progenies of cross between L. formosanum x L. longiflorum, eight progenies bolted and reached anthesis within one year. These progenies took 301 to 335 days to flowering from the time of seed sowing. These results suggest the possibility of breeding new types of indigenous cultivars with favorable traits from the cross between L. formosanum and other hybrid lilies with coloured flowers.

Partially vernalized bulbs of 11 lilium hybrids along with cv. Prato as a check were evaluated under polyhouse. The earliest flowering was recorded in hybrid PKLH 2 (153.5 days) followed by PKLH 8 (159.9 days). Plant height was observed maximum in PKLH 1 (103.3 cm), whereas, minimum was noticed in PKLH 3 (34.4 cm). The maximum number of flowers per plant was recorded in hybrid PKLH 2 (11.9). Individual flower longevity was observed maximum in PKLH 6 and PKLH 8 (6.4 days), respectively.

2.3.5 Iris

Nine genotypes of Iris are being maintained and evaluated for floral and seed set traits. The longest spike length (149.6 cm) was found in Iris ginger breadman. The number of flowers per stalk was also highest in Iris ginger breadman (4.0). Most of the genotypes set the seed except Iris hollandica.

2.3.6 Eustoma

A new floriculture crop Eustoma (Eustoma grandiflorum (Raf). Shinn) was introduced at IARI Regional Station Katrain. A total of seven Lisianthus genotypes, namely, Echo Double Yellow, Echo Double Champagne, Echo Double Pure White, Echo Double Lavender, Echo Double Pink Picotee, Echo Double Blue and Echo Double Pink were evaluated for their suitability for cut flower production. The earliest (63.7 days) flowering was recorded in Echo Double Pink Picotee. The maximum cut stem length (38.1 cm),
flower size (8.5 cm) number of buds/ stem (7.33) and vase-life (16.0 days) was recorded in Echo Double Blue. Although, it is a newly introduced flower, due to its rose-like bloom, excellent post-harvest life and availability of different shades of blue, Eustoma has huge potential for its popularization in the Indian market.

2.3.7 Turf Grasses

In order to promote better growth in Dichondra repens L., a study was undertaken to understand the role of different coloured shadenets, namely, green, black, red and white (all 50%). The morphological evaluation during March revealed that the number of shoots /25 cm² (217) and leaf width (2.42 cm) were more under green shadenet followed by red shadenet. However, the shoot length (12.42 cm) and leaf length (2.15 cm) were found maximum under black shadenet. The maximum root length (6.77 cm) was observed under green shadenet followed by red (6.59 cm). A perusal of the light intensity recorded under different shade nets at the canopy level indicated that the light intensity was more under white shade net at 9.00 am (21,175 lux), 2.00 pm (53,400 lux) and 5.00 pm (6,450 lux) when compared to other coloured shade nets.

2.4 SEED PRODUCTION OF HORTICULTURAL CROPS

The Division of Fruits & Horticultural Technology and Seed Production Unit, New Delhi and IARI regional stations at Karnal, Katrain and Pusa Samastipur, produced nucleus, breeder and IARI seed of different horticultural crops. Apart from seed production, 10,301 saplings of horticultural crops were propagated during the year at the Division of Fruits & Horticultural Technology, Seed Production Unit, New Delhi and Regional Station, Karnal.

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Propagation of Horticultural Crops

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<tr>
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<td>10301</td>
</tr>
</tbody>
</table>
3. GENETIC RESOURCES AND BIOSYSTEMATICS

Collection, maintenance, characterization and utilization of germplasm are major activities in the crop improvement programmes of field and horticultural crops. A large set of germplasm lines including wild species were collected, evaluated and maintained as active germplasm and utilized in pre-breeding and genetic enhancement in various crops. The chapter also includes biosystematics and identification services related to fungi, insects and nematodes to explore, conserve and enrich the culture collections.

3.1 CROP GENETIC RESOURCES

3.1.1 Wheat

3.1.1.1 Genetic resources for conservation agriculture

Under multi-location testing for early (October) planting, a new pedigree bread line HDCSW18 yielded better than all national checks including HD 2967, HD 2733, GW 366 and DBW 17. Two more lines CSW 16 and CSW 18 from similar approaches are being characterized for their adaptation and stable response in multi-locations. Early seeding × genotype interaction study for identifying the genotypic suitability was carried out with 200 genotypes including 5 varieties released by coordinated programme. Entry like MW1006 (DL968/WR196//HW4622/DW1221) and MW1221 (HD 2967/NIVT1A-21) and MW 1559 (CL 1705/HD 2687) have consistently yielded better than the checks under maize-wheat cropping system for last two years. Entries MW1832, 1836, 1838 and MW 1915 also performed well under CA.

3.1.1.2 Genetic resources evaluation

A set of 70 germplasm lines from Uttarakhand grown in Almora were analysed for grain Fe and Zn concentration. Grain Fe ranged from 29-48 (mean = 36.9) and grain Zn ranged from 27-64 (mean = 42.1) ppm. A set of 155 genetic stocks carrying known rust resistance genes including near isogenic lines of leaf and stem rust resistance, race identification differential sets (A and B), lines for adult plant resistance (APR) and germplasm for known genes of rust resistance were rejuvenated.

More than 1700 germplasm lines including wild species, rust resistance lines, alien introgression lines and other diverse genotypes were maintained.

3.1.1.3 Maintenance of genetic stocks

Eighteen hundred indigenous and exotic genetic stocks for collected from different sources for moisture stress, early and terminal heat stress, leaf, stem and stripe rust and foliar blight were maintained in the field conditions. Besides, about 250 accessions of wild relatives of wheat are being maintained, some of which are being utilized in alien introgression programme. Several introgression lines derived from *Aegilpos markgrafii*, *Ae. speltoides* and *Triticum militinae* were evaluated for rust resistance.

3.1.1.4 Physiological trait based phenotyping for drought and high temperature tolerance

One hundred and forty six lines received from CIMMYT wheat physiology programme were evaluated for physiological and morphological traits under moisture stress conditions. Two hundred ninety four wheat association panel lines received from CIMMYT physiology programme were phenotyped for canopy temperature, relative water content and other physiological traits for their adaptability to drought and high temperature tolerance. Four F₇ crosses with 200 progenies each were phenotyped for physiological, morphological and other characters as per the trait dictionary from GCP at four locations, viz., Delhi, Ludhiana, Pune and Powarkheda.
3.1.1.5 Evaluation of material under field and artificial phenomic conditions

One hundred eighty lines from generation challenge programme core physiology set and 120 lines from four populations were evaluated in the controlled and field conditions under phenomics. The 14 lines identified as showing high resistance to water stress (controlled) and heat stress (field) have been entered in yield trials of 2014-15.

3.1.2 Rice

3.1.2.1 Development of high throughput screening protocol against bakanae disease

A rapid, reliable and high-throughput seed inoculation assay for screening against bakanae disease of rice caused by *Fusarium fujikuroi* was developed. Based on the high throughput screening protocol, rice genotypes such as Athad Apunnu, C101A51, Chandana, IR 58025B, Panchami, PAU 201, Pusa 1342 and Varun Dhan were found to be highly resistant, while BPT 5204, Himju, Peeli badam and Suphala were resistant. Rasi and TKM 6 were found to be highly susceptible exhibiting cent per cent mortality with elongation and mortality symptoms as early as on 8th day after inoculation.

3.1.2.2 Germplasm evaluation for yield and other components related to yield stability

A set of 556 aromatic rice germplasm was assessed with gene based/ linked markers for fertility restorer genes, *Rf3* and *Rf4* for identification of potential restorers and maintainers. The genotypes were identified for the improvement of parental lines in aromatic hybrid rice breeding based on evaluation of 94 test crosses for pollen, spikelet fertility, yield and yield component traits.

A set of 250 rice genotypes, including mega varieties, short grain aromatic rice, NPTs, newly identified potential rice restorers and lines collected from different parts of country were evaluated for yield and yield components such as number of tillers per plant, plant height, panicle length, days to 50% flowering and days to maturity, and rest of the traits like number of filled grains/panicle, spikelet fertility, yield/plant, 1000-grain weight during *Kharif* 2014.

3.1.3 Maize

3.1.3.1 Abiotic stress tolerant genotypes

Several inbreds were screened at different critical growth stages under drought and water-logged stress conditions and tolerant inbreds identified, viz., HKI 1105, CML 22, SKV 671 and SKV 38 (drought tolerant), CML 425, SKV 765 and SKV 204 (water logging tolerant), SKV143, SKV239, HKI 1105 and CML 425 (drought and water logging tolerant) and HKI 1105 (with stay green trait).

3.1.3.2 Biotic stress tolerant genotypes

Several inbreds were identified for resistance against various diseases, viz., the inbred BM 418, BM 105, HKI 163 and RNBL 4641 were tolerant to turcicum leaf blight (TLB) with a disease score of 1.5; based on two year data on maydis leaf blight (MLB) screening six inbreds, viz., BM 136, BM 84, BM 137, BM 35, BM 167 and BM 25 were found resistant (score <2.0); two inbreds, DK 130092 and DK 130158 were found tolerant to BLSB with a disease score of 2.0; six inbreds, BM 254-3, CM 213, BM 32, BM 59, CM 151y and BM 426 were tolerant to shoot borer with intensity of damage less than 1.4.

Inbreds with multiple desirable traits were also identified. The inbreds BM 40, BM 188 and BM 418 were resistant to both MLB and TLB. BM 188 was also promising for grain yield. The inbreds, DK 130092 and DK 130158 were found to be resistant to both MLB and BLSB while inbreds CM 151 and CM 213-1 were tolerant to both MLB and shoot borer.

3.1.3.3 Development of agronomically promising *sh2sh2/su1su1*- based sweet corn inbreds

Sweet corn inbreds with *sh2sh2/su1su1* genetic constitution has been developed. These inbreds possess higher brix value than the conventionally
bred \(sh2sh2\) and \(su1su1\) inbreds. Promising inbreds with high seed germination and good tassel- and plant-characteristics have been selected for their utilization in the sweet corn breeding programme.

### 3.1.3.4 Development of promising waxy corn inbreds for diverse end-uses

Several 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. These newly developed waxy inbreds possess desirable agronomic characteristics and grain yield potential. The kernels can be easily differentiated from the wild type and \(opaque2\) kernels using light box test.

### 3.1.4 Pearl Millet

#### 3.1.4.1 Maintenance of germplasm

A total of 855 germplasm lines of pearl millet including cytoplasmic male sterile lines, maintainers and restorers are being maintained at IARI. The traits include early flowering, high tillering, thick spike, bristled spike, long spike, variations in compactness of the spike, grain colour, etc.

#### 3.1.4.2 Biofortification

Development of pearl millet cultivars with elevated levels of micronutrients is one of the approaches to provide sustainable solution to various health problems associated with micronutrients malnutrition, especially in India. Efforts have been initiated at IARI, to develop high iron and zinc parental lines, and thus to develop biofortified hybrids to achieve this goal.

In a study conducted with a large number of hybrids tested for grain iron and zinc showed the promising hybrids with higher iron and zinc compared to the check.

Three breeding lines PPMI 903, PPMI 904 and PPMI 906 were found to possess stable high iron and high zinc content across different locations, namely, Coimbatore, Delhi, Durgapura, Gwalior, Hisar, Jamnagar, Ludhiana, Mandor and Tirupati in 2013 and in different years (2012-13 and 2013-14) at IARI, New Delhi in comparison to ICTP 8203 (Fe – 79 ppm; Zn – 61ppm) which is the check variety. The proposals for registration of these lines have been submitted.
3.1.5 Chickpea

One hundred and seventy seven land races obtained from ICARDA representing fifty seven countries of the West Asia and North Africa (WANA) region were extensively screened for yield and Fusarium wilt. ILC 0 from Latvia has shown resistance to foc 4 and foc 5 races of wilt. Two land races, viz., IG 6003 and IG 5982 had 100-seed weight of 51g under normal sown conditions. Some of the lines, FLIP 87-8C, FLIP 93-58C, FLIP 86-5C, FLIP 84-92C and FLIP 87-25C, produced higher yield than the local check Pusa1108 and found promising under late sown condition.

### 3.1.5.1 Evaluation of lines for protein content and hydration capacity

Evaluation of protein content and hydration capacity in chickpea varieties indicated that there was significant variation for seed protein concentration and it ranged from 19.61% (Pusa 2024) to 25.09% (Pusa 1003). Hydration capacity increased with increased seed size. Protein content of desi varieties was higher than the Kabuli types, whereas hydration capacity of Kabuli types was higher than desi types.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Grain Fe content (mg/kg)</th>
<th>Grain Zn content (mg/kg)</th>
<th>Grain yield (kg/ha)</th>
</tr>
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<tbody>
<tr>
<td>ICMA 843-22 × High Fe-20</td>
<td>72.00</td>
<td>59.00</td>
<td>2141</td>
</tr>
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<td>ICMA 843-22 × ICMR 06222</td>
<td>74.00</td>
<td>69.00</td>
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<td>65.00</td>
<td>2046</td>
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<td>ICMA 93222 × PPMI 15775</td>
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<td>62.00</td>
<td>3565</td>
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<tr>
<td>ICMA 93222 × ICMR 06222</td>
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<td>3534</td>
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<tr>
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<td>71.33</td>
<td>56.00</td>
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</tr>
<tr>
<td>ICMA 93222A × PPMI 760</td>
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<td>71.33</td>
<td>2947</td>
</tr>
<tr>
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<td>ICMA 93222 × PPMI 15774</td>
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<td>63.66</td>
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<tr>
<td>ICMA 96666 × ICRI 12999</td>
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<td>72.66</td>
<td>2447</td>
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<td>ICTP 8203 Fe (Dhanshakti)</td>
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<td>49.66</td>
<td>2246</td>
</tr>
</tbody>
</table>

3.1.5.2 Resistance sources for Colletotrichum blight disease

Chickpea genotypes Avarodhi, GCP 101, T-2, ICCX 930024 and FLIP 87-59C were moderately resistant to Colletotrichum blight at Dharwad.

3.1.5.3 Genotypes with erect plant type identified

ICCV 13645, ICCV 13646, BG 261, BG 276 and BG 1077 were erect and found to be suitable for mechanical harvesting.

3.1.5.4 Phenotyping of the mapping population of Pusa 362 × SBD 377 for drought related traits

F$_{11}$ & F$_{12}$ mapping populations derived from Pusa 362 × SBD 377 were phenotyped in 2013 (series 1) and 2014 (series 2) for Relative Water Content (RWC) and Membrane Stability Index (MSI). The distribution of mapping population for the above two physiological parameters related to drought tolerance followed a polynomial distribution indicating the quantitative nature of the traits. Tagging QTLs for these traits would be of immense use to plant breeders.
3.1.5.5 Canopy temperature depression (CTD) as a screening tool for heat tolerance

A relative relationship between CTD and grain yield was worked out in the top 20 Kabuli lines of a genomic population with highest yield. It was found that ICCV 03301 showed higher yield with high CTD while ICCV 04303 had high yield but lower CTD. Higher CTD indicates the ability of the genotype to maintain cooler micro-environment compared to the ambient temperature where as those with lower CTD have almost the same temperature as the ambient. Thus, the genotypes with higher CTD will be able to withstand drought stress better. ICCV03408 had very high CTD but yield per metre row is lower among selected lines indicating that this would serve as an important donor line.

3.1.6 Mungbean and Lentil

Forty three accessions of 11 Vigna species (including V. daizelliana, V. glabrescens, V. hainiana, V. sylvestris, V. radiata, V. sublobata, V. stipulacea, V. trinervia var. bourneae, V. umbellate, V. unguiculata and V. vexillata) were procured from NBPGR. These are being multiplied for evaluation. Besides, 335 germplasm lines in lentil and 332 germplasm lines in mungbean were multiplied. In addition, 132 new entries of lentil were received from ICARDA in form of nurseries. Germplasm lines V28202 BG2 and V 2709 BG 5 (Bruchid tolerant) were multiplied, V 04718 (PM resistant) and bold seed lines VC 6510151 and VC 3890A were received from AVRDC, Hyderabad. One hundred and fourteen accessions of different wild species of genus Lens were multiplied in National Phytotron Facility.

Six ICARDA nurseries conducted

<table>
<thead>
<tr>
<th>Nursery</th>
<th>Entries</th>
<th>Replications</th>
<th>Promising entries</th>
</tr>
</thead>
<tbody>
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<td>LIEN-MN 2015</td>
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<td>2</td>
<td>P 45117, P 45207, P 45220</td>
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<tr>
<td>LIEN-E 2015</td>
<td>36</td>
<td>2</td>
<td>P 43105, P 43203, P 43204</td>
</tr>
<tr>
<td>LIEN SS 2015</td>
<td>36</td>
<td>2</td>
<td>P 42133, P 42205</td>
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<td>LAT 2015</td>
<td>28</td>
<td>2</td>
<td>P 46113, P 46226</td>
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<td>LIF4N</td>
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<td>1</td>
<td>P 47101, P 47120, P 47122</td>
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<td>LIPBNWF5</td>
<td>7</td>
<td>1</td>
<td>P 50103, P 50104</td>
</tr>
</tbody>
</table>

3.1.6.1 Evaluation for abiotic stresses

Mungbean. Three Vigna species were assessed in hydroponic assay in various concentration of Al (0, 74 and 185 µM) for 48 h. Variations in the Al tolerance were analysed based upon various traits such as root elongation rate, re-growth after hematoxylin staining, accumulation of aluminium and callose and their localization, H₂O₂ lipid peroxidation and antioxidant enzymes activity. Aluminium stress caused inhibition in root elongation rate and root re-growth and increased accumulation of aluminium, callose, H₂O₂ and lipid peroxidation in all three Vigna species. However, accumulation of aluminium, callose, H₂O₂ and lipid peroxidation was more in V. radiata (Pusa672) than in V. mungo (Mash 114) and V. umbellata (RBL 6). Higher activity of superoxide dismutase, guaiacol peroxidase and ascorbate peroxidase was observed in V. umbellata than in V. mungo and V. radiata. V. umbellata accession is a potential genetic resource for Al tolerance to develop Al tolerant genotypes in V. mungo and V. radiata.

Lentil. Two hundred and seventeen accessions were screened for heat tolerance at reproductive stage. High temperature stress (32/18 to 35/20 °C) was exposed at flowering to study the effects of heat stress on pollen viability, pollen germination, pod and seed set and seed yield, membrane stability index, osmolytes, lipid peroxidation and antioxidative enzymes in controlled environments. This was compared with a non-stress treatment (25/16 °C). Large genetic variation was observed for reproductive biology, physiological traits and seed yield. The reduction of pollen viability and pollen germination was minimum (PDL 1 and PDL 2), whereas reduction of pollen viability and in vitro pollen germination was maximum (JL 3 and E 153). However, stressed pollen from sensitive genotypes did not germinate on the stress stigma of tolerant genotypes. The reduction of pod and seed set in heat tolerant genotypes (PDL 1 and PDL 2) was minimum compared to heat sensitive genotypes (JL 3 and E 153) in both controlled and field conditions. Overall, pod and seed set showed greater sensitivity in the controlled environments. The most heat tolerant genotypes PDL 1 and PDL 2 also exhibited minimum reduction in seed yield, and possessed higher membrane stability index, osmolytes,
oxidant activities and lower lipid peroxidation as compared to most heat sensitive JL 3 and E 153.

3.1.7 Brassica

3.1.7.1 Maintenance of germplasm

Total 750 germplasm lines including B. juncea (440), B. carinata (170), B. napus (32), B. rapa (44), B. oleracea (7), B. nigra (14), B. tournifortii (4), B. caudatus (3), R. caudatus (1), R. sativa (1), S. alba (2), Eruca sativa (6), Crambe spp. (2), Lapidium spp. (1), Camellina spp. (1) and wild species (22) were maintained by selfing and used in crossing programme. Fourteen new accessions for earliness, dwarf plant type, long siliquae and high siliquae density were procured from NBPGR and have been used in crossing programme.

3.1.7.2 Development and utilization of introgression lines

Intermediate genotypes (introgression lines), 12 in number, developed from Brassica juncea/ B. carinata crosses were raised for rust reaction at IARI, RS Wellington. To infuse larger genetic variability 12 crosses were attempted between B. juncea and newly developed introgression lines. F1 generation was raised and advanced in the main season 2014-15.

3.1.7.3 Evaluation of double zero breeding lines/ genetic stocks

Thirteen double-zero genotypes from advance generations were raised in replicated trials with four checks (low erucic acid and conventional variety) for yield evaluation. Out of these two, namely, PDZ 3 and PDZ 4 were found to be promising and agronomically suitable and were contributed for AICRP Rapeseed Mustard trials during 2014-15. Another Station Trial on Quality Indian mustard comprising of ten Double-Zero and eight Low Erucic acid genotypes was constituted and is being evaluated with four checks.

3.1.8 Soybean

3.1.8.1 Maintenance of germplasm

Seeds of 29 Glycine soja accessions were received from Sipani Krishi Anusandhan Farm (SKAF), Mansour, MP. The seeds were in ambient storage since 2007. These were germinated in the National Phytotron Facility, IARI where only 19 lines germinated. The germination level ranged from 10% to 50%. The seeds produced by the surviving plants were harvested and stored for further testing. Two mapping populations have been advanced to F5 stages through single seed descendent (SSD) approach. Such population would be suitable for mapping YMV and other phenotypic traits.

3.1.9 Fruits

Mango. Three polyembryonic mango rootstocks (13-1, Turpentine and Bappakai) and eight exotic cultivars, i.e., Palmer, Lily, Kensington, Tommy Atkins, Maya, Kent, Keitt and Bajrang were introduced planted in the germplasm block. An off-season fruiting genotype was introduced and grafted on rootstock.

Acid lime. In acid lime, 5 new collections were made. A survey was conducted in different districts of Punjab. Five superior trees have been identified based on tree health and yield potential. The heaviest fruits (113.40 g per fruit) were recorded in LS 11, while the highest juice (50.43%), acidity (6.38%) and TSS (7.57°Brix) contents were recorded in LS-10. Selections LS 8 and LS 9 were found seedless. The content of ascorbic acid was highest (51.00 mg 100 ml-1 juice) in LS 8.
Pummelo. For the identification of superior pummelo clones, the gardens in Muzaffarpur and Samastipur districts of Bihar were surveyed and 100 seedling plants were characterized. From these characterized clones, 14 superior clones were collected and grafted on rootstocks for evaluation.

Grapes. About 24 germplasm from NRC on Grapes, Pune, Grape Research Station, Hyderabad and PAU, Ludhiana were collected for evaluation and using in breeding. Five rootstocks were also introduced from NRC on Grapes, Pune, and Grape Research Station, Hyderabad.

Guava. Fourteen genotypes were collected during the period and planted for evaluation. The fruiting genotypes were evaluated for different physico-chemical characters. A dwarf genotype was observed during evaluation and has important characteristic like dwarf in stature, minimum in plant height (2.60 m) compared to other genotypes, short inter-nodal length (3.4 cm) and spread of 2.60 to 3.4 m (N-S and E-W) direction and the fruits have soft seeds weighing 180-200 g. Second genotype was identified during evaluations with purple pulp colour and brownish skin, having high antioxidant content.

Temperate fruits. New varieties of apple, viz., Jeromine, Red Velox, Scarlet Supr-II and Super Chief-II were introduced and planted for further evaluation. Twenty five Russian /temperate type accessions (hardwood cuttings) collected from NRC on Pomegranate, Solapur were rooted successfully and planted for evaluation under Shimla conditions. Different pomegranate cultivars have also been introduced and established for evaluation as alternative to apple cultivation under climate change situation.

3.1.10 Vegetables
Cauliflower. In early group, 45 fertile inbred lines were evaluated, maintained and used for hybrid development. Ten SI lines, namely, CC12, 13, 14, 15, vv, ccM, 327-14-8-3, 395aa, 351aa and xx were assessed for curding ability, tested for SI level and selected plants were multiplied through bud pollination. Ogura CMS system established in two genetic backgrounds (Pusa Meghna & DC 41-5) was maintained and exploited in hybrid development. Besides, this system was transferred to ten new genetic backgrounds.

In mid-early maturity group, seven SI lines, namely, CC32, 35, 22, ccM5, ccM8, ccM & cc were assessed for curding ability, tested for SI and advanced through bud pollination. Thirty five inbred lines were evaluated, maintained and promising ones were used for hybrid development. Ogura CMS system established in three genetic backgrounds was evaluated, maintained and exploited in hybrid development.

In mid late group, Ogura CMS system established in two genetic backgrounds was evaluated, maintained and used in hybrid development. Besides, new CMS systems available in three commercial back grounds were transferred into 20 new genetic backgrounds using reverse breeding methodology. Ten black rot and downy mildew resistant lines and thirty other inbreds were evaluated, maintained and promising were used in hybrid development.

Bitter gourd. Seventy two genotypes were evaluated and maintained in the field conditions. Thirty seven genotypes were screened for nutrient, vitamins and antioxidant properties. Out of 36 genotypes, 6 were evaluated under protected conditions, the genotypes DBGS 32-1 and BBGS 57 were found promising and produced 376 and 364 kg fruits per 100 m², respectively.

Cucumber. A total of 69 germplasm with novel traits consisting of gynoecious lines, carotene-rich cucumber, Cucumis hytivus disease resistant lines, parthenocarpic and gherkin types, Cucumis sativus var. hardwickii and multiple pistillate types collected from USA and China through NBPGR and other sources were maintained and utilized in the breeding programme.

Luffa. Fifty five advance breeding and 53 virus resistant lines were evaluated during spring summer and Kharif season, respectively and promising lines were maintained. In ridge gourd, 22 and 36 advance breeding
lines including Satputia and its genetic stock were evaluated during spring summer and Kharif season, respectively and promising lines were maintained. A gynoecious genetic stock of ridge gourd was developed which segregates into gynoecious and hermaphrodite (Satputia) in the ratio of 1:1 and maintained by sibbing utilizing Satputia as pollen parent.

**Pumpkin.** Fifty six germplasm/advanced breeding lines of pumpkin were evaluated and maintained.

**Muskmelon, watermelon and snapmelon.** One hundred fifty five lines of muskmelon were evaluated and maintained. Two hundred lines of muskmelon, watermelon and related species introduced from USDA, USA were maintained. Twenty one snap melon lines were also maintained.

**Long and round melon.** Thirty two and 21 germplasm/advanced breeding lines of long and round melon, respectively were evaluated and maintained. Long melon line DLM 19-2 with segmented leaf was maintained.

**Brinjal.** One hundred fifty five working germplasm maintained in the previous years were purified, evaluated and maintained. Wild brinjal species, *Solanum aethiopicum*, *S. incanum*, *S. gilo*, *S. insanum*, *S. indicum*, *S. torvum*, *S. khasianum* and *S. integrifolium* were maintained.

**Tomato.** A total of 15 breeding lines from AVRDC-World Vegetable Centre, Taiwan were obtained through NBPGR, New Delhi. The lines are carrying genes for resistance to ToLCV, late blight, *Fusarium* wilt and bacterial wilt with desirable horticultural traits. The breeding lines were grown for seed enhancement and transfer the resistance genes to IARI cultivars. Fifty germplasm accessions were grown for seed regeneration. A total of 90 exotic germplasm accessions of tomato were grown for seed enhancement. Ninety-five germplasm accessions of *S. lycopersicum* and *S. peruvianum* were grown for seed regeneration, morphological characterisation and screened against ToLCV. The variability for leaf characters, days to flowering, days to fruiting, fruit characters, thermo-insensitivity and days to maturity was recorded.

**Chilli.** Seed multiplication of 67 chilli lines collected from USDA and AVRDC was carried out.

**Carrot.** Fifty five fertile inbred lines were maintained and assessed for their performance. Nine CMS lines were maintained and exploited in hybrid development using twelve promising fertile inbreds.

**Onion.** Seven onion accessions from AVRDC, Taiwan, eighty accessions from HRI, UK and 181 accessions from NIAB, Japan were imported through NBPGR. These lines have been planted during Rabi season for characterization and multiplication. In addition, 107 local onion germplasm was procured from NBPG and out of them 46 lines germinated and were propagated during Kharif season. An exploration trip to Leh, Ladakh, J&K was undertaken during September, 2014 and 29 accessions of onion and related wild species were collected.

**Garden pea.** Forty germplasm lines were evaluated for *Fusarium* wilt and powdery mildew and maintained the resistant lines.

**Okra.** One hundred forty one cultivated and 21 wild accessions were maintained.
**Minor leafy vegetables.** Twenty lines of Chenopodium sp., 6 lines of palak, 5 lines of spinach, 14 lines of fenugreek and 23 lines of amaranth were maintained.

**Temperate vegetables.** Thirty four new and about 70 already available germplasm lines of cabbage, 9 self-incompatible lines, 15 CMS lines and their respective maintainers were maintained. Ninety five lines of snowball cauliflower along with 11 CMS lines and their maintainers were maintained as core collection. Fifteen germplasm and 5 CMS lines along with their maintainer lines of broccoli were purified and maintained. Nine paprika and 25 capsicum germplasm lines were maintained. Two stable and two moderately stable CMS lines were identified in capsicum. Fifty lines of pepper (including wild relatives) from USDA were evaluated, characterized and maintained for horticultural traits. Forty five germplasm lines and 21 CMS lines of carrot along with their maintainers were maintained.

### 3.1.11 Ornamental Crops

**Rose.** Eight new varieties (Lagerfeld, French Perfume, Magic Lantern, Red Chief, Bacardi, Kardinal, Yankee Doodle and Amethyst Royal Rose) were collected.

**Marigold.** Three varieties (Summer Saugat, Hawaii Orange, Valencia Yellow) were collected and grown during winter season for evaluation.

**Lilium.** Three varieties of LA lily, viz., Brindisi (pink), Pavia (yellow) and Ercocana (white) were collected.

**Turf grasses.** The sprigs of three species of turf grasses, namely, Paspalum notatum, Bouteloua dactyloides and Zoysia japonica and seeds of Cynodon dactylon were collected from secondary sources to enrich the germplasm for further evaluation.

**Temperate ornamental crops.** Fifty cultivars of liliums, 3 species of lilium (Lilium lancifolium, L. formosanum, Lilium longiflorum), 20 species of iris, 23 varieties of dahlia, 20 genotypes of tulip; 25 genotypes of Narcissus; 12 varieties of Eustoma; 12 varieties of Alstroemeria, 40 varieties/hybrids of gladiolus, Acididenthira bicolor, and other bulbous crops like, torch lily, watsonia, canna, Amaryllis, Freesia, cyclamen, zinger lily, Lycoris, primula, primrose, temperate orchids and some wild ornamentals are being maintained and used for crop improvement programme at Katrain station.

### 3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

#### 3.2.1 Indian Type Culture Collection

About 3,946 fungal cultures representing Mastigomycotina, Zygomyctina, Ascomycotina and Deuteromycotina and 253 bacterial cultures are being preserved in ITCC. During the year, 42 new fungal and 3 bacterial cultures were added. As for national service, a total of 213 fungal and 45 bacterial cultures were supplied. A total of 347 cultures/specimens were identified up to species level, which represented Hyphomycetes followed by Coelomycetes, Zygomyctina and bacteria. A total of 10,000 specimens belonging to genera such as Absidia, Achlya, Acremonium, Agaricus, etc. and 29 fungal species of ITCC collection were digitized during the period. Collectively, a revenue of ₹ 7,48,400/- was generated. Trichoderma species identification was undertaken using different genomic markers such as Internally Transcribed Spacer (ITS) region, tef1, calmodulin and β-tubulin. These markers were found to be efficient in differentiating Trichoderma species such as T. virens, T. asperellum, T. harzianum and T. longibrachiatum.

#### 3.2.2 Insect Biosystematics

A total of 3,145 insect specimens were identified for various correspondents under the Insect Identification Service. Revisionary studies were conducted on genus Sycophila Walker, 1871 (Hymenoptera; Eurytomidae: Chalcidoidea). The genus was redescribed. Eight already described species under this genus associated with Ficus spp.,
viz., *Sycophila benghalensis* (Joseph & Abdurahiman, 1968), *S. decatomoides* Walker, 1871, *S. dharaorensis* (Joseph & Abdurahiman, 1968), *S. fici* (Joseph, 1961), *S. karnatakensis* (Joseph & Abdurahiman, 1968), *S. pilosa* (Joseph & Abdurahiman, 1968) and *S. robusta* (Joseph & Abdurahiman, 1968) were redescribed and six species new to science, *S. delhiensis*, were described. Fifty characters of head, 67 of mesosoma, 15 of metasoma along with 46 ratios were used to place the earlier descriptions on a firm footing. These descriptions included around 280 illustrations including photographs. The existing key for the species of this genus based only on females was augmented with new characters and modified to include the new species. As the males of this genus are morphologically very distinct from the females, therefore, a key for identification of the males was also prepared.

Identification of white grubs (Coleoptera: Scarabaeidae) from their larval stages was attempted. Thirty eight important diagnostic characters for identification of each of the five species, viz., *Holotrichia serrata* (F.), *H. consanguinea* Blanchard, *Schizonycha ruficollis* (F.), *Brahmina coriacea* (Hope) and *Sophrops irridipennis* belonging to subfamily Melolonthinae were documented. Distinct variations were observed in the raster pattern, epipharynx, mandibles and stridulatons among the species. The ventral portion of last abdominal segment called as raster showed distinct patterns, which can be used for easy field level identification.

![Larval raster patterns](image)

Scanning electron microscopy (SEM) studies on egg chorion microsculpturing were carried out for seven species of Melolonthinae and Rutelinae (Coleoptera: Scarabaeidae). The chorion microsculpturing revealed significant differences, which can be used as diagnostic characters. The protuberances varied among and within genera, viz., *Anomala*, *Mimela* and *Adoretus* of Rutelinae.

Two new species of *Igerna*, namely, *I. shillongensis* and *I. kolasibensis* (Hemiptera: Cicadellidae: Mego-phthalmineae) were described from North-East India along with updated keys to the species along with a taxonomic note on the genus.
A check-list of Genus *Mythimna* (Lepidoptera: Noctuidae) from India was prepared including details of 4 subgenera and 96 species. A serious invasive insect pest known as South American tomato pinworm or tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) was recorded for the first time infesting tomato plants grown in polyhouses and fields during October 2014 in Pune, Maharashtra. This pest has been classified as the most serious threat for tomato production worldwide and can cause up to 90% loss of yield and fruit quality. Subsequently, the pest was also recorded in other tomato growing districts of Maharashtra, viz., Ahmadnagar, Dhule, Jalgaon, Nashik and Satara.

Tomato leaf miner, *Tuta absoluta* Meyrick: A: Male moth, B: Female moth, C&D: Larval mine on leaves, E: Pin holes on fruit

### 3.2.3 Nematode Biosystematics

Two new species, i.e., *Deladenus albicus* n. sp. and *D. processus* n. sp. (Nematoda: Hexatylina) of insect parasitic nematodes were described in association with CCSHAU, Hisar. The populations of *Pratylenchus* species were collected from the rhizosphere of different crops at IARI farm, New Delhi to determine the population diversity in *Pratylenchus* spp. present in soil. The detailed morphological, morpho-metrical and molecular characterization of the nematode populations were carried out. Integration of morphological and molecular data led to identification of the two species of *Pratylenchus* spp. as *P. zeae* and *P. thornei*. In addition, a compendium was prepared for a check-list of 75 globally known species of *Pratylenchus* till to date, along with a
polychotomous key for identification for all the species, including the species variability within the genus.

For creation of virtual collection of nematodes one hundred species of nematodes at the National Nematode Collection of India were digitized using motorized Zeiss Axioimager M2 microscope. More than one lakh images (1,12,375) of the nematodes in all the three dimensions were taken occupying 501.14 GB space.

Coco peat resists bacterial and fungal growth and the tissue culture plants grown in it usually do not get challenged by these pathogens. Banana plantlets grown in coco peat were received from private firm for nematode-free certification. Plantlets were found to be heavily infected with root-knot nematode (112-143 juveniles (J2s) per 20 cc coco peat). Each plantlets had >50 galls. Perineal pattern of mature females matched with *Meloidogyne incognita*.

Summer mungbean was found to be severely damaged by the high population of reniform (2.6-75/cc soil) and cyst (1-9/10cc soil) (*Heterodera cajani*) nematodes forming nematode complex.

Thirty two soil and roots samples from pomegranate trees in Maharashtra were found to be infected with root-knot and reniform nematodes. On the basis of both morphological and molecular characteristics the root knot nematode females of Maharashtra population identified as *Meloidogyne incognita*. Occurrence of both the nematodes caused huge losses up to 40%.
4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

Efficient management of resources, crop, soil and environment has been the major focus in recent years for enhancing agricultural sustainability. This has been well addressed through the research programmes in various divisions in the Schools of Natural Resource Management. Conservation agriculture, integrated nutrient management and various resource conserving technologies are evolved and evaluated to enhance use efficiencies of resources (water, nutrient, energy) and improving soil health. Divisions are actively involved in developing environmentally sound and economically viable technologies on balanced usage of chemical fertilizers, organic manures, crop residues and biofertilizers for sustainable high productivity of cropping systems involving cereal, pulses, oilseeds, vegetables and flowers. Management practices for wastewater and poor quality irrigation water in crop production have been evolved. Protected cultivation technologies were developed for growing off-season vegetables and flowers. New farm machineries, viz., tractor operated garlic planter and harvester, ergonomically modified wheel hoe for female worker, wheel weeder and solar powered refrigeration system, etc. were developed and evaluated. Post harvest technologies were evolved for value addition of farm produces, led to vertical crop diversification. Bioprospecting of rhizospheric and endophytic cyanobacterial for nutrient uptake and crop yield, encapsulated microbial inoculants for phosphorus nutrition and crop productivity, evaluation of effect of bio-control agents on rhizospheric microbial communities, microbe mediated nutrient cycling for improved productivity, development of biological techniques for in-situ/ex-situ biomass degradation and evaluation of microbial inoculants in different crops and agro-ecosystems are important achievements.

4.1 AGRONOMY


Sustaining the productivity of rice–wheat system under conventional transplanted rice (TPR) and conventional till wheat (CTW) while enhancing soil carbon sequestration and mitigating greenhouse gases (GHGs) emissions is a great challenge. Conservation agriculture (CA) practices have potential to sustain the productivity of rice–wheat system. A study carried out for five years (since 2010) towards replacing TPR with DSR through interventions of CA practices revealed that a system of ZT DSR with summer mungbean (SMB) residue retention - rice residue (RR) retention in ZTW – wheat residue retention in ZT summer mungbean (SMB) results in comparable rice yield, but higher system productivity, partial factor productivity of N, P & K, net returns, B:C and system water productivity than that in TPR-CTW/ZTW system. An improvement in SOC & total N in surface (0-5 cm) soil and a reduction in global warming potential (GWP) through reduction in methane emission from rice field has been observed in this treatment. This ZT DSR with summer mungbean (SMB) residue retention - rice residue (RR) retention in ZTW – ZT summer mungbean (SMB) with wheat residue performed
better than conventional TPR-CTW system and could be a possible alternative to TPR-CTW. This could be another adaptation-led mitigation strategy to climate change.

### 4.1.2 Conservation Agriculture-based Maize-Wheat-Mungbean Cropping System for Enhanced Productivity and Resource-use Efficiency

An experiment on conservation agriculture-based maize-wheat-mungbean cropping system was conducted during 2011-12 after a three-year experiment on cotton-wheat system (2008-09 to 2010-11) to study the long-term impact of different tillage and crop establishment practices on the performance of this system. Main plot treatments included four combinations of conventional and zero tillage on flat and raised-bed. Four sub-plot treatments were: no residue (NR), wheat residue (WR @ 3 t/ha), cotton/maize (CR/MR) residue @3 t/ha each for three years, and cotton/maize + wheat (CR/MR+WR) residue. Green gram residue after harvest was uniformly applied in all the plots except the no residue control.

ZT raised bed (ZT-B) and flat bed (ZT-F) planting resulted in higher maize grain yield compared to CT bed or flat planting, but in wheat, flat bed planting with ZT or CT gave higher grain yield compared to bed planting with respective tillage. In mungbean, CT bed planting resulted in significantly higher grain yield. However, system productivity, system partial factor productivity (NPK), net returns and B:C were significantly higher in ZT-F and ZT-B than in CT-F. Application of residues of wheat (in kharif) + maize (in rabi) resulted in higher grain yields of maize, wheat and mungbean, and, as a result, system productivity, system partial factor productivity (NPK), net returns and B:C were higher in both seasons residue treatment. ZT bed and flat planting with residues of wheat (in kharif) + maize (in rabi) resulted in significantly lower bulk density and higher infiltration rate in soil compared to other treatments. In ZT-B or ZT-F bed with C/M + W residue retention, 290 and 283 kg total N are retained over a period of 4 years, i.e., around 70-75 kg total N/ha/year. Similarly, equivalent amount of CO₂ was retained/sequestered in soil.

### 4.1.3 Terminal Heat Stress Management in Wheat

A two-year field experiment was conducted to determine to what extent heat stress reduces wheat yield and how effective are agronomic management practices in maintaining wheat yields under heat-stressed environment. The treatments consisted of four heat stress environments created through staggered sowing dates 15th Nov., 30th Nov., 15th Dec.
and 30th Dec. assigned to main-plots, two irrigation methods – surface irrigation and sprinkler irrigation allotted sub-plots and two foliar-applied growth enhancing chemicals NO₃ (1%) and Cytokinin, (N6 benzyl amino purine (BAP), 6 ppm and two control treatments- farmers’ practice for normal date of sowing (15 Nov. sowing and surface irrigation, no-growth enhancing chemicals) and complete stress (30th Dec. sowing, surface irrigation, no-growth enhancing chemicals). Wheat variety used was HD 2967. Wheat yield consistently decreased with every 15-day delay in sowing from 15th November to 30th December. Water productivity also followed the same trend. Sprinkle irrigation improved wheat yield by 10.2 % and water productivity by 18.2 % over surface method.

### 4.1.4 Varietal Diversification and Precise Nitrogen Management in Pigeonpea-Wheat Cropping System

Pigeonpea-wheat cropping system is looked upon as a potential alternative to unsustainable rice-wheat cropping system in the Indo-Gangetic plains of India. Although, pigeonpea is a long-duration crop, cultivars of short duration (120-145 days) are available now. Similarly, in wheat, cultivars of different duration and yield potential have been developed. A field experiment was conducted during 2011-2013 with the objective to find out suitable pigeonpea and wheat cultivars fitting well in the pigeonpea-wheat cropping sequence, and the strategies to meet the in-season nutrient requirement of both crops using precision tools. Among the pigeonpea cultivars (Pusa 2001, ICPL 88039 and SKFA 970) under test, Pusa 2001 with an average yield of 1.66 t/ha and net returns exceeding 41,000 ha⁻¹ showed better prospects for inclusion in pigeonpea – wheat system. ICPL 88039 cultivar was the next best option. Fortifying nutrient supply in pigeonpea through two foliar applications of DAP (2%) + SOP (1%), 1st during vegetative and 2nd at flowering stage, met the in-season nutrient demand and increased seed yield by 17%. Yields of wheat varieties, WR 544 and HD 2894 grown in sequence with pigeonpea were statistically alike. Nutrient management in pigeonpea had no consequence on the succeeding wheat yield. Chlorophyll meter based (SPAD value ≤ 42) N application significantly improved yield, net returns and B:C ratio from wheat compared to soil based N application. Overall, pigeonpea variety Pusa 2001, wheat (WR 544 or HD 2894) with a system productivity of > 8 t/ha (wheat eq. yield) and net returns of about ₹ 1 lakh ha⁻¹ was a better option and hence suggested as an alternative to rice-wheat cropping system.

### 4.1.5 Crop Residue and Sulphur Management in Pearl millet–Mustard Cropping System under Different Tillage Practices

A field experiment was conducted during Kharif 2013 on sandy loam soil under rainfed conditions. Twenty treatment combinations were tested in split
plot design, allocating tillage and crop residue to main plots and sulphur levels to sub-plots. Conventional tillage with crop residue (mustard) at 4 t/ha recorded significantly higher grain yield of pearlmillet over conventional tillage without residue. Whereas, maximum net returns were realized under zero tillage with crop residue at 2 t/ha and B:C under zero tillage with crop residue at 2 t/ha. Application of 30 kg S/ha proved significantly superior in terms of grain yield and economics as compared to control but remained at par with 45 kg S/ha.

### 4.1.6 Optimization of Nutrient Use and Productivity in Maize-Wheat Cropping System through Nutrient Expert System under Different Tillage Scenario

A field experiment was conducted to optimize nutrient use efficiency and productivity in maize-

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### Yield and economics of pearlmillet as influenced by tillage practices and sulphur levels

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (t/ha)</th>
<th>Net returns (₹/ha)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tillage and crop residue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional tillage without residue</td>
<td>2.08</td>
<td>22,900</td>
<td>1.31</td>
</tr>
<tr>
<td>Conventional tillage with crop residue @ 2.0 t/ha</td>
<td>2.39</td>
<td>27,300</td>
<td>1.43</td>
</tr>
<tr>
<td>Conventional tillage with crop residue @ 4.0 t/ha</td>
<td>2.45</td>
<td>27,000</td>
<td>1.32</td>
</tr>
<tr>
<td>Zero tillage with crop residue @ 2.0 t/ha</td>
<td>2.24</td>
<td>26,900</td>
<td>1.63</td>
</tr>
<tr>
<td>Zero tillage with crop residue @ 4.0 t/ha</td>
<td>2.38</td>
<td>28,200</td>
<td>1.58</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.12</td>
<td>2,315</td>
<td>-</td>
</tr>
<tr>
<td><strong>Sulphur levels (kg/ha)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2.09</td>
<td>22,600</td>
<td>1.26</td>
</tr>
<tr>
<td>15</td>
<td>2.30</td>
<td>26,200</td>
<td>1.44</td>
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<tr>
<td>30</td>
<td>2.42</td>
<td>28,400</td>
<td>1.55</td>
</tr>
<tr>
<td>45</td>
<td>2.43</td>
<td>28,500</td>
<td>1.55</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.09</td>
<td>1,986</td>
<td>-</td>
</tr>
</tbody>
</table>

### Effect of tillage and nutrient management strategies on yield and net returns of maize-wheat cropping system

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Maize yield (t/ha)</th>
<th>Wheat yield (t/ha)</th>
<th>System productivity (MEY) (t/ha)</th>
<th>System net returns (x 10^3 ₹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tillage and crop establishment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZT + residue</td>
<td>4.85</td>
<td>4.65</td>
<td>10.39</td>
<td>113.16</td>
</tr>
<tr>
<td>CT - residue</td>
<td>4.59</td>
<td>4.40</td>
<td>9.83</td>
<td>103.09</td>
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<tr>
<td>CT + residue</td>
<td>4.67</td>
<td>4.55</td>
<td>10.09</td>
<td>101.17</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td><strong>Nutrient management strategies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrient Expert 80:20</td>
<td>4.50</td>
<td>4.41</td>
<td>9.74</td>
<td>102.51</td>
</tr>
<tr>
<td>Nutrient Expert 33:33:30</td>
<td>4.95</td>
<td>4.72</td>
<td>10.35</td>
<td>109.87</td>
</tr>
<tr>
<td>Nutrient Expert 50 + GS</td>
<td>5.07</td>
<td>4.88</td>
<td>11.11</td>
<td>120.27</td>
</tr>
<tr>
<td>Farmers fertilizer practice</td>
<td>4.30</td>
<td>4.13</td>
<td>9.22</td>
<td>91.89</td>
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<tr>
<td>State fertilizer recommendations</td>
<td>4.69</td>
<td>4.52</td>
<td>10.08</td>
<td>104.48</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>0.17</td>
<td>0.15</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>
wheat cropping system through nutrient expert system (NE). Tillage had no effect on grain yield and system productivity of maize and wheat cropping system. Though, nutrient management strategies significantly influenced grain yield and net returns of the system. The nutrient management through nutrient expert (NE) enhanced grain yield, system productivity and net returns as compared to state fertilizer recommendations (SFR) and farmer’s fertilizer practice (FFP). On an average, NE-based nutrient management increased maize grain yield by 3.20 % and 12.55 % over SFR and FFP, respectively. Among the NE, NE+ Green Seeker (GS) gave highest maize yield (5.17 t/ha) and system productivity (11.11 t/ha) than the rest of treatment. Highest net returns were recorded in NE based recommendation compared to the rest of treatments. On an average, NE-based nutrient management increased net returns by ₹ 18,000 /ha over FFP.

4.1.7 Mungbean Residue Recycling and Varietal Combinations: Impact on System Productivity, Profitability and Soil Health in Basmati Rice–Wheat Cropping System

Basmati rice–wheat cropping system (BRWCS) is the most remunerative production system and in order to overcome production vulnerabilities in this system; it needs to be diversified with legumes and other viable options like summer–mungbean residue recycling besides genotypic diversification. A field experiment was conducted on summer mungbean (SMB) residue recycling and BRWCS genotypic diversification at New Delhi, India. Mungbean inclusion in BRWCS and its in–situ residue–recycling enhanced the system productivity by 19.1% over basmati rice–wheat–summer fallow (BR–W–SF) system. P 2511/HD 2967 genotypic combination registered highest system productivity in terms of basmati rice–equivalent yield; followed by PB 1/HD 2733, P 1401/HD 2894 and P 1121/HD 2851, respectively. Net returns in BR–W–SMB were enhanced by 22.1% over BR–W–SF during study with highest magnitude in genotypic combination of P 2511/HD 2967 followed by PB 1/ HD 2733. BR–W–SMB system also registered 13.5% higher microbial biomass carbon (MBC) than BR–W–SF. Alkaline phosphatase activity was also higher in BR–W–SMB over BR–W–SF system. Total soil organic carbon stock was increased by 6.8% besides total soil organic carbon retained in 0–30 cm soil layer after two cropping cycles in BR–W–SMB plots over BR–W–SF. BR–W–SMB system resulted in 19.1, 11.5, 22.1 and 5.82% higher energy output, energy efficiency, net energy and energy intensity, respectively over BR–W–SF system.

4.1.8 Evaluation of Various Planting Techniques on the Performance of Wheat Varieties

An experiment was conducted during 2013-14 on clayey soil of IARI Regional Station, Pusa, farm to assess the proper planting technique on performance of various improved varieties of wheat. Four Planting techniques, namely, furrow irrigated raised bed (FIRB), bed planting (BP), system of wheat intensification (SWI) and conventional system were undertaken in main plots while four improved varieties such as HD 2733, HD 2967, DBW 39 and Raj. 4229 were sown in sub-plots. The experiments was laid out in split plot design and replicated thrice. Recommended doses of Fertilizer were applied as 120: 60: 40 kg NPK/ha and crop was irrigated as per needs at 6 critical growth stages. Amongst all planting techniques, SWI and conventional methods were at par in grain production. However, both the methods were significantly superior over FIRB and bed planting. Out of four varieties tested HD 2733 and HD 2967 were significantly superior over other varieties tested.

4.1.9 Effect of Seedling Age on Seed Productivity and Quality of Paddy cv. PB 1509

Staggered nursery was sown and seedlings of 20, 23, 26, 29, 32 and 35 days old were transplanted in puddled field on 20th July 2014. There was gradual reduction in panicles/m² with increase in seedling age and there was 12.4% increase in number of panicles in 20 days old seedling compared to 35 days
old seedlings, however difference was not significant and this increase in number of panicles could not increase the seed yield significantly. Twenty six and 29 days old seedling recorded significantly higher test weight compared to 35 days old seedlings. Germination remained above the seed standard of 85% in paddy for all the treatments however both seedling length and seedling dry weight and seedling vigour was significantly higher in 26 and 29 days old seedlings compared to 35 days old seedlings.

4.1.10 Response of Nitrogen and Seed Rate on Productivity and Quality of Wheat Seed

There was significant increase in seed yield with increase in nitrogen up to 120 kg N/ha and maximum seed yield was recorded with 120 kg N/ha. There was reduction of 52.7, 27.2 and 18.87% in seed yield in control, 40 and 80 kg N/ha compared 120 kg N/ha. The positive influence of nitrogen fertilization on yield parameters resulted in higher yield of wheat. Seed yield as well as yield attributes were not significantly affected by different seed rates.

Results indicate that the response of nitrogen on seed yield was quadratic. From the equation the maximum yield of 5438 kg/ha was obtained by the application of 172.4 kg/ha of nitrogen. The optimum dose of nitrogen was 167.8 kg/ha with a corresponding yield of 5436 kg/ha.

4.2 SOIL MANAGEMENT

4.2.1 Carbon Input and Carbon Sequestration Efficiency in Inceptisol under Rice-Wheat Cropping System

The estimated return of carbon (ERC) measured as a sum of stubble biomass C, root biomass C, rhizodeposition C, and external organic amended C for continuous nine years in rice-wheat system in Inceptisol was assessed and the relationship between the changes in ERC and soil carbon was derived for estimation of decay rate constant (k) and humification rate constant (h). The ERC ranged from 4.02 Mg ha\(^{-1}\) yr\(^{-1}\) under unmanured control to 16.49 Mg ha\(^{-1}\) yr\(^{-1}\) in the treatment receiving Sesbania green manure + farmyard manure + blue green algae (SGM + FYM + BGA) in rice, and LGLM (Leucaena green leaf manure) + FYM + Azotobacter in wheat. The contribution of C from FYM alone treatment was 37.10 Mg ha\(^{-1}\). It was assumed that the root biomass and rhizodeposition were the major contributors of ERC into soil. The changes in soil C over time (dCs/dt) were greater in SGM + FYM + BGA and the treatment receiving SGM + FYM in rice, and LGLM + FYM in wheat than the other treatments. The C sequestration efficiency (CSE) across the treatments varied from 6.05% in control to 21.29 % in SGM+BGA in rice and LGM+FYM in wheat. The annual rate of change in soil C correlated positively (P<0.01) with ERC. Using the Jenkinson’s equation on two C pool model, the humification rate constant and decay rate constant were calculated as 0.2028 and 0.0079, respectively. The C loss from native SOC over 9 years of cultivation was 0.79% of the initial soil C content. To offset the C loss from native soil organic matter, around 1104 kg C ha\(^{-1}\) yr\(^{-1}\) is needed to maintain the SOC in equilibrium.

4.2.2 Effect of Tillage and Crop Residue Management Practices on Stability of Clay-humus Complex in Rice – Mustard Cropping Sequence

An attempt was made to study the effect of tillage and crop residue management practices on the stability of clay-humus complexes under rice-
mustard cropping sequence started during kharif 2009 at IARI, New Delhi. Stability of clay-humus complex was measured based on first order release kinetics of soil organic C. Clay-humus stability constant varied under different tillage and residue management practices. The highest stability was observed under treatments MBR+ZTDSR-RR+ZTM-WR+SMB and WR+ZTDSR+BM-RR+ZTM, where rice and wheat residues wide C:N ratio were applied. The lowest stability was observed under treatment MBR+ZTDSR-ZTM-ZTSMB, where moongbean residue (narrow C:N ratio) was applied.

### Stability of clay- humus complexes under different conservation agriculture (CA) practices and crop residue management

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Rate Constant (s⁻¹)</th>
<th>Stability (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPR-ZTM</td>
<td>0.070</td>
<td>14.29</td>
</tr>
<tr>
<td>MBR+ZTDSR-RR+ZTM-WR+SMB</td>
<td>0.050</td>
<td>20.06</td>
</tr>
<tr>
<td>MBR+ZTDSR-ZTM-ZTSMB</td>
<td>0.080</td>
<td>12.50</td>
</tr>
<tr>
<td>WR+ZTDSR+BM-RR+ZTM</td>
<td>0.057</td>
<td>19.64</td>
</tr>
<tr>
<td>TPR-CTM</td>
<td>0.069</td>
<td>14.55</td>
</tr>
<tr>
<td>WR+ZTDSR-RR+ZTSM</td>
<td>0.060</td>
<td>16.78</td>
</tr>
<tr>
<td>ZTDSR+BM-ZTM</td>
<td>0.063</td>
<td>15.94</td>
</tr>
<tr>
<td>ZTDSR-ZTM</td>
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<td>16.45</td>
</tr>
</tbody>
</table>

TPR = transplanted rice, CTM = conventional tillage mustard, ZTM = zero tillage mustard, MBR = moongbean residue, ZTDSR = zero tillage direct seeded rice, RR = rice residue, WR = wheat residue, SMB = summer moongbean, ZTSMB = zero tillage summer moongbean, BM = brown manuring

4.2.3 Effect of Long-term Irrigation with Zinc Smelter Effluent on Heavy Metal Status of Soil

Effect of long-term irrigation with zinc smelter effluent on important soil properties and heavy metal accumulation in the soil was assessed. Agricultural lands receiving effluents of zinc smelter plant at Debari, Udaipur for about five decades were sampled. Soil samples were also collected from the adjacent agricultural lands irrigated with tubewell water. Results indicated that long-term irrigation with zinc smelter effluent resulted in significant build-up of EDTA-extractable Zn (57.7 fold), Cu (4.51 fold), Mn (1.77 fold), Ni (1.20 fold), Pb (45.1 fold) and Cd (79.2 fold) compared with the tubewell irrigated soils. Total Zn, Cu, Mn, Ni, Pb and Cd contents in effluent-irrigated soils were increased by 27.0, 1.60, 1.40, 1.30, 26.2 and 167 fold, respectively, over tubewell irrigated soils. The order of the build-up of total and EDTA-extractable heavy metals due to long-term effluent irrigation was Cd>Zn>Pb>Cu>Fe>Mn>Ni. On an average, soil pH dropped by 0.31 unit as a result of long-term irrigation with zinc smelter effluent. On the other hand, soil organic C, electrical conductivity (EC) and CaCO₃ content were significantly higher in effluent irrigated soils compared with tubewell irrigated soils. Among other nutrients, available N and P content in effluent irrigated soils were lower by 21% each compared with tubewell irrigated ones, whereas an increase in available K (102%) was recorded in effluent irrigated soils. Long-term irrigation with effluents resulted in reduced microbial activities in soil as evidenced from relatively lower values of microbial biomass C and dehydrogenase activity.

4.2.4 Effect of Organic Manures on Bioavailability of Zinc and Iron

A greenhouse experiment was conducted with zinc (Zn) and iron (Fe) deficient calcareous soil to study the effect of organic manure, ZnSO₄ and FeSO₄ on yield, and Zn and Fe content in the leaves of spinach (Beta vulgaris). Results revealed that application of FeSO₄ and ZnSO₄ along with organic manures, namely, FYM, poultry manure, and vermicompost significantly enhanced the dry matter yield of spinach as compared to sole application of FeSO₄ or ZnSO₄ or organic manure. Among organic manures, poultry manure emerged out to be the best for increment of yield and enrichment of spinach leaves with Zn and Fe. In the soil, there was significant improvement in nutrient status under combined application of organic manures along with ZnSO₄ or FeSO₄.
4.2.5 Evaluation of Nano-clay Polymer Composites (NCPCs) Loaded with Urea and Neem Oil as a Source of Nitrogen

A series of NCPCs was prepared using two types of polymers (polyacrylamide and starch grafted polyacrylamide) with different concentrations of bentonite (6, 12, 18 and 24%). The NCPCs were loaded with urea (1:1 ratio on weight basis) and neem oil (0 and 1% of N loading), and the products were evaluated under greenhouse experiment using wheat (cv. HD 3059) as a test crop. Recovery efficiency (RE, %), agronomic efficiency (AE, kg grain/ kg N applied) and physiological efficiency (PE, kg grain/ kg N absorbed) of N for urea, NCU and urea+ DCD applied at 90% N varied from 40 to 75, 9 to 16 and 17 to 25, respectively. The corresponding values for the NCPCs with 90% recommended N varied from 60 to 88, 9 to 21 and 17 to 30, respectively. The RE, AE and PE values increased with a decrease in N rate, highest N use efficiency was recorded at 60% of recommended N in all the treatments.

4.2.6 Evaluation of P Loaded Nano-clay Polymer Composites

In a greenhouse experiment, response of wheat crop to applied nano-clay polymer composite (NCPC) loaded with oxalic acid, PSB and phosphorus (P) in an alluvial soil was evaluated. Application of half of recommended P through NCPC and full of recommended P through DAP were equally effective as far as dry matter yield and uptake of P by wheat were concerned. Application of DAP, oxalic acid @ 40 ppm and PSB through NCPC increased soil available P significantly from 5.2 mg kg$^{-1}$ (control) to 8.5, 8.0 and 8.07 mg kg$^{-1}$, respectively.

Further, starch-based nano-clay biopolymer composites (NCBPCs) and NCPC-coated DAP were synthesized in order to make NCPCs economically viable. Among these novel products, NCBPC starch2 (12 % clay) and NCPC-coated DAP (C and D) showed relatively slower release rates of P. However, these are cheaper than NCPC synthesized from acrylic acid and acrylamide.

4.2.7 Evaluation of Coated Phosphatic Fertilizers as Source of Phosphorus

In the quest for developing slow release P fertilizers, four novel P-fertilizer products were synthesized and characterized for their chemical as well as structural composition. Characterization of newly synthesized products through FTIR indicated the presence of phosphate (PO$_4^{3-}$) group. Presence of $\sim$NH group was evident in Product-A and Product-B (synthesized by reacting NH$_3$ and H$_3$PO$_4$ at 2:1 and 1:1, respectively) but such $\sim$NH stretching was absent in case of both Product-C (RP+H$_2$SO$_4$) and Product-D (RP+H$_3$PO$_4$). The SEM and TEM studies showed that the surface morphology of Product-A and Product-B were smooth while Product-C and Product-D had irregular surface morphology. The X-ray diffraction studies revealed the superior crystalline structure of Product-B over the other products. Chemical analysis of the four products showed that Product-B had the highest total P (28.8%) than others. Synthesized coated products proved to be better in controlling the release of P than commercial DAP. Among different sources, Product-B was most effective in enhancing the yield and P uptake by wheat, followed by Product-D, C and A. Post-harvest soil analyses revealed that application of modified coated fertilizers maintained significantly higher amount of available N and P over unfertilized control as well as DAP treated pots. It is thus apparent that coated P fertilizers could be developed by reacting ammonia with phosphoric acid, or rock phosphate with mineral acids followed by coating with liquid.
Characterization of synthesized coated fertilizer products prepared using rock phosphate, mineral acids and ammonia

<table>
<thead>
<tr>
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<tbody>
<tr>
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<td>7.90</td>
<td>2.0</td>
<td>2.40</td>
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<tr>
<td>Total N (%)</td>
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<td>15.3</td>
<td>trace</td>
<td>trace</td>
</tr>
<tr>
<td>Total P (%)</td>
<td>25.7</td>
<td>28.8</td>
<td>8.9</td>
<td>21.6</td>
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<tr>
<td>Water soluble P (%)</td>
<td>22.1</td>
<td>24.6</td>
<td>5.2</td>
<td>8.20</td>
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<tr>
<td>Citrate soluble P (%)</td>
<td>1.80</td>
<td>3.80</td>
<td>2.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Citrate insoluble P (%)</td>
<td>1.80</td>
<td>0.50</td>
<td>1.0</td>
<td>2.70</td>
</tr>
<tr>
<td>Shape (Scanning electron micrograph, SEM)</td>
<td>Granular shape (Cubical, Hexagonal)</td>
<td>Needle shaped</td>
<td>Alveoly shaped</td>
<td>Irregular flakes shaped</td>
</tr>
<tr>
<td>Particle size (TEM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>Pale white crystalline</td>
<td>Pure white crystalline</td>
<td>Light grey</td>
<td>Dark grey</td>
</tr>
</tbody>
</table>

paraffin or polyvinyl alcohol which could serve as better P fertilizers than conventional DAP.

**4.2.8 Use of Rock Phosphate as a Source of Phosphorus in Calcareous Soil**

Use of rock phosphate (RP) as a source of P in alkaline and calcareous soil is not common because of its low solubility. Incubation and greenhouse studies were conducted to evaluate the effect of partially acidulated RPs on P release pattern in alkaline calcareous soil as well as their agronomic effectiveness using wheat as a test crop. Three acidulants and two levels of acidulation were used to prepare different partially acidulated RP product using RPs of varying origin viz., Syria, Jordan, Udaipur and Purulia. Chemical analysis of acidulated RP showed that both total and citrate insoluble phosphate fractions decreased with an increase in the degree of acidulation, whereas water soluble P and citrate soluble P as a percentage of respective total P increased with an increase in the acidity levels. Significant positive responses of wheat crop (drymatter yield, P content and P uptake) to applied partially acidulated RP products prepared with sulphuric acid or pyrite were observed over control. Effectiveness of RPs of different origin as source of P to wheat followed the order: Jordan > Syrian = Purulia > Udaipur, while the acidulation agents followed the order: sulphuric acid > pyrite > oxalic acid. This was also reflected in the elevated available P status in the post-harvest soil.
However, applied P through SSP was more effective in enhancing P content in soil and plant, P uptake and drymatter yield of wheat as compared to those obtained with partially acidulated RPs.

### 4.2.9 Evaluation of Zinc Loaded Nano-clay Polymer Composites

Working on development of novel delivery micronutrient fertilizers, nano-clay polymer composites (NCPCs) containing 5 and 10% Zn were prepared using ZnSO$_4 \cdot 7$H$_2$O. In a pot culture study, responses of wheat in terms of grain yield to soil application of Zn through zinc sulphate, NCPC (1/5$^{th}$ of recommended dose of Zn) and seed coating with Zn-NCPC were at par. On the other hand, soil application of nano ZnO was ineffective in enhancing the grain yield of wheat. Superiority of Zn-NCPC in enhancing Zn content of wheat plant at different growth stages over other sources was also recorded. There was no adverse effect of Zn-NCPC on germination of wheat seed even with the loading of 2333 $\mu$g Zn per g of coated seed.

In another study, Zn-NCPC having 6.6% Zn was prepared using Zn-citrate. Soil Zn application through NCPC was more effective in enhancing DTPA-extractable Zn content in rhizosphere of wheat crop at panicle initiation stage. Zinc content in wheat plant at panicle initiation stage was significantly higher in NCPC-treated pots as compared to conventional zinc sulphate application. Use of NCPCs also enhanced the availability of P owing to solubilization of inorganic P due to citrate liberated from NCPCs as well as mineralization of organic-P due to increase in acid and alkaline phosphatase activity. Overall increase in microbial activity as evidenced by elevated level of dehydrogenase activity was recorded in NCPC treated pots.

### 4.3 WATER MANAGEMENT

#### 4.3.1 Crop Water Foot Print Assessment of River Basins for Sustainable Agriculture

Crop water footprint (WF) has been recognized as potentially useful concepts in water resource management at river basin scale. Water foot print within the Gomti and Betwa river basins of India were assessed and the sustainability of WFs within the basins were determined. Impact of crop management options on basins’ WF was also evaluated. Spatial Resolutions Units (SRUs) were delineated on the basis of homogeneity in soil, agro-climatic sub-regions, district boundaries and spatial variability in crop evapotranspiration (ETc). Optimization models were used for suggesting the cropping patterns to reduce the WF within the basins. Results showed that WFs of Gomti and Betwa river basins were 12773 million m$^3$ and 9186 million m$^3$, respectively. The agricultural sector accounted for 96.1% and 97.8% of the total WF in Gomti and Betwa basins, respectively. Paddy, wheat and sugarcane had largest WF accounting for 88.3% of the total WF in Gomti basin. In Betwa basin, wheat, soybean and chickpea accounted for 75.3% of the total WF. At present, about 5054 million m$^3$ and 3590 million m$^3$ of water is being exported from Gomti and Betwa basins, respectively. Optimal cropping pattern with relocation of crops from high to low WF areas would result in savings of about 9.26% and 25.12% of blue water in Gomti and Betwa basins, respectively. Sustainability analysis of WFs indicated that water consumption and pollution pattern in Gomti basin are sustainable while in Betwa basin there is need for reduction of WF. With the adoption of improved irrigation methods, laser land leveling and optimal cropping pattern at basin scale, it is possible to reduce the WF and VW imports to the basins.
Green, blue and grey water footprints of important crops in Gomti river basin

4.3.2 Validation of ADI with SPI (Meteorological Drought Index) for Monitoring of Drought in Maharashtra State

This study investigated and compared the aggregated drought index (ADI) and standardized precipitation index (SPI) for drought monitoring in Maharashtra state for the year 2002. Precipitation data were used for SPI calculation. SPIs’ of 1 month, 3 months, 6 months, 9 months and 12 months was calculated for Maharashtra state. Four variables including precipitation, potential evapotranspiration, stream flow and ground water level were used for ADI calculations using principal component analysis (PCA). Results of SPI showed normal and moderately drought situation in year 2002 during both pre and post monsoon seasons. On the other hand, ADI showed the capability to detect dry and wet conditions in the same year. The results showed close agreement between 12 month SPI and ADI for Maharashtra State.

Comparison of ADI and SPI for both pre and post monsoon in Maharashtra State during 2002

4.3.3 Water Productivity of Rice – Wheat Cropping Systems/Varities under Three Cultivation Methods

Experiment was undertaken involving wheat cultivars DBW 17 and HD 2967 during Rabi 2013-14 and rice cultivars PUSA 1509 and Pusa Sugandh-5 during Kharif 2014 under three different cultivation methods. The results revealed that the highest water productivity (8.54 kg/ha mm) was for PUSA 1509 and HD 2967 combination under DSR method of cultivation. Such combination produced total rice and wheat grain yield of 10.7 t/ha with total water use of 1252 mm. However, the total grain yield of RWCS was highest 12.32 t/ha for rice (Pusa Sugandh-5) and wheat (HD 2967) under SRI method of cultivation with total water use of 1744 mm.

4.3.4 Estimation of Single and Dual Crop Coefficient and Water Productivity of Mustard (Pusa Vijay) in Weighing Type Lysimeters

Determination of regional crop coefficient has potential advantage for proper irrigation
scheduling. An attempt was made to determine the single crop coefficient (Kc), dual crop coefficients, ratio of transpiration to evapotranspiration and water productivity of mustard cultivar Pusa Vijay (NPJ 93) (Brassica juncea) through conduction of field experiments in weighing type lysimeters in the research farms of Water Technology Centre, IARI, New Delhi. Three weighing type lysimeters in the farm were used for cultivation of mustard crop during 

<table>
<thead>
<tr>
<th>Crop growth stages</th>
<th>Single crop coefficient (Kc)</th>
<th>Dual crop coefficients</th>
<th>Ratio of transpiration to evapotranspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial (0-30DAS)</td>
<td>0.27</td>
<td>0.11</td>
<td>0.75</td>
</tr>
<tr>
<td>Development (31-70)</td>
<td>0.59</td>
<td>0.38</td>
<td>0.21</td>
</tr>
<tr>
<td>Mid-season (71-110DAS)</td>
<td>1.04</td>
<td>0.94</td>
<td>0.1</td>
</tr>
<tr>
<td>Late-season (111-140DAS)</td>
<td>0.54</td>
<td>0.24</td>
<td>0.26</td>
</tr>
</tbody>
</table>

4.3.5 Drip Fertigation in Summer Squash Crop under Plastic Low Tunnel

Summer squash is one of the vegetable crops among the cucurbits which may be grown under the temperature range of 15-25°C. Plastic low tunnels are considered to be highly suitable and profitable for off season cultivation from December to March, when the open field is not favourable for growing such crop. An experiment was conducted with the aim to mitigate the negative effect of low temperature. The study included drip irrigation scheduling and recommended dose of fertilizer application in Australian green summer squash and aimed to observe the response of growth and yield of off season summer squash under plastic low tunnel. The experiment was laid out in split plot design with three replications. Irrigation treatments consist of three different irrigation water levels in terms of crop water requirement (CWR); (I_1 = 1 CWR, I_2 = 0.8 CWR and I_3 =0.6 CWR) and three N:P:K water soluble fertilization levels in terms of recommended dose of fertilizer (RDF) with the ratio 5:3:5 of (F_1 = 1 RDF kg ha^-1; F_2 =0.8 RDF kg ha^-1; and F_3 = 0.6 RDF kg ha^-1). Data showed that the summer squash yield and growth attributes increased with the increase of irrigation water level. However, the I_2 along with F_1 increased yields due to increase in the mean weight of the fruits and fruit number. The results of the study showed that fertigation
of 0.8 CWR and 1.0 RDF under plastic low tunnel produce the highest fruit yield to the tune of 31.2 t ha\(^{-1}\) which was significantly higher than that of the two other drip fertigation levels. The total crop water requirement was estimated to be 158 mm. The results of the economic analysis revealed that interactive effect of \(I_2\) and \(F_1\) resulted in highest net income, maximum benefit cost ratio and lowest payback period.

### 4.3.6 Antioxidant Defense System of Drought Tolerant and Susceptible Maize Cultivars under Irrigated and Water Deficit Stress Condition

Experiment was conducted to analyze maize hybrids for antioxidant enzymes and non-enzyme compound at two leaf stages, under normal irrigation (IRR) and water deficit stress (WDS) during Kharif 2014. Under WDS, glutathione reductase activity increased in all hybrids except VIVEKHYD-9 whereas the increase was highest, 37.4\% in tolerant than the susceptible hybrids. Catalase activity increased by 56\% in tolerant hybrid whereas a decrease of about 30\% was observed in susceptible under WDS. Also, ascorbate peroxidase activity increased in tolerant hybrids and decreased in susceptible hybrids under WDS. These hybrids exhibited wide variability in their antioxidant pools combined with activities of enzymes involved in defense against oxidative stress.

### 4.3.7 Impact of Treated vs Untreated Wastewaters on the Quality and Yield of Peri-urban Vegetables

An experiment to study the impact of untreated vs treated wastewaters on the yield and the quality of the okra (var. A 4) and the cabbage (var. Indu) vegetables was conducted during 2014-15 at IARI, New Delhi. The investigation revealed that though the fruit yield (15.3 t ha\(^{-1}\)) and the nutrient contents (3.1 to 3.4\% N, 0.58 to 0.68\% P and 1.1 to 1.4\% K) of the okra were significantly higher when irrigated with the untreated wastewaters than those irrigated with the local groundwater (12.3 t ha\(^{-1}\)) or the treated wastewaters (13.5 to 13.9 t ha\(^{-1}\)) yet the crop irrigated with untreated wastewaters was having 10-times higher pathogen infestation (Coliform and heterotroph counts of 5.37x10\(^4\) cfu g\(^{-1}\) and 8.43x10\(^4\) cfu g\(^{-1}\), respectively) than those irrigated with treated wastewaters (Coliform count: 2.09x10\(^3\) cfu g\(^{-1}\) and heterotroph count: 4.67x10\(^4\)). This was also reported to be the case for cabbage with boll yields ranging between 166 to 200 t ha\(^{-1}\).

### 4.3.8 Impact of Varied Wastewater Irrigation Schedules and Conjunctive Water Use Practices on Vegetative Growth and Floral Characteristics of Non-food Crop, viz. Tuberose (*Polianthes tuberosa* L.)

A field experiment was conducted to assess the impact of varied wastewater irrigation schedules and
conjunctive water use practices on vegetative growth and floral characteristics of tuberose (*Polianthes tuberose* L. cv. Prajwal) at WTC farm of IARI, New Delhi in 2013. Results indicated significantly higher plant height (70.45 cm), leaves per plant (84.09), spike length (98.5 cm), rachis length (39.3 cm), number of florets per spike (62.6) and hence cut spike yield (1.05 lakh/ha), for the crop irrigated with waste waters at 1.4 ID/CPE irrigation scheduling criteria.

**4.3.9 Impact Assessment of Untreated Wastewater and Varying Nitrogen Doses, under Different Land Configurations on Marigold Productivity**

Experiment was undertaken to assess the impact of waste water irrigations and varying nitrogen levels, under different land configurations on marigold productivity in IARI, New Delhi during *Kharif* 2014. The experiment consisted of two sources of irrigation water (ground and wastewater) and three levels of nitrogen (0, 60 and 120 kg/ha) under raised and flatbed conditions with three replications in split plot design. The crop was raised through 30 days old seedling of marigold (var. Pusa Arpita). Irrigation with untreated wastewaters and ground water, under same N-levels and land configurations, showed statistically non-significant differences in terms of flower yield. However, raised bed planting produced significantly higher flower yield (13.26 t/ha) as compared to the flatbed planting. Similarly application of 120 kg N/ha of recommended dose of nitrogen resulted in higher flower yield of 17.20 t/ha.

**4.3.10 Antioxidant Defense Mechanism and Its Role in Wastewater Heavy Metal Reduction Efficiency of Emergent Macrophyte species**

Heavy metals stimulate the formation of free radicals and reactive oxygen species (ROS) such as superoxide radical, hydroxyl radical, hydrogen peroxide and singlet oxygen, either by direct electron transfer involving metal cations or as a consequence of metal-mediated inhibition of metabolic stress. If the scavenging system of a plant does not cope well with the formation of free radicals or ROS, it leads to uncontrolled oxidation and radical chain reactions, which result in oxidative stress to the plants. To combat these effects, the cells are normally equipped with intricate anti-oxidant systems comprising of enzymatic (Superoxide dismutase, SOD; Catalase, CAT; Guaiacol Peroxidase, GPX; Ascorbate Peroxidase, APOX, etc.) and non-enzymatic (ascorbate, glutathione, proline and phenolic compounds) systems. The ability of an organism to prevent specific and nonspecific ROS-mediated cellular damage is therefore key to its survival/ better performance. Role of antioxidant enzymes such as superoxide dismutase (SOD), Catalase (CAT) and Ascorbate peroxidase (APX) on the overall metal (viz., Ni, Pb and Cr) reduction potential, of five test emergent macrophyte species (such as *Typha latifolia*, *Phragmites karaka*, *Arundo donax*, *Acorus calamus* and *Vetiveria zizanoides*) in the vertical sub-surface flow wastewater treatment systems of IARI was thus, assessed. In general, all macrophyte systems showed an increased trend with increasing pollutant concentrations. Phragmites and Arundo based wastewater treatment systems were observed to be associated with highest (84-86% and 90-92%, respectively) metal removal efficiency at lower (1 to 1.5 ppm) and highest (5-10 ppm) metal concentrations, respectively. However, in case of Cr, with increased metal concentrations, in general a decrease in the metal reduction efficiency of all test plants was observed; with Arundo out-beating the rest (88 to 82%). This was followed by Acorouscalamus (with 79% Cr efficiency) and Typha, Phragmites and

![Graph showing SOD activity in emergent macrophyte species used for treating metal spiked waters.](image)
Vetiver (with just 50-54% Cr efficiency). Observance of highest activity of SOD, Catalase (CAT) and Ascorbateperoxidise (Apx) in the leaves and the roots of the Arundo plants exposed to variable Pb, Cr and Ni metal concentrations re-confirmed the aforementioned findings.

4.4 NUTRIENT MANAGEMENT

4.4.1 Sulfur-coated Urea as a Source of Sulfur for Enhanced Efficiency of Nitrogen in Spring Wheat

Nitrogen application as uncoated prilled urea (PU) significantly increased grain and straw yields of wheat. Four or 5% SCU recorded significantly higher grain yield over 1, 2 and 3% SCU and uncoated PU. As regards, straw yield, only 5% SCU recorded a significant increase over 1, 2, 3 and 4% SCU and uncoated PU. Five % SCU recorded the highest recovery efficiency (RE\textsubscript{N}), significantly higher than 3 or 4% SCU, which in turn recorded significantly more than 1 or 2% SCU. The RE\textsubscript{N} increased from 31.6% with uncoated PU to 51.6% with 5% SCU, an increase of 63.3%, which is fairly high. As regards agronomic efficiency (AE\textsubscript{N}), 3, 4 and 5% SCU were at par and significantly superior to 1 or 2% SCU. A significant increase in partial factor productivity of nitrogen (PFP\textsubscript{N}) was observed only with 4 or 5% SCU.

4.4.2 Precision Nutrient Management in Rice with Different Crop Establishment Methods under Rice-Wheat Cropping System of NEPZ

Five rice establishment methods: Bed planting (BP), puddle transplanted rice (PTR), machine transplanted unpuddled rice (MTUPR), direct sowing rice (DSR), and system of rice intensification (SRI) in main plot and four nutrient management systems: Recommended dose of fertilizers (RDF, 120: 60:40 NPK/ha), RDF + green seeker (GS), site specific nutrient management (SSNM) based on Leaf Color Chart and control in subplots were evaluated during 2014 on clayey soil of IARI Regional Station, Pusa, Samastipur. The experiment was laid down in split plot design with 3 replications. Rice cv. Pusa Sugandh 5 (P 2511) was used for sowing. A significant difference in grain yield was observed among establishment methods; however the yields in MTUPR and SRI methods were at par. Among all nutrient management system, RDF + GS method produced significantly higher yield followed by RDF and SSNM over control.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (t/ha)</th>
<th>Partial factor productivity (kg grain kg\textsuperscript{-1} N applied)</th>
<th>Agronomic efficiency (kg grain increased kg\textsuperscript{-1} N applied)</th>
<th>Crop recovery efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute control</td>
<td>2.92</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Prilled urea</td>
<td>4.28</td>
<td>32.9</td>
<td>10.5</td>
<td>31.6</td>
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<tr>
<td>1.0% sulfur-coated urea</td>
<td>4.45</td>
<td>34.2</td>
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<td>SEm\textsubscript{2}</td>
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<td>0.69</td>
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<tr>
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<td>0.362</td>
<td>3.07</td>
<td>2.19</td>
<td>4.04</td>
</tr>
</tbody>
</table>
4.4.3 Moisture Management and Zinc Fortification in Pearlmillet (*Pennisetum glaucum* L.)-Chickpea (*Cicer arietinum* L.) Cropping System

A field study was conducted during *Kharif* and *Rabi* seasons of 2012-13 under limited moisture conditions. Flat bed planting with 5.0 t/ha crop residue recorded significantly higher system productivity in terms of pearlmillet grain equivalent yield (9.09 t/ha) and moisture use efficiency (15.24 kg/ha-mm) as compared to flat bed without residue and flat bed with 2.5 t/ha crop residue followed by narrow bed and furrow with 2.5 t/ha crop residue. This treatment also resulted significantly higher Zn content in grain of pearlmillet (35.95 mg/kg) over flat bed without residue and flat bed with 2.5 t/ha crop residue and in grain of chickpea (47.70 mg/kg) over flat bed without residue only. Zinc applied to pearlmillet increased the system productivity, profitability and moisture use efficiency only up to 2.5 kg Zn/ha. Increasing levels of

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effective tillers (l/m sq)</th>
<th>Grain yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main plots</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td>180.5</td>
<td>4.24</td>
</tr>
<tr>
<td>PTR</td>
<td>169.4</td>
<td>4.417</td>
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<td>MTUPR</td>
<td>175.3</td>
<td>4.76</td>
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<td>DSR</td>
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<td>3.97</td>
</tr>
<tr>
<td>SRI</td>
<td>178.8</td>
<td>4.75</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>3.2</td>
<td>0.142</td>
</tr>
<tr>
<td><strong>Sub plots</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDF</td>
<td>182.6</td>
<td>4.85</td>
</tr>
<tr>
<td>RDF+GS</td>
<td>190.5</td>
<td>5.01</td>
</tr>
<tr>
<td>SSNM (LCC)</td>
<td>176.1</td>
<td>4.63</td>
</tr>
<tr>
<td>Control</td>
<td>147.5</td>
<td>3.27</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>2.85</td>
<td>0.186</td>
</tr>
</tbody>
</table>

**System productivity, profitability, moisture use efficiency and Zn content in grain of pearlmillet and chickpea as influenced by moisture management and zinc fortification**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>PMGEY (t/ha)</th>
<th>Net returns (Rs./ha)</th>
<th>MUE (kg/ha-mm)</th>
<th>Zn content in grain (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pearlmillet</td>
</tr>
<tr>
<td><strong>Moisture management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat bed</td>
<td>6.65</td>
<td>64,171</td>
<td>10.75</td>
<td>31.33</td>
</tr>
<tr>
<td>Flat bed with 2.5 t/ha residue</td>
<td>8.04</td>
<td>77,149</td>
<td>13.27</td>
<td>34.44</td>
</tr>
<tr>
<td>Flat bed with 5.0 t/ha residue</td>
<td>9.09</td>
<td>85,903</td>
<td>15.24</td>
<td>35.95</td>
</tr>
<tr>
<td>NBF with 2.5 t/ha residue</td>
<td>8.86</td>
<td>88,264</td>
<td>14.76</td>
<td>34.98</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.71</td>
<td>10,553</td>
<td>1.18</td>
<td>1.27</td>
</tr>
<tr>
<td><strong>Zinc fortification to pearlmillet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>7.61</td>
<td>70,948</td>
<td>12.68</td>
<td>29.39</td>
</tr>
<tr>
<td>2.5 kg Zn/ha</td>
<td>8.29</td>
<td>80,769</td>
<td>13.72</td>
<td>35.01</td>
</tr>
<tr>
<td>5.0 kg Zn/ha</td>
<td>8.58</td>
<td>84,897</td>
<td>14.12</td>
<td>38.12</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.39</td>
<td>5,522</td>
<td>0.64</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>Zinc fortification to chickpea</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>7.54</td>
<td>70,339</td>
<td>12.59</td>
<td>31.39</td>
</tr>
<tr>
<td>2.5 kg Zn/ha</td>
<td>8.30</td>
<td>80,763</td>
<td>13.72</td>
<td>34.66</td>
</tr>
<tr>
<td>5.0 kg Zn/ha</td>
<td>8.64</td>
<td>85,512</td>
<td>14.20</td>
<td>36.48</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.31</td>
<td>4,301</td>
<td>0.51</td>
<td>0.75</td>
</tr>
</tbody>
</table>
zinc fortification up to 5.0 kg Zn/ha applied to chickpea significantly improved the system productivity and profitability, whereas, the moisture use efficiency was improved significantly only up to 2.5 kg Zn/ha. The content of Zn in grain of both pearl millet and chickpea were increased significantly with increasing levels of direct as well as residue zinc fortification up to 5.0 kg Zn/ha.

4.4.4 Long-term Effect of Fertilizers and Manures on Crop Yields and Soil Fertility

Highest grain yield of maize and wheat (5.36 and 5.86 t ha⁻¹, respectively) was obtained with the application of 5 t FYM ha⁻¹ along with recommended NPK or the super-optimal NPK (i.e., 150% of recommended rate) during 44th cropping cycle of the long-term experiment continuing since 1971-72 on a Typic Haplustept of IARI Farm. The yields in these treatments were significantly greater than 100% of recommended NPK, underlining the necessity of upward revision of the fertilizer recommendations. The yield differences between NPKS and NPK, NPK and NP, and those between NP and N alone confirmed a significant response to S, K and P fertilization, respectively. Long-term intensive cropping with recommended fertilizer use either maintained or moderately increased soil organic C compared with the initial content (0.44%), although organic C content was highest (0.55%) under NPK+FYM treatment. On the other hand, a decrease in soil organic C was recorded under unbalanced fertilizer use i.e., N or NP.

4.5 PROTECTED CULTIVATION TECHNOLOGY

4.5.1 Vegetable Crops

4.5.1.1 Evaluation of coloured capsicum varieties under semi climate controlled greenhouse

Capsicum varieties, namely, Swarna (yellow), Orobeli (yellow), Natasha (red) and Indra (red) were grown under semi climate controlled greenhouse. 25 days old seedlings were transplanted at a spacing of 50x30 cm. Among the yellow fruited varieties Swarna produced higher fruits yield (11.50 kg/m²) as compared to Orobeli (10.30 kg/ m²). However, among the red fruited varieties, Indra produced highest fruits (10.50 kg/m²) as compared to Natasha (9.15kg/ m²).

4.5.1.2 Studies on the effect of coloured plastic mulches on tomato under insect proof net house

Indeterminate tomato variety, GS-600 was evaluated on 25-30 micron different coloured plastics mulches i.e., Silver/black, Red/black, Yellow/black and Black/black under insect proof net house equipped with drip fertigation system on 10 cm raised beds, transplanted at 50x50 cm spacing. It was observed that the black/black colour plastic mulching set early flowering and fruiting and harvesting (10 days) along with higher fruit yield (6.50 kg/plant) and maximum cost benefit ratio (1:2.50) as compared to other coloured plastic mulches. However, all the four coloured plastics mulching showed an increase of 10-15% fruit yield over the non mulched tomato plants.

4.5.2 Flower Crops

4.5.2.1 Studies rose varieties for cut flower production under naturally ventilated polyhouse

Rose varieties, namely, Avalanche, Buggati, Golden Strike, Poison and Tajmahal were planted on 20 cm raised beds at 40x20 cm and evaluated for their
performance under naturally ventilated polyhouse (242 m²). It was noted that variety, Buggati could produce longest (117.5 cm) stems along with maximum flower size (8.82 cm diameter across) followed by Avalanche (116.5 cm and 8.73 cm, respectively). However, Golden Strike could produce shortest (55.8 cm) stems with smallest flower size (6.2 cm).

4.5.2.2 Evaluation of cut spray chrysanthemum varieties under low cost polyhouse

Five chrysanthemum varieties, namely, Pusa Anmol, Pusa Ajay, Golden Ball, Ravi Kiran and Haldi Ghati were planted on 10th September at 32 plants/m² without any additional photoperiod and pinching. It was noted that the variety, Pusa Ajay could produce good quality stems with a maximum stem length (78.5 cm), number of branches (12.3) and flower buds (102.2) per plant followed by Ravi Kiran (62.5 cm, 9.1 and 55.8, respectively) and Pusa Anmol (41.4 cm, 8.3 and 54.5, respectively).

4.5.3 Drip Irrigation and Fertigation

4.5.3.1 Fertigation scheduling for capsicum grown in soil-less grow bags

Experiment was laid out inside 200 m² greenhouse with soil-less grow bag system for estimating the water and nutrient requirement of capsicum. Yellow colored capsicum variety Orobell was transplanted on 13th Oct. 2014 in soil-less grow bags with drip fertigation system having lateral pipes of 16:1:30 accommodating three plants per bag, neutral of EC-pH. The Ec and pH of fertigation solution were closely monitored and maintained in the range of 2.0-3.0 dS/m and 6-7, respectively, maintained in the range of 0.8-1.5 dS/m and 7-7.5, respectively. It was observed that plant water requirement increased with increased age and was maximum (800 ml) in March with a reduced irrigation interval of 3 days as compared with November (250 ml/plant at 6 days interval).

Drip irrigation scheduling for soil-less grow-bags for coloured capsicum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Item/month</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CWR* per plant</td>
<td>250 ml</td>
<td>300 ml</td>
<td>400 ml</td>
<td>600 ml</td>
<td>800 ml</td>
</tr>
<tr>
<td>2</td>
<td>CWR for 200 sqm greenhouse</td>
<td>125 litre</td>
<td>150 litre</td>
<td>200 litre</td>
<td>300 litre</td>
<td>400 litre</td>
</tr>
<tr>
<td>3</td>
<td>No of irrigation</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Irrigation duration</td>
<td>15 min</td>
<td>20 min</td>
<td>25 min</td>
<td>35 min</td>
<td>50 min</td>
</tr>
<tr>
<td>5</td>
<td>Irrigation interval</td>
<td>6 days</td>
<td>5 days</td>
<td>5 days</td>
<td>4 days</td>
<td>3 days</td>
</tr>
</tbody>
</table>

* CWR: Crop water requirement as per FAO guidelines
4.5.3.2 Water and nutrient budgeting analysis for vegetable and flower crops

Studies on water and nutrient budgeting study was conducted for calculating total crop water requirement and number of irrigations. Drip fertigation system was laid out with the 16 mm drip lateral lines fitted with drippers of 1-2 litre per hour discharge capacity. The total crop water requirement was calculated on per plant basis for different vegetables and flower crops grown inside greenhouse. The total crop water requirement on per plant basis was estimated as 22 litre, 45 litre and 70 litre for cucumber, capsicum and tomato crops, respectively, grown inside 1000 m² greenhouse. The total crop water requirement on per plant basis was estimated 4.5 litre, 18 litre and 27 litre, respectively, for chrysanthemum, gerbera and rose crops grown inside 1000 m² greenhouse.

Crop water budget (CWR) in vegetables and flowers under greenhouse (1000 m²)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crop</th>
<th>No. of plants</th>
<th>No. of irrigation</th>
<th>CWR (m³)</th>
<th>CWR (Litre/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tomato</td>
<td>2800</td>
<td>57</td>
<td>198</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Capsicum</td>
<td>4200</td>
<td>55</td>
<td>190</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>Cucumber</td>
<td>4200</td>
<td>20</td>
<td>90</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>Rose</td>
<td>12,000</td>
<td>80</td>
<td>320</td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>Gerbera</td>
<td>16,000</td>
<td>75</td>
<td>280</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>Chrysanthemum</td>
<td>65,000</td>
<td>80</td>
<td>295</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Nutrient consumption in vegetables and flowers in greenhouse (1000 m²)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crop</th>
<th>No. of plants</th>
<th>Major nutrient consumption (Total/kg)</th>
<th>Major nutrient consumption (per plant/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>Tomato</td>
<td>2800</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Capsicum</td>
<td>4200</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Cucumber</td>
<td>4200</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Rose</td>
<td>12,000</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Gerbera</td>
<td>16,000</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>Chrysanthemum</td>
<td>65,000</td>
<td>21</td>
<td>13</td>
</tr>
</tbody>
</table>

4.6 AGRICULTURAL ENGINEERING

4.6.1 Development of Self Propelled Garlic Planter

A self propelled garlic planter was designed and developed by the Institute, for mechanized planting of garlic cloves to reduce drudgery of operation and increase production as a whole. The prime mover of the planter is a 2.65 kW petrol engine. The prototype consists of main frame, inclined plate metering mechanism, hopper, furrow opener and speed reduction system, etc. The metering mechanism was designed based on the physical and engineering properties of the garlic cloves. The size of circular cups, and triangular cells on the periphery of a plate were decided taking characteristic dimensions as greater than or equal to maximum clove dimensions. To ensure free flow of seeds in the hopper, the angle
of inclination of hopper was taken as 40°, which is more than angle of repose of the garlic cloves (37.5°). Various performance parameters such as average seed spacing, miss index, multiple index, quality of feed index, precision and seed damage were 9.42 cm, 6.8 %, 12.72 %, 80.48 %, 22.67 % and 8.26 %. Precision was found to be 22.67 %. Field capacity of the planter was found to be 0.09 ha/h with a field efficiency of 77.7 % when operated at a operational speed of 1.5 km/h. The average depth of placement was found be 2.6 cm. The cost of the machine was ₹ 48500/- with an hourly cost of operation of ₹ 150/-. The cost of operation per hectare was ₹ 1670/- as compared to manual hand planting with cost of ₹ 7500/- per hectare. This in turn saves 77 % per hectare basis. The break even point was found to be 106.9 h/yr, and it was having a pay back period of 2.29 yr.

4.6.2 Development Oscillating Soil Separator for Garlic Harvester

An oscillating soil separator for garlic harvester was designed and developed by the Institute, for better soil separation. Amplitude of 10 mm and rpm of 540±10 was taken for this study. The length and width of soil separator was kept as 1000 and 900 mm. For free and efficient dropping of soil-mass from the separator, the rod spacing was kept as 50 mm. The depth of garlic bulbs of different varieties in soil and to harvest them without damage, minimum depth of operation was selected as 120 mm. Highest garlic harvesting percentage (98.07%), maximum soil separation index (0.20) and minimum damage percentage of 3.47% was occurred in sandy loam soil at moisture of 12.88±0.35 percent (d.b). Minimum power requirement (2.43 kW) for operation garlic harvesting system also occurred at 12.88±0.35 %. Highest garlic harvesting percentage, maximum soil separation and minimum damage percentage (97.78%, 0.19 and 3.76%, respectively), was observed at 25 rake angle. The maximum power requirement (9.46 kW) was observed at 4.5 km.h⁻¹ speed of operation and minimum power requirement (2.43 kW) was observed at 1.5 km.h⁻¹ speed of operation. The average harvesting efficiency, bulb damage, soil separation index for garlic harvester was found to be 94.76%, 4.81% and 0.23, respectively. The optimum power requirement of the harvester was 5.74 kW for soil moisture content of 12.88±0.35 per cent. The total cost of machine was ₹ 24700/- and its estimated cost
of operation ₹ 1670/- per ha, which is lower than cost of manual harvesting (₹ 8250/- per ha). The garlic harvester had a breakeven point at 125.36 hyr⁻¹ with a pay back period of 2.6 years.

### 4.6.3 Design and Development of Pneumatic Precision Planter for Vegetable Crops

Pneumatic precision planter was designed and developed in joint collaboration with CSIR-CMERI-CoCPM. The prototype planter was evaluated in the laboratory and experimental farm of the IARI. The planter was calibrated in the laboratory for singulation and miss. Cauliflower, radish and onion seed were used for calibration. The quality of feed index, miss index and multiple index were computed at different suction pressure. Initial test results are encouraging. Germination, plant spacing and other parameters were recorded. The field capacity of the machine was 0.2-0.3 ha/h with a field efficiency of 78%. About 15-20% of seed saving was recorded when compared with conventional planting or transplanting. Uniform germination helps in uniform maturity, thereby mechanized vegetable farming can be practiced.

### 4.6.4 Ergonomic Design Modification of Wheel Hoe for Female Worker

Wheel hoe was ergonomically evaluated in the field to assess their compatibility for women farm workers. Physiological parameters were evaluated for operator working with wheel hoe for weeding operation in field crops. The heart rate, oxygen consumption and energy expenditure was observed in the operation of wheel hoe. Working with wheel hoe was categorized in heavy work and body part discomfort and overall discomfort score had higher values. Wheel hoe was modified with geometric reduction in the cutting blade and handle width. Blade dimension reduced by 5% (S1) and 10% (S2) with handle width dimensions of 400 mm (W1), 440 mm (W2) and 480 mm (W3), were evaluated for work output and ergonomic parameter for female farm workers. It was observed that heart rate, oxygen consumption and energy expenditure were lowest for S2-W2 modified wheel hoe (10% blade reduction and 440 mm handle width). It was observed that heart rate with modified wheel hoe reduced by 11 beats per minutes as compared to the existing wheel hoe and the work was classified in “moderate” category. Resting period for modified hoe was reduced from 33.33 min to 20.63 min. There was no significant difference in the field capacity. The postural parameter like average twisting velocity, maximum sagittal flexion and maximum lateral velocity were lowest in modified tool with (S1-W3), (S2-W2) and (S1-W2). The modified tool also minimized shoulder, elbow and wrist deviation. The body part discomfort score and overall discomfort of workers also reduced to 18.38 and 1.47 for (S2-W2) compared to the existing wheal hoe (body part discomfort and overall discomfort score i.e., 31.01 and 2.51) making it ergonomically suitable for women farm workers.
4.6.5 Development of Interventions for Manual Load Carrying on Indian Farms

An assessment of load carried, mode, quantum and related detrimental health effect was undertaken in crop production and animal husbandry related activities in villages of Haryana, Odisha and UP. A questionnaire was prepared which included the personal details of worker, anthropometric dimensions, occupations, load carried, and mode of load carrying, working experience, work schedule, health problems, body part discomfort, and medical assistance taken. Musculoskeletal problems were assessed by using Nordic Questionnaire. The characteristics of load carried include; volume, quantum and type of commodities. The observations from surveys in manual load carrying are: in northern part of India load is mostly carried on head; volume, quantum and distance determine the mode of load carrying; voluminous load like fodder, harvested crop, etc. were carried on head; Heavy load like grain /vegetables in gunny bags are carried on back using Indigenous Harness to minimize slippage of load; in undulating terrains in eastern India, loads are carried on shoulders with bamboo harness; health problem of neck and back spine were prevalent in workers; agricultural activities being seasonal, load carrying pattern is not similar throughout year, therefore, the detrimental effect may be visible after a long duration. To minimize the adverse impact of carrying load on head, ergonomic interventions are being developed to reduce stresses on cervical spine without introducing element of eccentricity during load carrying on human body.

4.6.6 Design and Development of Four-wheel Weeder for Wide Row Crops

Vegetable crops are planted at row spacing of 30 to 50 cm for which no manual weeders are available. Keeping in view of above, an idea of four-wheel and swinging handle was conceptualized for development of a wide-row weeder on flat bed. Using ergo-mechanical considerations, a final prototype of Four-wheel weeder was designed, developed and fabricated. From lab study conducted in soil bin at two bulk densities (1.26 and 1.334 g/cc), it clearly indicates the force requirement increases with increase in bulk density at all the studied handle angles (34-43°) for 15 mm depth of cut. The force requirement to operate this weeder was 6.34N per cm width of cut compared to 10-15N per cm with available weeders having 15-20 cm size of blade.

Brief technical specifications and the performance of the final prototype of four-wheel weeder

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall dimensions, (l x w x h) mm</td>
<td>1480 x 270 x 300</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>9</td>
</tr>
<tr>
<td>Ground clearance, mm</td>
<td>125</td>
</tr>
<tr>
<td>Handle dimension (l x w), mm</td>
<td>1220 x 135</td>
</tr>
<tr>
<td>Size of T-type grip of handle, (dia x l), mm</td>
<td>25 x 500</td>
</tr>
<tr>
<td>Number of shanks</td>
<td>2</td>
</tr>
<tr>
<td>Rake angle</td>
<td>15°</td>
</tr>
<tr>
<td>Shoe clearance from ground, mm</td>
<td>10</td>
</tr>
<tr>
<td>Mounting of shank to shoe for weeding blades</td>
<td>Parallel to line of action</td>
</tr>
<tr>
<td>Number of weeding blades</td>
<td>2</td>
</tr>
</tbody>
</table>
4.6.7 Solar Powered Refrigeration System

A solar panel of 400W (100W each solar module, open circuit voltage 17V) was used to generate the power for operation of refrigerator system. The DC power of the solar panel was converted into single phase AC power with the help of a 1400VA inverter. A battery (24V, 150Ah) was used to provide back up to the system in the absence of solar energy. With the above system a refrigerator system of capacity 292 L was operated successfully for 15 days. The system is further used for development of storage system for fresh fruits & vegetables.

4.6.8 Development of IARI Pigeonpea Mini Dal Mill

Pulses are generally consumed in the form of dal i.e., dehusked split cotyledons. More than 75% of the pulse processing is done by large capacity commercial dal mills. The value addition to pulses at farm level will add to rural employment and income. With this objective, a new mini dal mill has been developed at IARI, which is useful for making dal of almost all pulses. It is powered by 2hp electric motor and is suitable for the small entrepreneurs. Its components includes emery roller with sieve for pitting and dehusking, emery roller with rubber-concave system for dehusking and splitting and grader for finished products. The dehusking and splitting operations are performed simultaneously by aligning the two operational units in vertical positions. Pulse grains are passed through emery roller with sieve for pitting and dehusking, after that subsequently it passes through rubber-concave system for splitting and residual minor dehusking. This system gently splits and dehusks the pitted grains. This type of splitting and dehusking mechanism results into reduction in powdering loss and higher dal recovery. Hence, making the dal in single pass is possible. The emery rollers dimensions are 10” long and 6” diameter. The preliminary testing of this developed mill gave satisfactory performance and better dal recovery (>75%). The capacity during trial was approx. 50 kg per hour for pigeonpea dal.

4.6.9 Farm Operation Services

The Farm Operation Service Unit (FOSU) managed all field operations including field preparations to crop sowing, harvesting and threshing in 750 acres of IARI farm using indigenous and imported machines. Timely tillage, field preparations, Laser levelling, sowing, inter-culture and harvesting of the experimental fields were accomplished in time during Rabi and Kharif seasons. FOSU has provided Irrigation water to 750 acres of IARI fields by the 18 tube wells linked by two big water reservoirs of 45 lakh litres capacities each. Rain gun irrigation system is running in 20 acre area of IARI farm for efficient distribution of irrigation and to save irrigation water. Providing water tanker facility to staff for social welfare activities. FOSU has collected biomass using Biomass Grabber during Kharif and Rabi seasons to
the tune of about 1400-1500 numbers of trollies from various fields of IARI farm. This biomass/crop residue was transported to the site of “Biomass Utilization Unit”, for preparing of FYM. This FYM (Farm Yard Manure) was also distributed to all the users at IARI experimental farms by FOSU. Weed control work was carried out at non–cropped area of IARI farm i.e., farm road sides, bunds, channels, Nala sides and security road by manual, chemical and mechanical weed control by FOSU. In addition to above work, FOSU has distributed and managed all the DPL’s and contractual labours to different divisions and projects of IARI.

4.7 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.7.1 Ripening and Quality Response of Selected Mango Cultivars to Ethylene

Mango fruits were exposed to various ethylene doses (80 and 100 ppm) for 16 and 24 h at 25°C temperature and 95% RH. Treated fruits were stored at 14°C temperature for 12 days. While comparing the results obtained after 48 h of storage, it could be inferred that Dashehari was more prone to ethylene exposure followed by Chausa and Langra. For Dashehari ripening, 80 ppm C₂H₄ exposure for 16 h proved ideal under ethylene based ripening chamber.

4.7.2 Effect of Kaolin-based Films in Apple

The kaolin-based particle film, Surround, imported from France was applied on Royal Delicious apples. Three sprays of Surround (3%) were given on fortnightly interval, starting from 15th June. It was observed that Surround-treated apples developed very good red colour (Hunter ‘a’ value = 52.4) than untreated fruits. The Surround-treated fruits matured about 5-day later, but have better fruit firmness (28.8 N) and TSS (14.6%) than untreated fruits. Interestingly, the incidence of Sanjose scale (2.8%) and apple scab (2.2%) was drastically reduced by Surround sprays but that of woolly apple aphid (8.6%) was increased over untreated fruits (7.8%).

4.7.3 Increasing the Shelf Stability of Minimally Processed Vegetables

Owing to the high browning and respiration rate, shelf life of minimally processed vegetables such as lotus stem and baby corn is very limited. Hence attempts were made to develop the minimally processed products
with retarded browning and increased shelf stability. Different antibrowning agents were applied to retard the browning reactions in both the vegetables. Citric acid @1.5% was found to be the most promising to prevent browning in lotus stem when stored at 10°C and shelf life could be extended by up to three days without any discolouration. In case of minimally processed baby corn, 1% ascorbic acid and 1.5% citric acid were found to be best to maintain the textural integrity and overall quality when stored for 5 days at low temperature.

4.7.4 Storage Stability of Passion Fruit Powder

Passion fruit powder developed by freeze drying was packed in three packaging material of 200g HDPE, 260g ALPE and 200g LDPE and stored at ambient and low temperature for its storage study. The total phenolics and ascorbic acid decreased with increase in storage period, and the loss of total phenolics and ascorbic acid were slightly higher at ambient condition (38-43%) as compared to low temperature (14-20%), respectively, during 4 months of storage period when the samples were packed in 260g ALPE pouches as compared to others. However, after 4 months, of storage the samples stored at both ambient and low temperatures were found free from any microbial load.

4.7.5 Processing of Pineapple for Development of Fermented Beverage

Fermentability of three yeast strains viz, *Saccharomyces cerevisiae* var. *ellipsoideus* ITCC 1030, *S. cerevisiae* var. *ellipsoideus* UCD 595 and *S. cerevisiae* Y 11857 was evaluated for development of pineapple wine. Strain *S. cerevisiae* var. *ellipsoideus* UCD 595 at inoculum level of 10% (v/v), performed the best with regard to maximum utilization of reducing sugars (97%) and an alcoholic content of 8.65% in the final product. Pineapple vermouth developed from pineapple base wine, with two levels of alcohol (15 and 17%), sugar (8 and 10%) and spice extract (2.5 and 5%), evaluated for physico-chemical changes revealed significant increase in esters and total phenolics. On the basis of sensory quality characteristics, vermouth with 17% alcohol, 8% sugar and 2.5% spice extract levels was adjudged the most acceptable product.

4.7.6 Development of Fermented Drink from Apple

Apples hard cider was made from apples having 9 % TSS. The TSS of apple must be chaptalized to 15 % TSS with pure honey (62% TSS) and then fermented with active yeast (*Saccharomyces cerevisiae*) for 72 h in 500 mL batch volume. The final alcoholic product so obtained was sweet and contained 3.72 % Alc (by vol) and ~11.2 g/L alcohol. The cider had a pale brownish color with an appealing taste.

4.7.7 Development of Multigrain Bread Having Low GI Using Sourdough Technology

Multigrain bread was developed using flour mixtures of whole wheat, sorghum, barley and finger millet. Fermentation of flour mixture was carried out with native flora as well as with pure cultures for sour dough development. Sourdough mix when propagated with native microflora and fermented till a 7 day period showed maximum total reducing sugars at 0 day (53 mg%) that reduced with fermentation to 18.22 mg % on 7th day whereas the corresponding values for sourdough with pure inocula were 32.55 and 11.66 mg%, respectively. The hydrolysis index for the native and pure culture inoculated fermentation doughs were 31.12 and 27.86, respectively, at the end of 7th day fermentation period. The sourdough fermented from a pure culture as inoculum was a better potential starter.
for producing low glycemic bread within 3 days of fermentation as compared to 5 days of fermentation with native microflora.

4.7.8 Development of Chickpea Flakes

Pusa green flakes were prepared from the chickpea variety Pusa Green 112. It is a ready-to-eat crunchy product and can be used as snacks. Natural green colour of the variety has been retained in the flakes. The product has low glycemic index, hence suited for diabetic people. Organoleptic trials have shown good product acceptability.

4.7.9 Development of Soy based Vita

Soy based vita was developed in powdered as well as granular form. It can be consumed just by mixing in milk. The product can easily be customized to suit the taste of different age-group people. It is rich in protein, fat, micronutrients, antioxidants and flavonoids. TIA has been reduced by more than 90% in the product.

4.7.10 Development of Pearl millet Cookies through Replacement of Refined Sugar with Jaggery

Composite flour cookies using whole wheat flour and pearl millet flour (unhulled) were formulated with partial replacement of refined sugar using powdered jaggery (shakkar). Replacement of refined sugar up to 40% was found acceptable based on sensory score using 25 semi trained panellists. The optimized cookies had 4.15% protein; 4.9% crude fibre and antioxidant capacity of 2.22 µmol TE per gram. Interestingly, hardness of cookies as measured using snap test decreased with increasing levels of jaggery. Browning index of the 40% jaggery, composite cookies
was not too different from whole wheat cookies made with refined sugar.

4.7.11 Microencapsulation of Flaxseed (*Linum usitatissimum* L.) Oil

Flaxseed oil was encapsulated using a combination of protein (whey and soy) and polysaccharide (tapioca and jackfruit) matrix using drying. A maximum oil loading of 24% was obtained using a protein: polysaccharide ratio of 1:3 spray dried at 174°C inlet temperature. The best combination of protein and polysaccharide was found to be whey protein isolate and jackfruit seed polysaccharide in terms of the encapsulation efficiency and residual peroxide value of the encapsulated oil.

4.8 MICROBIOLOGY

4.8.1 Restoration and Improvement of Soil Health

4.8.1.1 BGA based composite liquid inoculant for sustaining crop productivity and soil health improvement

Oil based liquid formulations were prepared using different combinations of carriers (Mahua oil, Diesel oil, Paraffin oil), Emulsifiers (Teepol, Tween 80, Triton X-100) and binders (Starch, Gum Arabic and CMC). Out of 54 formulations, 23 were found stable and characterized for pH, breaking length and viscosity. The pH of different formulations ranged between 4.68 to 5.94. The breaking length was between 1.5 to 11 cm and the viscosity at different temperatures ranged between 0.062 to 0.528. These formulations have further been used to prepare liquid formulations of BGA biofertilizer. It was observed that eight preparations were able to maintain stable active population of inoculated cultures to the tune of 10⁴ cells/mL after 60 days of incubation at 4°C, 28°C and 40°C.

4.8.1.2 Encapsulated microbial inoculants for phosphorus nutrition and crop productivity

Seven fungi and two bacterial strains were evaluated for their dual potential to mineralize organic phosphorus and solubilise inorganic phosphates. Fungi of genus *Aspergillus*, *Trichoderma* and *Penicillium* were recorded to be more efficient in releasing inorganic P (Pi) from sodium phytate (5-21 EU Pi) and tested inorganic P sources such as tricalcium phosphate (TCP), iron and aluminium phosphate (FP and AP) compared with bacteria of genus *Pseudomonas* and *Bacillus*. However, the ability of microbial strains to release P varied with inorganic phosphate sources under study. Depending upon the growth characteristics of fungal strains, the extent of solubilization varied with incubation period also. *Aspergillus niger* was superior to other fungal isolates in terms of its ability to mineralize organic P and solubilise 18, 65 and 20 % of P from AP, TCP and URP, respectively. However, *T. harzianum*, a potential phytate mineralizer was most competent to solubilise FP to the extent of 14 %.

4.8.1.3 Effect of bio-control agents and their impact on rhizospheric microbial communities under soybean-wheat cropping system

Microbial community structure was studied as influenced by inoculation of BCA (biocontrol agent). Isolations carried out from soybean rhizosphere, inoculated with *Paenibacillus polymyxa* HKA 15 (a BCA) were screened against soil borne pathogens for antibiosis. A high degree of antibiosis was found in the isolates studied.
4.8.2 Integrated Crop and Resource Management for Enhanced Productivity and Profitability

4.8.2.1 Enhancing cropping system productivity and profitability under irrigated conditions

To enhance microbe mediated nutrient cycling under non-flooded (aerobic) and flooded (anaerobic) conditions for improved productivity in rice-wheat cropping sequence. A pot experiment was conducted to evaluate the effect of flooding on nutrient cycling, and subsequently the bioavailability of nutrients for plant uptake. The microbial biomass C content in the rice rhizosphere was more under aerobic (35.8 µg g\(^{-1}\)) than under anaerobic condition (27.8 µg g\(^{-1}\)) in the Temperature Gradient Tunnel (TGT) but without any significant variation in the Free Air Temperature Increment (FATI) system. The anaerobic microbial activities such as arginine ammonification (5.1 mg kg\(^{-1}\) h\(^{-1}\)), dissimilatory nitrate reduction to ammonium (DNRA) (0.32 mg kg\(^{-1}\) d\(^{-1}\)) and iron reduction (22.59 mg kg\(^{-1}\)) activities were more under the anaerobic conditions suggesting the interactive effect of flooding and temperature in the TGT. Both urease and aryl sulphatase activities were more under aerobic condition in the FATI System. The potential nitrification activity was more under the DSR method of planting compared to conventional method. Alkaline phosphatase and aryl sulphatase activities were more influenced by the DSR method. Real-time quantification of copy numbers of 16S rRNA sequences showed that eubacteria and archaea were ~ 10\(^4\) and 10\(^2\) per gram, respectively, in these soils.

A significant influence of cyanobacterial inoculation on the diversity and abundance of members belonging to the soil microbiome was observed. Cultivation independent approach by extracting the phospholipid fatty acids (PLFAs) of rhizosphere and bulk soil gave more than 30 distinct types of PLFA(s) and other mixed functional groups. Principal component analysis (PCA) revealed that inoculation with cyanobacterium brought about distinct spatial and temporal changes in the concentrations of individual PLFA(s) and in the biomarkers representing different microbial guilds.

Eight chickpea genotypes (BGD 72, PUSA 372, GNG 1581, PUSA 547, BG 112, PUSA 362, PUSA 1103 and BG 256) were grown in soils collected from rice and maize field during Rabi 2014-15 under phytotron conditions. Nodulation potential of the genotypes was high in soils collected from maize field compared to that of rice field. In order to enhance the overall nodulation and plant growth, plant associated endophytic bacteria were isolated from shoots and root tissues of these genotypes using different media.

4.8.2.2 Enhancing cropping system productivity and profitability under rainfed conditions

Microbes mediated water stress alleviation in crops. Endophytic bacteria were isolated from tissues of pearl millet and mustard grown under rainfed conditions using different bacteriological media. Eighty isolates were found tolerant to 30% PEG 6000. A pot experiment conducted under water stress conditions revealed positive effect of inoculation with osmotolerant bacteria on shoot and root fresh weight, shoot and root dry weight and water use efficiency of mustard. Isolates NA D7, MR D8 and MR D17 were observed to be promising cultures for water stress alleviation in mustard. A bacterial isolate from *Cyamopsis tetragonoloba* was able to withstand high moisture stress (~70% PEG) and exhibited temperature tolerance (60°C). However, it was negative for P solubilization, siderophore production.
In another study microbial isolates (bacteria and fungi) isolated from various tissues of mustard and maize are being tested for various plant growth parameters and moisture and temperature stress tolerance. The functionally annotated bacterial endophytes from mustard on the basis of qualitative functions are 22 isolates as P solublizers, 17 as K solublizers, 39 as Zn solublizers and 14 as moisture stress tolerant. Similarly, bacterial endophytes of composite varieties of maize demonstrated plant growth attributes as 18 isolates as P-solublizer, 15 as Zn solublizers but in hybrid varieties only 2 isolates could solublize Zn.

4.8.3 Agri-residue and Biomass Management

4.8.3.1 Design and development of technologies for utilization of biomass as feed and other value added products

A comparative study was conducted to examine the biomass production and compositional analysis of two different species of *Azolla* viz. *A. microphylla* and *A. caroliniana* in order to better utilize the biomass as an efficient feed supplement. The compositional analysis of *A. microphylla* biomass revealed 3.63% crude fat, 17.2% crude fibre and 10% moisture content in the biomass as compared to 3.17% crude fat, 12.4% crude fibre and 8.3% moisture content in *A. caroliniana*. However, the cellulose and lignin content was 11.3 and 21.5%, respectively, in *A. microphylla* as compared to 13.4 and 24.1% in *A. caroliniana*. The crude protein and sugar content in case of *A. microphylla* was in the range of 24.4 and 1.39%, respectively, as compared to a value of 18.1% and 0.14% in case of *A. caroliniana*. While the carotenoid content was almost identical in both the species of *Azolla* the total carotenenes and xanthophyll content was found to be significantly high in *A. caroliniana*. Analysis of the vitamin content showed high levels of vitamin C, B2, B3, and B9 content in *A. microphylla*. However, the levels of vitamin B1 and B12 were found to be high in case of *A. caroliniana*. The amino acid profiling also showed a distinctly different composition in both the species of *Azolla*. The results of the present study show that *A. microphylla* is a suitable candidate in terms of biomass production and proximate composition and could be selected for further exploitation as feed supplement.

4.8.3.2 Developing efficient low cost technologies for utilization of biomass as fuel

Holocellulotic enzymes have potential applications in saccharification of lignocellulosic biomass. Secretome of *Streptomyces* sp. ssr198 gave a wide range of hydrolytic enzymes, It constituted of 12.5% cellulases, 17.5% hemicellulases, 21.25% proteases, 17.5% hypothetical proteins, and 31.25% other proteins. Multiple endoglucanase and xylanases with diverse molecular weights were detected in the zymogram. Among the bacterial isolates screened for β-glucosidase production, *Pseudomonas lutea* BG8 was found most promising.

The effect of β-glucosidase supplementation on enhancement of cellulase activity and increase in sugar yields was evaluated by using combinations of commercial cellulases and β-glucosidase. About 15% increase in saccharification efficiency was observed on addition of Novozyme 188 to Celluclast®1.5L. Maximum reducing sugar yield was obtained at 20% substrate loading but saccharification efficiency
was found to be highest at 10% substrate loading (88.07%) as compared to 15% substrate loading (68.69%) and 20% substrate loading (59.26%).

4.8.3.3 Design and development of mechanical and biological techniques for *in-situ/ex-situ* biomass degradation

Low temperature tolerant microorganisms were isolated by using enrichment technique at 10°C for utilizing starch, tannic acid, lipids, pectins, and xylan, respectively. On the basis of zone of hydrolysis four bacteria (STB1, STB2, PEB3 and TRB2) and one fungus (PEF2) were found amylolytic. Three bacterial strains (TRB2, TAB2 and STB2) and one fungus TAF3 were highly pectinolytic. The bacterial strains PEB1, STF4, TAB2 and fungal strain TRB1 were xylanolytic while TRB1, TAB2, STB1, PEB3 bacterial strains and TAF3 fungus were tannase producing at 10°C, respectively. Besides this, four bacterial strains TRB3, TAB2, STB2, PEB3 and fungus TAF3, TAF2 were cellulolytic at 10°C. Among all the isolates, the amylolytic strain PEF2 showed 1.5 cm, STB2 1.0 cm; lipolytic strain STB2 (1cm), STB1 (1.5cm); lignolytic strain TAB2 (0.8cm) and cellulolytic strain TAF3 (0.5cm), TAF2 (0.6cm) zone of hydrolysis at 10°C in 24 hours. All the selected isolates are further being screened for their hydrolytic potential and enzyme stability at 10°C and 50°C, respectively.

*In situ* degradation of wheat biomass was undertaken using a consortium of fungi (*Aspergillus nidulans*, *Trichoderma viride*, *Phanerochaete chrysosporium* and *Aspergillus awamori*) and bacteria (*Azotobacter chroococcum*). The consortium was mixed with compost and spread in the field at 1 t ha⁻¹. Untreated field was maintained as control. A set up was arranged in the field for *in situ* measurement of CO₂ evolved and the measurements were done at interval of 3 days. In both treated and control plots, *Sesbania* seeds were sown to look for the influence of degradation of biomass on *Sesbania* crop. The time required for *in situ* degradation was 33-36 days as indicated by the amount of CO₂ evolved.

4.9 ENVIRONMENTAL SCIENCE AND CLIMATE RESILIENT AGRICULTURE

4.9.1 Net Impacts of N Fertilizer on Global Warming

Nitrogen fertilizer plays a crucial role in food security and also for climate change. Nitrogen has direct and indirect and also short- as well as long-term effects on global warming. The warming effects...
of N include N₂O emission which is a greenhouse gas with long atmospheric lifetime; NOₓ emission, which contributes to formation of tropospheric O₃, a short-lived greenhouse gas and detrimental effects of ozone on plant C sequestration. The cooling effects include C sequestration due to application of N, which increases CO₂ fixation by plant and in soil; losses of N to water bodies, where freshwater and marine eutrophication can increase CO₂ removal from the atmosphere; increasing oxidation potential of the atmosphere by O₃ which decreases the atmospheric lifetime of CH₄ and increases rates of aerosol formation; and NO and NH₃ emissions, which contribute to formation of ammonium and nitrate aerosols. In addition, tropospheric O₃ and NH₃ both accelerate the oxidation of sulphur dioxide to sulphate aerosols. The N supply also affects CH₄ production and consumption in soil and albedo of the land surface by affecting vegetative cover and increasing chlorophyll content of vegetation. The quantitative importance of these effects is, however, uncertain. The magnitude of these factors on global warming potential for Indian agriculture was quantified. The preliminary analysis showed that considering only the increased emission of N₂O due to N fertilizer application, global temperature potential of N fertilizer application from Indian agriculture is about 39 Mt CO₂ eq. However, when all the direct and indirect effects as well as short- and long-term effects of N fertilizer application in Indian agriculture were considered, the net global warming potential was reduced to 35 Mt CO₂ eq. The study suggested that there is a need for comprehensive assessment of various impacts of N fertilizer on global warming.

4.9.2 Greenhouse Gas Emission during Life Cycle of Potato

Greenhouse gas emissions in crop production, processing and distribution arise from a variety of processes and sources. Potato, one of the most important tuber crops worldwide, is consumed as fresh vegetable, as raw material for processing into food products. Vegetable fields are characterized by intensive production and high N application rates contributing to N₂O emissions. Environmental impact of potato cultivation, processing and transportation for distribution to super markets in terms of greenhouse gas emissions was evaluated using Life Cycle Assessment (LCA) methodology. Average seasonal emission of N₂O ranged from 0.36 kg ha⁻¹ to 2.11 kg ha⁻¹ and CO₂ varied from 1461 to 3220 kg CO₂ ha⁻¹. Substitution of 25% of inorganic fertilizer with FYM increased N₂O emission by 8.5%, and CO₂ emission by 29% as compared to urea alone. Application of N using neem oil coated urea (NOCU) decreased N₂O emission by 15 - 22.6% and CO₂ emission by 7-13%. Application of N through NOCU in three splits increased the yield by 10.4 - 15.3% as compared to urea N application in two split. Production of 1t of potato chips emitted 1.85t CO₂ eq. t⁻¹. Processing contributes 73% to the total GHG emissions followed by cultivation (24%) and transportation (3%) for production of 1t of potato chips. Soil emissions and farm operation together contributed 55% out of the total GHG emission from potato cultivation. The study revealed that application of N through NOCU in three splits has the potential to reduce the soil emissions from potato cultivation.
4.9.3 Impact of Elevated Carbon Dioxide (CO₂) and Temperature on Greenhouse Gas Emission and Soil Nitrogen and Carbon Content in Rice

Field experiments were conducted growing rice in open top chambers for assessing how soil N₂O and CH₄ fluxes responded to elevated air temperature (+1.5°C) and increased atmospheric carbon dioxide emissions (550ppm) under different fertilizer treatments. Elevated levels of CO₂ increased the methane and nitrous oxide emissions, however, the difference were not significant for nitrous oxide. Elevated temperature significantly increased emission of both the greenhouse gases. No significant interactive effects of increased levels of carbon dioxide and temperature were observed on nitrous oxide emission, however, the increase in methane emission was significant. The presence of elevated CO₂ and temperature increased the global warming potential (GWP) of rice paddy soils by 31 % as compared to ambient levels. Thus, combined levels of increased air temperature and enhanced carbon dioxide will have a positive feedback on global warming due significant increase in methane emissions.

There was no significant change in soil organic carbon. The total N content of soil decreased in no nitrogen control irrespective of the CO₂ and temperature treatments. Under ambient condition total N content of soil increased in urea, nitrification inhibitor coated urea (NICU) and neem oil coated

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<th>Effect of elevated CO₂ and temperature on global warming potential (GWP) in rice under urea treatment</th>
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<td><strong>Treatment</strong></td>
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Total N and available N content of soil under different fertilizer treatments and varying CO₂ and temperature levels
urea (NOCU). Total N content of soil decreased in urea, NICU and NOCU treatment under elevated CO$_2$ and temperature interaction treatment. Higher crop growth and yield under elevated CO$_2$ treatment resulted in higher N uptake in rice crop resulting in lower soil N content. High temperature treatment also reduced soil N content by increasing the N losses from soil. Increase in both temperature and CO$_2$ also resulted in increased crop growth and N uptake and lesser N content of soil. Available N content of soil decreased in all the treatments after harvesting of crop. No significant trend was observed in soil available N with fertilizer treatments under different CO$_2$ and temperature levels.

4.9.4 Effect of Elevated Temperature and CO$_2$ on Grain Yield of Wheat Cultivars

Six wheat cultivars, namely, HD 2285, HD 2932, HD 2967 and WR 544, Kundan and PBW 550 were subjected to elevated temperature (2 & 3 °C above ambient) and CO$_2$ level (550 ppm) in different tunnels to assess the response of wheat varieties to elevated temperature with and without elevated CO$_2$ concentration. The results show that increasing the temperature by 2 and 3 degree Celsius reduced the average grain yield of wheat cultivars to the extent of 7% and 13%, respectively, while enhanced level of CO$_2$ (550 ppm) helped in countering the negative effect of elevated temperature and finally enhanced the grain yield of wheat markedly under elevated temperature of 2°C. This indicate that in future climatic scenario the rise in atmospheric CO$_2$ level might be help in countering the negative effect of rise in atmospheric temperature on crop yield.

4.9.5 Impact of Initial and Terminal Heat Stress on Wheat Yield and Its Adaptation Options

Heat stress, especially at the terminal stage, is a major reason of restricting wheat yield in India. The proximity to the equator and late sowing of wheat in India, expose the crop to high temperature during grain filling stage (February-March), which is one of the major environmental constraints that limit productivity of wheat. Use of stress-tolerant varieties, changing planting dates and improved irrigation and nutrient management practices are possible adaptation strategies for alleviating terminal heat impact on wheat. Six wheat cultivars of short (WR 544, HD 2285, K 7903 and K 9423), medium (HD 2932) and long (HD 2967) growth duration were grown from 15th October to 15th January at 15 days interval to expose the crop to high thermal stress during initial vegetative growth stage by early sowing in October as well as terminal heat stress during grain filling stage by delayed sowing in January to assess the growth and yield response of wheat cultivars of varying growth duration to initial as well as terminal heat stress. All the wheat cultivars irrespective of their growth duration registered poor yield when subjected to initial and terminal heat stress. Among the cultivars, the medium and long duration wheat cultivars (HD 2932 and HD 2967) invariably recorded higher yield both under normal as well as early and late sown conditions, whereas among the short duration cultivars, HD 2285 and WR 544 performed well under extreme late sown condition. The medium and long duration cultivars recorded significantly higher yield as compared to short duration cultivars when subjected to heat stress during initial vegetative growth stage (tillering). Reduction in yield by initial heat stress was mainly attributed to marked reduction in spikes/m$^2$, while terminal heat stress caused drastic reduction in yield mainly by reducing the growth duration, grains/spike and 1000-grain weight. Both
initial and terminal heat stress hastened flowering in all the cultivars, while, total days to maturity reduced gradually with delayed sowing. It is concluded that short duration cultivars may be suitable only for late sowing, while long duration cultivars may perform better both under early and late sown conditions especially under mild terminal heat stress condition.

Field experiments were also conducted since 2010 to evaluate the impacts of various adaptation strategies on alleviating terminal heat stress. During all these years, the varieties and irrigation practices performed at par. However, planting dates affected yield of wheat. Coincidently, there was very limited terminal heat stress in north-west India during the last 5 years. Therefore, the full efficacy of the adaptation strategies on alleviating terminal heat stress could not be judged explicitly.

4.9.7 Effect of Irrigation and Nitrification Inhibitors on Ammonia Volatilisation from Rice Soils

Ammonia volatilization from fertilised soil is one of the major N loss mechanisms that cause environmental pollution. Mitigation strategies are needed to reduce the N loss and increase the N use efficiency. Field experiment was conducted to study the influence of urea, nitrification inhibitor (neem oil coated urea; NOCU, nitrification inhibitor coated urea; NICU), and irrigation (intermittent flooding; IF and continuous flooding; CF) on NH₃ volatilization from rice soils. The total amount of NH₃ volatilization in rice soils ranged from 7.8 kg N ha⁻¹ to 24.49 kg N ha⁻¹ among different treatments. Per cent loss of applied N as ammonia was highest in NICU with IF (13.9%). A significant positive correlation was observed between NH₄⁺ concentration in soil (+0.62), air temperature (+0.24) and NH₃ volatilization.

4.9.8 Emission of organic air toxins from crop residue burning in Indo Gangetic Plains

The use of combines leaves a large amount of crop residue in the fields which is disposed of by on-farm burning especially in the states of North West India. The amount of rice, wheat and sugarcane residues burned in fields of Punjab, Haryana and Uttar Pradesh was approximately 50.6 Mt per annum. Burning of these residues in field resulted in emission of 45.8 Tg of VOCs. Total VOC emission is higher in Uttar Pradesh followed by Punjab and Haryana. Rice crop (48%) and wheat crop (33%) residues are the major contributor in VOC emission followed by sugarcane (19%). Rice and wheat together accounted for 80% of total VOC emission. Acetol and acetaldehyde are major VOC emitted during burning of crop residues.
4.9.9 Suspended Particulate Matter (SPM) Load in IARI and Its Impact on Wheat

To assess the impact of SPM pollution load on wheat crop, a field experiment was carried out at IARI with 21 wheat varieties. A large variation was observed in the deposition rate of SPM on the canopy of different wheat cultivars. A positive correlation was observed between SPM deposition rate and leaf area (\( R^2 = 0.52 \)). PM 5.0 mass concentration was maximum on December 19, 2014 and minimum on January 29, 2015. Wind trajectory analysis reveals that wind was predominant from N-W side during this period. Analysis of dominant particulate matter in air parcel revealed the presence of carbonaceous particles, mineral dust, clay particles and trace amount of heavy metals such as Hg, Pb and Ti in SPM.
4.9.10 Effect of Low Radiation Stress on the Productivity of Wheat Cultivars

Five promising wheat cultivars subjected to low radiation stress (40%) during germination to flowering, flowering to maturity and germination to maturity showed differential yield response to low radiation during various growth phases. Low radiation stress imposed during pre-flowering stage (germination to flowering) caused greater reduction in yield (10%) compared to low light stress imposed during post-flowering phase (flowering to maturity) (4%), whereas low light stress imposed throughout the entire growth duration (germination to maturity) resulted in highest extent of reduction in grain yield (18%). Among the cultivars HD 2967 and HD 2932 registered invariably higher yield as compared to other cultivars both under normal and low radiation stress imposed during different growth phases. Pre-flowering growth phase showed greater sensitivity to low radiation stress as compared to post-flowering growth phase in all the tested wheat cultivars.

4.9.11 Assessment of Air Pollution on Wheat Growth and Productivity

Effect of short term exposure of sulphur dioxide ($\text{SO}_2$; concentration 1.15 to 584 $\mu$g m$^{-3}$) on seeds and 20 day old potted seedlings of bread (HD 2967) and durum (HI 8713) wheat, on germination and plant growth attributes, was measured. The seed germination was marginally affected even at the lowest concentration of $\text{SO}_2$. Durum wheat was more sensitive to the $\text{SO}_2$ stress than the bread wheat. GI$_{50}$ in both wheat types ranged between 18.5 to 37.0 $\mu$g m$^{-3}$ $\text{SO}_2$ and GI$_{100}$ between 148 to 296 $\mu$g m$^{-3}$ $\text{SO}_2$. A significant increase in shoot and root mass was measured in both wheat types at 1.15 $\mu$g m$^{-3}$ $\text{SO}_2$ when compared with the unexposed control. Negligible plant growth was measured above 74 $\mu$g m$^{-3}$ $\text{SO}_2$ concentration. Seedling vigour index I and vigour index II were negatively affected only at moderate to high level of $\text{SO}_2$ exposure of seeds. Effect of short term $\text{SO}_2$ stress (37 to 584 $\mu$g m$^{-3}$ $\text{SO}_2$) during crop growth in 20 days old potted plants of bread and durum wheat resulted in intermittent leaf chlorosis to complete loss of chlorophyll as early as 24 hours of $\text{SO}_2$ exposure. Loss of shoot vigor at 24h of stress was least at 37 $\mu$g m$^{-3}$ $\text{SO}_2$ but exceeded beyond 50% at $\text{SO}_2$ levels above 74 $\mu$g m$^{-3}$ $\text{SO}_2$.

4.9.12 Upgradation of InfoCrop Model

InfoCrop V2.1, a decision support system (DSS) for agricultural management in tropical regions is released for wider use by the researchers, agricultural development personnel and students. The DSS have the database with district-wise soil data, location-wise weather data and varietal coefficients for wheat, rice, maize, sorghum, millets, mustard, ground nut, soybean, cotton, potato, pigeon pea and chickpea crops. InfoCrop V2.1 is compatible with the operating system versions of Windows 7 onwards (32 or 64 bit).

4.9.13 Development of DSS for Grape

Grape vine requires intensive management and is highly sensitive to weather and water regimes while at the same time responsive to management. Grape growers are entrepreneurs and demand timely information on various aspects of management to maximize the yield and profits. A well informed grape grower can take timely appropriate steps. Based on the stakeholder requirement a dynamic simulation model for growth, development and yield of grape vines is being developed. The model uses weather, soil and management characteristics to simulate the
grape growth, development and yield. The model performance has been tested using the observed phenological data from the experimental plots at NRC on Grapes, Pune. Further validation of the model will be done using the phenology data from farmers fields.

4.9.14 Methane Enrichment of Biogas Using Microalgae

Biogas consists of 55-60% methane, 30–35% CO₂ and traces of H₂, N₂ and H₂S. The calorific value of biogas can be enhanced by removing CO₂ from the biogas either by quenching it in a chemical medium or by sequestration in algal biomass. Lab experiment was conducted to evaluate the CO₂ sequestering ability of Chlorella sp. from biogas. A special glass assembly consisting of rectangular container (capacity 12L) with removable lid and biogas inlet and outlet ports in diagonally opposite direction was designed. An impressive gas motor was fixed inside the assembly. Chlorella culture (3 L) was added to 5 L of biogas in nitorgen medium (pH 7.2) and the assembly was made air tight. Florescent rods of two light intensities (650 and 1296 µmol m⁻² s⁻¹) were used as light source. It was observed that the chlorophyll content of the Chlorella sp. first increased with passage of biogas then decreased after 30 minutes at both the light intensity. The CO₂ content of biogas decreased by 22-25% with the growth of microalgae thereby increasing the methane content of biogas.

4.9.15 Effect of Biogas Slurry on Yield and Nutritional Quality of Baby Corn

A large amount of biogas slurry (BGS) is produced in India. Discharging the unprocessed BGS will lead to environmental pollution, while disposing as sewage will cost a great deal because of its large pollution load. Using BGS as a source of nutrient is a potential option for reducing chemical fertilizer use and control environmental pollution. The present investigation was carried out to assess the effectiveness of biogas slurry as a nitrogen source for the production of baby corn. Results showed that 50% BGS along with 50% chemical fertilizer gave 20% more yield in terms of cob as well as biomass yield. Thus, a farmer could save the 50% inorganic fertilizer and generate 20% additional revenue with application of biogas slurry. It has been found that combination of BGS and N fertilizer also increased protein, total sugar,
phosphorus and potassium contents of the baby corn cob and the nutritional value of the produce. The study standardized the optimum application rate of BGS and N fertilizer to achieve the highest economic benefit.

4.9.16 Assessment of Accumulation and Translocation of Heavy Metals in Non-basmati and Basmati Rice Crops from Heavy Metals Contaminated Soil

Pot study was carried to assess the accumulation and translocation of heavy metals (Cr, Ni, Cd, Hg and Pb) in non-basmati rice (Pusa 44) and basmati rice (PB 1509) varieties. Heavy metals were found to accumulate in different parts of rice plant including the grains. However, accumulation was more in non-basmati rice in comparison to basmati rice. The highest concentration of heavy metals in this study was in the roots rather than shoots and grains in both the varieties. The bioaccumulation factor was highest for Ni followed by Cd, Cr, Pb and Hg. Soil to grain transfer factor of Ni, Pb, Cd, Cr and Hg was 0.070, 0.028, 0.079, 0.0058 and 0.0049, respectively, for Pusa 44 and 0.065, 0.023, 0.072, 0.0050 and 0.0038, respectively, for Pusa 1509.
5. CROP PROTECTION

The world sustainable agriculture for the developing countries is to maintain food production or more realistically to maintain an increasing trend in food grain production while preserving the underline resource base. The continued growth of agriculture sector should not be at the cost of soil, plants and the environment. Predicted changes in rainfall and heat as a result of global climate change will be most severe in developing countries and also impact the demographics of agricultural pest populations. The School of crop protection develops an employs innovative control measures to counteract the impact of insects, plant diseases and weeds—collectively referred to as pest. Correct diagnosis is prerequisite to sustainable management. During the year under report efforts have been made to identify races, genetic diversity and new disease outbreaks. All integrated management strategies including host resistance, biological control and newly developed chemical molecules having no residual effects have been developed to enhance production and productivity and to bring about economic benefits.

5.1 PLANT PATHOLOGY

5.1.1 Pathogen Diversity, Race Profiling and New Diseases

_Bipolaris species._ Twenty four isolates of _Bipolaris_ species were grouped into five species, viz., _Bipolaris oryzae, Bipolaris maydis, Bipolaris spicifera, Bipolaris hawaiensis_ and _Bipolaris sorokiniana_ based on morphology. ITS region was found to be the best to discriminate the species. All the _Bipolaris_ species sequences were submitted in BOLD website under the project ITCCB and Barcodes were obtained.

_Phoma species._ Smaller Sub Unit (SSU) sequences of rDNA was found to be the reliable DNA barcode region for identification of _Phoma_ spp. DNA barcodes for different species of _Phoma_ viz., _P. eupyrena, P. exigua, P. multicrostata, P. sorghina_ and _P. tropica_ were developed and sequences deposited in GeneBank.

_Alternaria spp._ Morphological, cultural and pathogenic variability analyzed in 32 isolates of _A. brassicicola_ causing black leaf spot disease in Cauliflower, revealed 9 isolates to be highly pathogenic and isolates CaAbcP1 and CaAbcWB3 were closely associated showing similarity coefficient of 0.85 while the isolates CaAbcK1 and CaAbcH1 were most distantly related having similarity coefficient of 0.22.

**New report of Alternaria tenuissima.** _Alternaria tenuissima_ causing leaf and pod spot was observed on lentil ( _Lens culinaris_ ) plants at IARI, New Delhi. The spots on leaves and pods were brown and circular with concentric rings. Colony colour is dark brown to black. Conidia solitary or in short chains; straight or curved, obclavate, tapering to the beak, conidium 25-63µ × 11-14µ in size, with 4-7 transverse and many oblique septa. The pathogenicity of the fungus was confirmed.

![Spots on leaves and pods of lentil (Alternaria tenuissima) (a); Conidia of Alternaria tenuissima (b)](image-url)
**Puccinia graminis tritici in barberry.** Urediniospores from rust pustules collected from barberry leaves representing two different locations in Nilgiri revealed that spores from Doddpetta were smaller than that of sample from another location, Mynala in Nilgiri hills. Purified uredospores appeared to be stem rust pathogen, *Puccinia graminis tritici* through scanning electron microscope.

**Magnaporthe oryzae-rice.** Virulence analysis of 50 isolates of *Magnaporthe oryzae* revealed that four isolates (Mo-ni-0068-Panipat, Mo-si-mnd1-Mandya, Mo-et-ggt1-Gangtok and Mo-et-ctc4-Cuttack) when tested on 27 monogenic differentials, belonged to highly virulent race U77-i7-k177-z17-ta733 as these isolates were able to knock down all known blast resistance genes.

**Fusarium fujikuroi-rice.** Mating types were determined for 63 isolates of bakanae pathogen, *Gibberella fujikuroi* based on PCR markers. Dominance of mating type 2 (71.4%) over mating type 1 (28.6%) was observed among the collections.

**Fusarium oxysporum f. sp. ciceris-chickpea.** Sequence-related amplified polymorphism (SRAP-PCR) revealed rich diversity in *Fusarium oxysporum f. sp. Ciceris* populations representing diverse geographical region. SRAP markers displayed 100% polymorphism and grouped the isolates into 6 clusters. Furthermore intra racial diversity could also be found.

**Ralstonia solanacearum-potato.** Characterization of seventy isolates of *R. solanacearum* isolated from wilted potato representing the states of Uttarakhand (20), Meghalaya (21), West Bengal (6), Himachal Pradesh (3), Orissa (11) and Karnataka (9) indicated the prevalence of race 1/biovar 3 and race 3/biovar 2 in India. These isolates belonged to predominantly phylotype I (54.3%) followed by phylotype IV (34.3%) and phylotype II.

**Ralstonia solanacearum-tomato.** In order to establish the role of extra cellular polysaccharide in pathogenicity of *Ralstonia solanacearum*, deletion mutants of *Ralstonia solanacearum* were developed. *eps BDEL* mutant of *R. solanacearum* race 1 (Isolate: UTT-25) produced significantly less extracellular polysaccharide as compared to wild type, indicating the role of extracellular polysaccharide in pathogenicity.

**Xanthomonas oryzae pv. oryzae-rice.** Among the six races tested, race 4 was found to be most virulent. Furthermore, transcript expression of Xop family-Type III effectors (T3Es) were observed in *X. oryzae pv oryzae*.

**Burkholderia glumae causing panicle blight in rice.** Etiology of new disease termed as panicle blight in rice was established. Panicle blight was destructive on emerging panicles and leaf sheaths of basmati and non-basmati rice varieties. The causal agent was confirmed to be *Burkholderia glumae*. 16S rRNA gene sequence of three isolates shared 99% nucleotide sequence identity with *B. glumae* (Acc No. NR102846). Whole-cell fatty acid methyl ester (FAME) analysis further confirmed *Burkholderia*. Pathogenicity was

![Typical symptoms of panicle blight on rice: A. On panicle; B. On leaf; C. On glumes](image-url)
confirmed at panicle initiation or boot leaf stage by infiltrating bacterial suspensions (1x10^8 cfu ml^-1) into the sheath, leaf and flag leaf of susceptible basmati rice (cv. Pusa basmati 1) in glasshouse conditions.

**Banana streak viruses in India.** Complete genome sequences of three episomal Banana streak MY virus (BSMYV) isolates generated by rolling circle amplification (RCA) representing triploid banana hybrids (Chini Champa: AAB; Malbhog: AAB and Monthan: ABB), indicated an identity of 45-50% with other BSV species and 43-44% with sugarcane bacilliform viruses (SCBV). Data on nucleotide substitution rates indicated low subpopulation variation.

**Leek yellow stripe virus (LYSV).** Analysis of complete genome of an isolate of Leek yellow stripe virus (LYSV) infecting garlic revealed genome size of ~10131bp excluding the 14’-terminal poly (A) tail. The genome consists of a single large open reading frame (ORF) of 9456bp which potentially encodes a polyprotein of 3152 amino acids. Maximum sequence identity of 79.9 and 87.2 % at nucleotide and amino acid level with an isolate from Australia (HQ258895) was observed. The functional region of P1, P3 and 3’ untranslated region was highly variable when compared to other isolates of LYSV.

**Identification of Pepper mild mottle virus (PMMoV).** A disease characterized by mottling and puckering of leaves was observed on commercial capsicum hybrids (Capsicum spp.) in Delhi. PMMoV was detected in capsicum hybrid Bombay by DAC-ELISA using PMMoV specific antisera as well as in RT-PCR using coat protein gene (CP-gene) based primers. The sequence of CP-gene showed 99% sequence identity with PMMoV sequence thus confirming the virus.

**Characterization of Cowpea mild mottle virus in mungbean and urdbean.** Viruses associated with mungbean and urdbean by next generation sequencing of small RNAs showed association of Cowpea mild mottle virus (CpMMV), a whitefly transmitted virus. Presence of CpMMV was further confirmed by DAS-ELISA, RT-PCR and analysis of the coat protein (CP) gene sequence. The length of CP gene in both isolates were similar (867bp) but shared only 90.9% identity at the amino acid level. The Nucleic acid binding protein (NB) gene differed in length by seven amino acids and shared sequence identity of 56.4% only at the amino acid level indicating presence of distinct strains of CpMMV in India.

**Characterization of begomoviruses associated with cotton leaf curl disease.** Based on genome of five CLCuD-begomovirus, two beta satellites and three alpha satellite molecules were obtained through rolling circle amplification, cloning and sequencing. Sequence analysis determined that out of five CLCuD-begomovirus isolates, three Cotton leaf curl Rajasthan virus (CLCuRV) and two isolates were identified as Cotton leaf curl Burewala virus (CLCuBuV). The present CLCuRV isolate was recombinant deriving a part of intergenic region (IR), and complete ORFs V1, V2 and C5 from CLCuBuV, Cotton leaf curl Bangalore virus and Mesta yellow vein mosaic virus. It is concluded that CLCuD incidence in Delhi in recent years could be attributed to emergence of Cotton leaf curl Burewala virus (CLCuBuV) and recombinant Cotton leaf curl Rajasthan virus (CLCuRV) along with in association with recombinant cotton leaf curl Multan betasatellite (CLCuMB^797) and alphasatellite molecules.

5.1.2 Molecular Diagnostics

**Puccinia striiformis.** A gene based specific marker (PST_1518) was developed for detection of P. striiformis causing yellow rust of wheat. The sensitivity and utility of pst_1518 was further enhanced by developing qPCR based assay by designing a primer set PSTKeto F1_1246/PST KetoR1_1547,
which amplified a product of 302 bp. The sensitivity limit was up to 1 fg of *P. striiformis* DNA. This marker based detection provides rapid and reliable method for efficient detection, quantification and monitoring of *P. striiformis*.

**Production of antibodies using two synthetic peptides of BSMYV and standardization of DAS-ELISA.** To simplify the methodology of antigen preparation, synthetic peptides representing antigenic epitopes were successfully used for production of polyclonal antibodies to BSMYV. Two immune dominant linear epitopes were identified at N and C-terminal of putative CP of BSMYV (pep-I and pep-II), synthesized and used for polyclonal antiserum production. Only anti pep-I antiserum strongly reacted with BSMYV virions in ISEM and ACP-ELISA (1:2000 and 1:4000) in crude sap exhibiting >3 folds differences in optical density (OD) values of infected and healthy samples. Employing the immune reagents developed in present study a sensitive duplex-immunocapture-PCR (D-IC-PCR) was standardized for the sensitive, reliable and accurate routine indexing of episomal BSV infection in tissue cultured and field banana samples. In a survey 46% of the samples collected from North, North-East, East, West and South India were indexed positive for BSV infection indicating its widespread occurrence.

**Recombinant coat protein based detection for LYSV.** Recombinant coat protein (CP gene) was successfully utilized as an antigen for rabbit immunization and polyclonal antisera production leading to an effective method of high titre polyclonal antisera production, which could detect *Leek yellow stripe virus* (LYSV) infecting garlic.

**Development of multiplex RT-PCR for simultaneous detection of six RNA viruses infecting potato in India.** RT-PCR based multiplex detection of six potato viruses such as PVX, PVY, PVM, PVS, PVA and PLRV was developed. Reproducible RNA isolation protocol was standardized for tuber and leaf tissues, which was validated using field samples of infected potato leaf sourced from fields of New Delhi, UP, Bihar and West Bengal. Randomly collected 600 samples representing potato growing areas in MP and UP were subjected to multiplex RT-PCR which successfully detected mixed infection of 2-4 viruses.

**Multiplex PCR based on CP-gene of six RNA viruses affecting potato in India**

**Development of a microarray chip for detection of all known plant viruses and viroids.** A microarray based virus detection kit was developed on Affymetrix platform which has probes to detect 1155 plant viruses and viroids. Both DNA and RNA viruses could be detected using the chip with a sensitivity of 25 ng of total plant RNA. The kit was validated with field samples of chilli, grapevine, tomato, soybean, sugarcane etc. The chip was also able to detect mixed infections.

**Phytoplasma and begomovirus affecting soybean crops.** A mixed infection of begomovirus as well as ‘Ca. *P. asteris*’ associated phytoplasma with soybean yellow leaf and witches’ broom syndrome was observed. The two weed species (*Digitaria sanguinalis* and *Parthenium hysterophorus*) were also recorded as alternative hosts for ‘Ca. *P. asteris*’ soybean strain. A leaf hopper, *Empoasca americana* was found as a putative insect vector.
Candidatus Phytomasa asteris association with little leaf and leaf yellows symptoms of Viola tricolor. Yellows and little leaf symptoms observed on Viola tricolor (Pansy) plants was attributed to ‘Ca Phytomasasteris’ on the basis of 16Sr DNA sequence identity. This is the first report of 16SrI group phytoplasma association with V. tricolor.

Development of a stable and highly infectious construct of CGMMV. The pCAMBIA2300 vector was modified with double 35S promoter, compatible multiple cloning sites, ribozyme sequence and NOS terminator. The full length CGMMV genome (6.4 kb) was cloned in the modified pCAMBIA 2300Rz and mobilized to Agrobacterium strain GV1301. The agro-infiltration of this construct resulted in high rate of infection in N. benthamiana as well as formation of CGMMV virion in the infected plants. The construct is stable in both E. coli and Agrobacterium and is highly useful for designing gene expression vector.

Development of stable infectious clone of Potato virus Y. The full length genome of PVY was amplified in two equal over lapping fragments of 4.8kb. A T7 promoter sequences was fused with forward primer of the 5’ segment of the genome and a 20 nucleotides poly-A sequence was fused with the reverse primer of the 3’ segment of the genome. The overlapping PCR was conducted using the two amplified fragments as template and the complete genome containing T7 and poly-A sequences at the 5 and 3 terminals, respectively was obtained. In vitro transcript of the amplified complete genome was rub-inoculated to (@10 µg/plant) Nicotiana tabacum cv. Xanthi, which developed vein clearing followed by mosaic symptoms at 9-10 days past inoculation. However, the clone from the 5’-amplified fragment was not stable in E. coli due to presence of PPLE at the end of Hc-Pro. Therefore, the genome was further divided in between -35 and -10 box of PPLE and two silent mutations were carried out in each of divided segment. The full-length amplicon generated by extension PCR using both the mutated fragment as template was cloned in E. coli to give stable replicon after transformation. The methodology will be useful in rapid generation of full-length infectious clone of PVY.

Development of Croton yellow vein mosaic virus replicon based vector for gene expression. A replicon vector (pCro) having AC1, AC2, AC3 and AC4 ORFs of the CYVMV was developed. A duplicated CR region and a cassette consisting of double 35S promoter, multiple cloning site (SmaI, KpnI, BamHI, EcoRI) and NOS terminator. The green fluorescent protein (GFP) was cloned into pCro-MCS. Both the constructs of pCro and pCro + GFP were mobilized into Agrobacterium strain and confirmed by colony PCR. After 5dpi, GFP expression was confirmed under UV. Replication of the pCro inside the plant cell was confirmed by inverse PCR using a outward primer confirmation.

5.1.3 Biocontrol Agents and Their Bioprospecting

Identification and characterization of antagonistic microbes. Biocontrol potential of two rhizobacteria (S2BC-1 & TEPF-Sungal) and a Trichoderma spp., against Fusarium oxysporum f.sp. lycopersici (FOL) causing vascular wilt of tomato was identified. Positive interaction between fungal and bacterial biocontrol agent was observed for a number of biocontrol traits including chitinase production.

Fungal origin silver nanoparticles against phytopathogenic bacteria. Silver nanoparticles biosynthesized from Beauveria bassiana, Trichoderma asperellum and T. harzianum showed antibacterial activity against Ralstonia solanacearum and Xanthomonas axonopodis.
Cellulase activity in Trichoderma harzianum. Cellulase activity in T. harzianum was maximum at the time of incubation (112hrs), optimum pH of 4 and the temperature 35°C. Sucrose (1%) was found to be the best carbon source followed by cellulose, glucose and maltose. Yeast extract (1.0%) was found to be the best nitrogen source followed by peptone.

Trichoderma and Bacillus subtilis formulations against sheath blight of rice. The combined effect of seed treatment and foliar spray of Trichoderma and Bacillus subtilis formulations was non-significant for seed germination, number of hills per pot and number of tillers per hill. Pusa 5SD (T. virens) gave the highest plant height, number of grains per earhead, dry plant weight and grain yield with the lowest relative lesion height and disease index. Plant height, number of grains per ear, grain yield, relative lesion height and disease index recorded in this interaction was statistically similar with the interaction of seed treatment with Pusa 5SD (T. virens) and spray with B. subtilis.

Bioefficacy of IARI bioformulations (Chaetomium globosum) against spot blotch of wheat. Bioefficacy of IARI bioformulations (Chaetomium globosum) Cg2WP and Cg2BP against spot blotch of wheat when tested underfield conditions showed higher shoot length, root length and higher yield with minimum leaf blight severity (23) in comparison to control (68) in soil amendment with biopellets (@ 5 g/plot) + three sprays (@ 2 g/l water) with wettable powder.

5.1.4 Evaluation of Crop Genotypes for Disease Resistance and Mechanisms of Resistance

Rice. Blast resistance (R) genes, viz., Pita2, Pi9, Pi12(t) and Piz5 exhibited resistance to 20 isolates of blast pathogen. Out of 11 advanced breeding lines evaluated for blast resistance, only 3 lines viz., ABL 17, ABL 18 and ABL19 were highly resistant. Among 25 rice entries of Directorate of Rice Research (DRR) tested, Oryza minuta, Raminad STR-3, Zenith, Rasi and Tetep were highly resistant. Out of 96 short grained aromatic rice genotypes evaluated against growth of S17TH and chitinase activity in fungal-bacterial interaction

<table>
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<tr>
<th>Treatment</th>
<th>Mycelial weight of S17TH (g)</th>
<th>Chitinase (N-acetyl-β-D glucosaminidase)* activity (U/ml of culture filtrate)</th>
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<tr>
<td></td>
<td>S2BC-1</td>
<td>TEPF-Sungal</td>
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<td>S17TH CFC</td>
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<td>S2BC-1-Live cells</td>
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<td>0.9</td>
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<td>S2BC-1-Heat inactivated</td>
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<td>S2BC-1-CFC</td>
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<td>TEPF-Sungal-Live cells</td>
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<td>TEPF-Sungal-Heat</td>
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<td>S2BC-1-Heat inactivated (CFC)</td>
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<td>Control (MSB alone)</td>
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<td>LSD (P=0.05)</td>
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Mean of three replications; One unit of the enzyme will release 1.0 µmole of p-nitrophenol from 4-nitrophenyl-N-acetyl-β-D glucosaminide per min at pH 4.8 at 37°C.

Genome mining in plant associated endophytic bacteria for natural products. The plant endophytic Pseudomonas putida BP25 and Bacillus megaterium BP17 were found to release antimicrobial volatile compounds having antifungal activities against Pythium myriotylum, Phytophthora capsici, Gibberella moniliformis, Rhizoctonia solani, Athelia rolfsii, and Colletotrichum gloeosporioides. Out of a number of compounds analysed by GC/MS, seven compounds such as Dimethyl trisulfide, 2-Ethyl-3, 6-dimethylpyrazine; 2-ethyl-3-methyl-Pyrazine; 2-ethyl-5-methyl-Pyrazine; 2-ethyl-Pyrazine; 2, 5-Dimethyl Pyrazine and 2-methyl-Pyrazine effectively inhibited Oomycete pathogen, Phytophthora capsici.

Mode of antagonism of Bacillus amyloliquefaciens on Ralstonia solanacearum. Gene coding lipopeptide antibiotic, iturinA was identified and characterized in B. amyloliquefaciens (DSBA-11 and DSBA-12), B. subtilis (DSBA-5), and B. licheniformis but iturinA was not identified in B. cereus. Iturin A gene (617 bp) from B. amyloliquefaciens (DSBA-11) has been cloned and sequenced.
bakanae disease, 3 genotypes C-4-63-G, Calrose 76 and IR74725-115-3-3-3 were resistant. For sheath blight disease, out of 1248 entries, CB10554, CB12584, CB11161, VL8915, VL8937, GSR 113, GSR 130, IET 22164, IET 21953, RP Patho -5, RP -Patho -24, DRR -LR -202, RPDN -185, T -30 -42 were moderately resistant. Among the 6170 rice lines screened against race 4 of *Xanthomonas oryzae* pv. *oryzae*, 260 lines including 245 advance backcross derived lines carrying Xa38, 10 lines carrying Xa38 gene in the genetic background of Pusa Basmati 6 and 5 F2-populations generated from the crosses PR114 and Xa38 were resistant. Among the R genes, xa13, Xa4, xa5, Xa21 were effective.

**Wheat.** Out of 216 entries of wheat screened for resistance to Karnal bunt (KB), 122 remained free of infection. Mapping populations of wheat for Karnal bunt resistance was developed. In three sets of crossing populations, HD 29 X HD 2009, HD 30 x WL 711 and HD 30 X HD 2009, KB resistance was found in 26 entries out 120 entries, 39 entries out of 170 entries and 70 entries out of 126 entries, respectively. Seventy one RIL populations (F5) of HD30 X WL711 were validated using four SSR markers, viz., Xgwm88-6B, Xgwm337-1D, Xgwm637- 4A and Xgwm538-4B linked to KB resistance. Among the 595 PDSN wheat entries evaluated for rusts resistance at adult plant stage, twenty six entries remained free from all three rusts at adult plant stage. Out of 270 CVT wheat genotypes evaluated for leaf, stem and stripe rust at seedling (SRT) and adult plant stage (APR), 13entries viz. DW 1543, ID 1306, ID 1309, ID 1310, ID 1316, ID 1320, SBP 13-29, ID 1332, ID 1341, ID 1342, WBM 3472, WBM 3469 and WBM 3468 were resistant to all the three rusts at both growth stages. For yellow rust, among CVT genotypes, 30 entries were highly resistant at both growth stages. Evaluation of wheat genotypes of IPPSN (1534), PPSN (552), EPPSN (110) and MDSN (49) revealed 705, 226, 20 and 15 entries, respectively resistant against leaf rust.

APR (slow rusting/partial resistance) assessed in wheat isogenic lines for Yr2, Yr9 and Yr18 taking parameters like relative area under disease progress curve (rAUDPC), final rust severity (FRS), infection rate and coefficient of infection (CI). On the basis of these parameters, promising APR was observed in genotypes DBW 71, PDW 314, HS 277, HS 507, VL 804, VL 829, VL 907, HPW 349, HD 2967, HD 3043, HD 3086, PBW 660, NIAW 34, C 306, HI 1563 and WH 1080 consistently during *rabi* seasons of 2012-14. At seedling stage, APR gene Yr18 was postulated in eight varieties namely HS 277, VL 804, VL 829, HD 2733, NI 5439, NIAW 34, PBW 175 and C 306. All these varieties exhibited effective adult plant resistance in field. Out of 253 lines of wheat genetic stocks screened for powdery mildew resistance in 2014 re-evaluated for the resistance against rusts and powdery mildew at Wellington station, only 78 lines (31%) had powdery mildew under severe epidemic conditions and 151 were absolutely free from both black and brown rusts infection.

Durum wheat genotypes HI 8702, HI 8708, HI 8709, HI 8715, and HI 8722 were identified as sources of triple rust resistance based on multi-location screening over five crop seasons. Bread wheat genotypes HI 1567, HI 1568, HI 1569, HI 1571, and HI 1572 were identified as sources of stable resistance to stem and leaf rusts based on multi-location screening over four crop seasons. Nine homozygous resistant lines in ‘NP 4’ background carrying singly the genes *Lr1*, *Lr2a*, *Lr2c*, *Lr3a*, *Lr9*, *Lr10*, *Lr15*, *Lr17*, and *Lr20* developed through six back-crosses, were validated through seedling tests with appropriate leaf rust pathotypes in the BC6F2 and BC6F3 generations.

**Maize.** Out of 455 maize genotypes evaluated against maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*), 80 entries were resistant to MLB disease, 41 entries were resistant to BLSB and only 12 entries [JH 13230, GK-3118, PM 14101L, CHH12-679, AH-
7002, PRO-392, NMH-1265, CMH 11-852, EHL 3412, KMMH-401013, JH 31613 and HQPM 4-C] were resistant against both the diseases. Out of 148 inbreds of Directorate of Maize Research (DMR) evaluated against MLB and BLSB, 7 entries showed resistant reaction to MLB and 3 entries for BLSB disease. Another 25 DQL lines were evaluated against MLB disease, of which 5 lines [DQL 2008-1, DQL 2028, DQL 2031, DQL 2071 and DQL 2113] showed resistance. Out of 50 inbred lines developed by IARI breeders, only 2 inbreds were resistant to MLB and none were resistant to BLSB disease.

**Pearl millet.** Out of 1380 entries of early genetic trials and mapping population screened against natural infection by *Pyricularia grisea* in field conditions, only 5 entries (6573, 8793, 8794, 9884 and 9885) were found highly resistant.

**Soybean.** Only two among the 32 soybean entries (IVT) screened were resistant against soybean yellow mosaic disease. Among the 9 AVT entries evaluated, one was highly resistant while two entries were resistant.

**Groundnut.** Out of 308 genotypes/RILs of groundnut evaluated under field and pot conditions against *Sclerotium rolfsii* causing Sclerotium rot, 235 showed resistance under field and net house conditions.

**Onion.** Out of 34 entries screened against purple blotch, 3 entries were resistant, 11 entries moderately resistant and rest entries were in moderately susceptible (MS) category.

**Capsicum.** A wild capsicum genotype from Kullu valley of North Western Himalayan Region exhibited multiple disease resistance to wilt, phytophthora blight and powdery mildew under natural epiphytotics at Katrain. This could be a potential root stock for grafting and introgression of disease resistance in to existing genotypes.

5.1.5 Epidemiology and Disease Management

**Rust trap nurseries in southern hills.** In order to elucidate the role of weather factors on survival, and inoculum potential of rust spores a set of susceptible genotypes (Kalyansona, LalBahadur, WH147, Agra local, HDW 234, Lok-1, NI 5439 and NP 200) were planted at different locations of different altitudes (ranging from 386 msl at Udumalpet (lower Palani area) to 2221 msl at Kodaikanal). Severe epidemic was observed at Ooty and nearby areas.

**Monitoring of blast disease in rice.** Simulation of spatio-temporal dynamics of blast infection in rice based on temperature-dependent hourly generation rate model \[y = 0.00001043 \times (\text{air temp}^\circ C - 2)^{1.114} \times (25 - \text{air temp}^\circ C)^{1.196}\] revealed that there was no significant change in blast incidence in rice. Interestingly the blast incidence was found increasing in boro rice grown in eastern Indo-Gangetic plains and Brahmaputra basin (Assam, West Bengal and adjoining Bihar) under climate change. Simulation information has relevance in short as well as long term management strategies.

**Development of web blight/wet root rot.** Influence of weather variables on web blight disease incidence was observed in mungbean/urdbean-wheat cropping systems in experimental field of IARI and three farmer’s fields at Hapur, Uttar Pradesh. Disease incidence varied from 4.5 to 29.8 % in IARI and it ranged from 12.8 % to 26.5 % at Hapur. Among the weather parameters, relative humidity and rainfall exhibited positive correlation with the disease development.

**Disease observation in coordinated trial of pigeonpea.** *Alternaria* and *Cercospora* leaf spot of pigeon pea was observed up to 30 per cent severity in all the genotypes tested. Sterility mosaic virus disease incidence was recorded from 0-40 per cent and *Sclerotinia* twig blight incidence was also observed up to 20.5 per cent.

**Management of bakanae disease of rice.** Four fungicides, viz., Copper oxychloride (0.2%), carbendazim (0.1%), Propiconazole (0.1%) and Nativo (0.1%) when evaluated against bakanae disease in rice genotype Pusa Basmati 1121 at 15 days post transplantation and subsequently 2 sprays at 15 days intervals showed that the fungicidal spray is not effective as there were no significant differences for disease incidence and yield.
Management of brown leaf spot and bakanae disease in rice. Kresoxim methyl 40% + hexaconazole 8% @ 0.1% was significantly effective against brown leaf spot disease with least disease severity ranging from 2.83-4.33%. Seed treatment with hexaconazole + captan @ 2.5 g/kg was highly effective showing 0.20% bakanae disease incidence as compared to 17.43% in untreated check.

Management of banded leaf and sheath blight of maize. Among five fungicides evaluated for management of BLSB disease, validamycin (0.1%) was found superior followed by Hexaconazole (0.1%), Carbendazim (0.1%), Tebuconazole (0.05%) and Pencycuron (0.1%).

Management of leaf crinkle of urdbean. Among the seed treatments and foliar spray using 3 insecticides, the highest seedling emergence and grain yield along with the lowest seedling mortality, lowest yellow mosaic and leaf crinkle incidence were recorded in seed treatment with Imidacloprid 48 % FS (Gaucho) 6.0 ml + Carbendazim (bavistin 50 WP) and TMTD (thiram 75 WP) 2.0 g (1:1) + Pusa 5 SD (Trichoderma viride) 4.0 g / kg and foliar spray of Imidacloprid 17.8 % sl (Confidor) 0.1% and Spinosad 45 % SC (Tracer) 0.05 % at 30 and 45 DAS, respectively on Barabanki local variety of urdbean.

Development of transgenic papaya resistant to papaya ringspot virus. Transgenic papaya was obtained with pBinAR: Full-PRSVP-CP gene construct through Agrobacterium-mediated transformation. Among the seven putative transformants of papaya in Pusa Delicious background, four plants were found to be positive through PCR amplification, PCR-Southern hybridization as well as through genomic Southern hybridization analysis.

Field efficacy of different fungicides against false smut disease in Paddy. Out of nine fungicides evaluated, copper fungicides as kocide and blitox-50 were found most effective in the disease control.

Integrated management of major diseases of Indian mustard (Brassica juncea) in NEPZ of India. Seed treatment with propiconazole plus two foliar sprays of propiconazole resulted in least disease severity and incidence of Alternaria leaf and pod blight, white rust and Sclerotinia rot. However, integrated treatment, i.e., seed treatment with propiconazole @ 0.1% + balanced fertilization [NPK, @ 100: 60: 40 Kg/ha; ZnSO₄ (21%, @ 25 kg/ha), borax (11%, @ 16 kg/ha) and bentonite sulphur (90%, @ 40 kg/ha)] + removal of four lower leaves at 60 days after sowing + one foliar spray of propiconazole @ 0.1% at 70 DAS resulted in significantly lower diseases.

Management of foliar blight of wheat through chemicals. Seed treatment with carboxin 37.5%+thiram 37.5% @ 2.5 g/kg seed + two spray of propiconazole @ 1 ml/liter resulted in significantly higher seed germination, yield (61.86 q/ha) and minimum foliar blight severity (12), in comparison to control where disease severity was noticed up to 68 in double digit scale.

5.1.6 Host Microbe/Virus Interaction
Magnaporthe oryzae-rice. Predominant Magnaporthe oryzae pathotypes causing rice blast was identified as O₂ type based on multi locus sequence typing, which infected wheat under artificial inoculations. qPCR based absolute quantitation of M. oryzae on rice and wheat revealed that the pathogen increased its population up to 100-1000 fold within 48 hours. The qPCR data was further confirmed

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A. Fluorescing conidia; B. Germination of conidia; C. Hyphal expansion; D. Mycelia growth; E. Tuft of mycelium on leaf surface; F. Typical lesion on rice (Co 39) and wheat (Agra Local)
in fluorescence microscopy with the help of green fluorescence protein (gfp) signals from conidia and mycelium on plant surfaces.

**Chaetomium globosum-wheat.** Enzymes such as polyphenol oxidase, peroxidase, phenyl alanine lyase and catalase involved in induced resistance in wheat against spot blotch disease were identified and characterized. Enhanced activities of these defense related enzymes were observed in the wheat seedlings raised from seed primed with *Chaetomium globosum* and challenged with *B. sorokiniana*. Plants treated with *C. globosum* spray bioformulation also exhibited higher levels of PAL activity as compared with mock.

**Bipolaris sorokiniana-wheat.** Out of 46 differentially expressed genes of wheat genotype Chiriya 7 (spot blotch resistant) shortlisted in SSH cDNA library screens, 15 (33%) were classified as plant defense responsive genes. Some of the significant defense genes identified are: Cysteine protease (CP), Calreticulin (CRT), Predicted omega amidase NIT-2 like, Dual specificity protein kinase pyk-1, Pacifastin like, Della (Rht-B1), and UDP-glycosyltransferase (UGT). All the sequence were submitted to Genbank.

**Fusarium oxysporum f. sp. ciceris-chickpea.** Gene expression analysis in chickpea treated with *Trichoderma harzianum* indicated that MAPK genes were up-regulated in susceptible variety (JG 62) and down-regulated in resistant variety (GPF 2). The expression was highest in *Foc* infected plants followed by *T. harzianum*+ *Foc* but least expression was recorded in *Foc* infected plants.

**Magnaporthe grisea-pearl millet.** Infection efficiency of rice leaf blast pathogen on pearl millet and rice leaf surface significantly varied. Higher infection efficiency on pearl millet leaf surface was ascribed to higher water retention capability (due to lower contact angle) as compared to lower water retention capability (higher contact angle) on rice leaf surface.

**Ralstonia solanacearum-Arabidopsis thaliana.** Among the *Arabidopsis* ecotypes, Landsberg Erecta...
was found to be resistant whereas Col 0 was highly susceptible to race 4 of *R. solanacearum*. Scanning and light microscopic analysis showed localized bacterial cells in different tissues. Gene expression analysis indicated that over 443 *Arabidopsis* genes were differentially expressed when roots interacted with *R. solanacearum* at $10^8$ cfu of bacterial suspension. The expression data further highlighted the existence of distinctive as well as shared metabolic and defense pathways between the seed and root mediated inoculations. Bacteria induced up regulated genes such as ATC, DIN11 & PAD3 and down regulated genes such as MYB domain protein 95 (MYB95), ARABIDOPSIS THALIANA PURPLE ACID PHOSPHATASE 29 (ATPAP29) and GERMIN 3 (GER3) were further validated using Real Time PCR.

**Avr genes of Xanthomonas campestris pv. campestris-cruccifer.** Two isolates each representing *X. campestris* pv.campestris race 1 (XCC-C16, XCC-C221), race 4 (XCC-C112, XCC-C231) and unidentified race XCC-C164, XCC-C205) were analysed for avirulence genes. Among the nine *avr* genes viz., AvrBs1, AvrBs2, AvrBs1.1 (XopH), AvrAC (XopAC), AvrGf1 (XopAG), AvrXccC (XopAH), AvrXccA, AvrXccA2 and XopE analysed, eight of them except XopE, were found in races 1, race 4 as well as in unidentified races. Sequence polymorphism could be observed for these *avr* genes among the races.

**Xanthomonas axonopodis pv. punicae XopN effector-pomegranate.** Cell-death based assay for PAMP triggered immunity (PTI) was standardized on *Nicotiana glutinosa* and it was confirmed that XopN played a key role in the pathogenicity of *Xanthomonas axonopodis* pv. *punicae*.

**ToLCNDV-tomato.** Gene expression profiles monitored in leaf tissues during symptom development in *Solanum lycopersicum*, revealed a total of 920 differentially expressed genes in ToLCNDV infected tomato. KEGG pathway analysis of these genes categorized these genes into 77 known pathways, related to increasing respiration rate, decreasing rate of photosynthesis, accumulation of soluble sugars/starch, etc.

**PRSV-papaya.** Microarray analyses of miRNAs, isolated from the leaves of healthy and PRSV infected papaya leaves revealed that PRSV infection significantly deregulated the miRNA profiling represented by 15 different groups of miRNAs which were altered more than two fold.

### 5.2 ENTOMOLOGY

#### 5.2.1 Integrated Pest Management

**5.2.1.1 Cereals**

*Analysis of leaf folder outbreak.* Likely causes of the leaf folder outbreak based on weather parameters of the June and July during 2007-2013 were investigated. $T_{max}$ during June differed significantly over the years, its value being maximum during 2012 (41.2°C) followed by 2009 and 2010. Minimum relative humidity ($RH_1$) and $RH_2$ during June as well
as July differed significantly over the years. The RH1 and RH2 during June were the lowest during 2012 followed by 2009 and 2010. Weekly total rainfall and sunshine hours, during June and July did not differ significantly over the years. Weather analysis thus depicted that occurrence of hotter and drier conditions during June and July in 2012 compared to other years might have played a role in the leaf folder outbreak, besides other factors.

**Effect of elevated CO\(_2\) on brown planthopper (BPH) population.** Elevated CO\(_2\) exhibited positive effect on BPH population and resulted in tripling of its population (39.9±13.9 hoppers/hill) compared to ambient CO\(_2\) (13.2±4.8 hoppers/hill) during the crop season. Elevated CO\(_2\) resulted in 24.8% higher fecundity and 72.7% higher honey dew excretion compared to ambient CO\(_2\). Stimulatory effect of elevated CO\(_2\) on BPH population could be attributed to denser plant canopy in terms of increased number of tillers (15.7%) and canopy circumference (22.6%) that created more congenial micro-habitat for BPH multiplication.

**Determination of damage thresholds of C. partellus populations from different agro-ecozones on susceptible and resistant maize and sorghum genotypes.** Leaf damage caused by C. partellus larvae from different populations on different maize and sorghum genotypes was significantly different. The Hisar population of C. partellus showed significantly lower damage potential than the Coimbatore population across maize and sorghum genotypes. The resistant sorghum genotypes, IS 2205 had significantly lower leaf feeding and lower larval survival across populations. Among the maize genotypes, CPM 18 (resistant) received less damage by Prabhani population asi Local.

The Genotype × Population interaction analysis showed that the C. partellus larval survival on resistant sorghum genotype, IS 2205 was significantly lower in Coimbatore and Surat populations, and on susceptible genotype, Swarna was significantly lower in Parbhani population.

### 5.2.1.2 Vegetables

In cauliflower based intercropping systems, incidence of three lepidopteran pests, viz., *P. xylostella*, *P. brassicae* and *T. ni* and two aphid species, viz., *Lipaphis erysimi* and *Myzus persicae* were noticed. The intercropping systems recorded significantly lower *P.xylostella* larval population (2.02 to 2.56) and pupal population (0.27 to 0.39) in comparison to cauliflower monocrop. Diversity created by intercropping system increased the abundance of natural enemies substantially in comparison to cauliflower monocrop. *Coccinella septumpunctata* was found to be most dominant, accounting for more than 80% of the total coccinellid population.

Four mixtures and three new formulates evaluated against sucking pests of okra revealed that fipronil @50g a.i./ha was most effective (7 leafhopper/15 leaves) followed by thiacloprid @24g a.i./ha (10 leafhopper/15 leaves) against control (25.33 leafhopper /15 leaves) at one day to spray. On 7th day again fipronil was most effective treatment followed by ethiprole + imidacloprid and profenphos + cypermethrin. Fipronil was most effective against whitefly at 1st, 7th and 14th day to spray. However, triazophos+deltamethrin was only effective mixture on 1st and 14th day to spray.

Screening of capsicum lines against aphid resistance carried out under polyhouse conditions at Katrain station revealed that lines such as, Bang-38 (8.5±1.08 aphid/plants), SSP (29.33±3.0) and KT-5 (45.89 ± 5.06 aphid/plant) had lesser aphid infestation compared to CW (627 ± 6.20 aphid/plant).

Importance of insect pollination (from managed and wild pollinators) was studied on broccoli seed crop at Katrain stations revealed significantly more pod weight (292.8 ± 69.46 g/plant) in plants pollinated under open conditions than manually pollinated (57.6 ± 15.87 g/plant) plants. Similarly, 1000 seed weight / plant was also higher in the plants pollinated under open conditions.

Efficacy of botanical on sucking pests in cabbage revealed that pest incidence was very low throughout
the season with 17.33 aphid/plant under neem soap (1%) and neem seed powder (1%) + petrol (0.1%) extract treated plants.

5.2.1.3 Oilseeds

Three different artificial infestation techniques along with natural infestation as control at two sowing dates were validated for screening of rapeseed and mustard genotypes for aphid resistance. Mustard aphid infestation using biological and behavioural studies revealed that B. carinata and B. nigra were less preferred than other U triangle Brassica species viz., B. juncea, B. napus, B. rapa, B. oleracea, B. carinata, and B. nigra.

Suppression of pest and disease of mustard by altering crop row direction. About 30% crop of mustard is damaged every year by pests and diseases. By selecting appropriate row direction the micro environment can be changed within mustard crop which can be useful to suppress the pests and diseases. Therefore, a study was taken to find out appropriate row direction to suppress pests and diseases without use of harmful chemicals. Three cultivars of oilseed Brassica namely, Pusa Vijay, Pusa Mustard-21 and Pusa Bold were sown in two row directions, viz. north-south (N-S) and east–west (E-W) at ICAR-IARI farm, New Delhi during the rabi season of 2013-2014. Aphid population and percent disease index (PDI) of white rust were found to be substantially low in north-south (N-S) rows in comparison to east-west (E-W) rows for all cultivars (pooled data). Probably, more radiation penetration and interception in N-S rows, increased the crop profile temperature and decreased humidity within the canopy and made the crop micro environment unfavorable for pest (aphid) and diseases (white rust). The findings of the study can be an input of IPM for mustard crop in N-W India.

5.2.2 Storage Entomology

5.2.2.1 Screening for resistance against pulse beetle, Callosobruchus analis (E.) in greengram accessions

The susceptibility of eighty five greengram accessions when evaluated against pulse beetle, Callosobruchus analis showed that no greengram accession was found immune to bruchid infestation. Two accessions viz., Km-12-5 and P-S-16 revealed lesser per cent adult emergence of 12.22 and 14.29 respectively, prolonged developmental period (25.67 and 26.0 days, respectively) and lesser susceptibility index (0.042 and 0.044, respectively) in comparison to highly susceptible Ganga 8. Correlation between GI and other growth parameters of pulse beetle on different accessions indicated that GI had negative relationship with mean developmental period (-0.924) and significant positive relationship with adult emergence (0.931), weigh loss (0.952) and eggs laid (0.734). Hence, these accessions can be effectively used as promising donors for developing bruchid resistant varieties.

5.2.3 Biological Control

5.2.3.1 Temperature tolerance in parasitoid Aenasius bambawalei

Sex ratio was affected when the parasitoids were subjected to high temperature. Depending upon the period of exposure the numbers of male individuals increased in each population. When the population subjected to six hour exposure, the sex ratio was affected in all populations. Out of nine populations tested at 38°C for varying periods, the sex ratio and reproduction potential was found to be less affected in Punjab, Haryana, Maharashtra and Tamil Nadu than the other populations.

5.2.3.2 Sensitivity of predator and parasitoid to insecticide

Studies were conducted to know the natural tolerance of different group of insecticides on adults of C. montrouzieri by surface residue method. Among the different insecticides thiamethoxam (LC₅₀ 0.0146%) were more toxic to the adults of Cryptolaemus followed by imidacloprid (LC₅₀ 0.0146%) and thiodicarb (LC₅₀ 0.0146%). Safety evaluations of three insecticides when conducted against four population of Aenasius bambawalei revealed that profenofos was more toxic to all populations tested.
5.2.4 Insect Physiology

Ingestion of bacterially expressed double-stranded RNA induces chitinase gene specific RNA silencing in Spodoptera litura (Lepidoptera: Noctuidae). A study was conducted to determine whether RNAi was induced in insects by ingestion of bacteria expressing dsRNA. Results suggested that RNAi in S. litura could be triggered by ingestion of dsRNA expressing bacteria. As expression of chi gene coincided moulting process, the feeding of dsRNA expressing bacteria caused insect mortality up to 53% especially during moulting that led to morphological symptoms like incomplete shedding of old exuviae larval-pupae intermediates and malformed adults.

Efficacy of native Bacillus thuringiensis strains isolated from different sources against Spodoptera litura. Ninety native Bt strains, isolated from three different sources, viz., soil samples (42), insects (24), ware houses (24) along with reference strains (HD-1) when screened against neonates of S. litura by diet incorporation method at single concentration of 10 µg/gm of diet, revealed that on 7th day maximum mortality up to 83% with (Bt isolates from insects)> up to 40% (Bt isolates from soil) > up to 30% (Bt isolates from ware house) > 26.6% (reference strain HD-1). PCR based characterization showed that cry1B gene was found in all seven native Bt strains and cry1, cry1A, cry2, cry2a in HD-1.

Characterization of native Bacillus thuringiensis (Bt) isolates and their evaluation for insecticidal activity against Tribolium castaneum (Coleoptera: Tenebrionidae). Fifty one native Bt isolates from various habitats when screened for their insecticidal activity against neonates and adults of red flour beetle Tribolium castaneum, revealed that toxicity ranged from 10% to 46 % on the 7th day of treatment at 10 µg/gm of diet whereas, against adults toxicity ranged from 10% to 63%.

Standardization of mass rearing maggot diet and radiation dose. Stable meridic maggot diets standardized resulted in high pupal production (86.1%) with an adult emergence of 85.33%. Fruit-based diet were shown highest flying ability (84.1%) and fecundity (10.13 eggs/female/ day) with highest egg hatch percentage (85.33%). Healthy adults mass produced are being studied for pre-oviposition period, fecundity and fertility. The Percentage of deformed pupae increased with increased doses of gamma radiation. The adult longevity (days) was also decreased with increased doses of gamma radiation. Egg laying ability of adult female flies that were confined and mated with irradiated males of equal age were 24.66, 22.00, 18.86, 11.00, and 8.33 eggs/female/day at 5, 10, 15, 30 and 50 Gy respectively, compared with 27.66 eggs/female/day for control.

Studies on Endosymbionts. Studies on gut bacterial diversity in developmental stages of whitefly, Bemisia tabaci detected 17 genera with 32 bacterial species belonging to Firmicutes, Alpha-, Beta-, Gamma-proteobacteria and Actinobacteria. The studies have shown significantly higher gut bacterial diversity in Asia II 1 than Asia I populations of B. tabaci. Phylogenetic analysis revealed that about 29 of these isolates may represent novel bacterial phylotypes. Kinetics of Alkaline phosphatase (ALP) activity revealed high affinity of this enzyme to the substrate in Asia I population of B. tabaci. Studies have also shown that B. tabaci Asia I had significantly higher virus transmission efficiency than Asia III populations of B. tabaci with respect to Mungbean Yellow mosaic virus.

5.2.5 Insect Toxicology

Field populations of B tabaci collected from five cotton growing regions of India viz., Sriganganagar (Rajasthan), Ludhiana (Punjab), Khandwa (Madhya Pradesh), Amravati (Maharastra) and Delhi were evaluated against neonicotinoids. Bioassay results clearly indicated a low level of neonicotinoid susceptibility in populations from Sriganganagar, Ludhiana and Amravati which also had high enzyme activity of cytochrome P450. All the populations found to be of Asia II 1 genetic group, whereas laboratory susceptible population collected from wild host, Leucaena leucocephala commonly known as white tamarind was identified to be Asia II 7 genetic group.
**Insecticide Resistance.** Genotyping analysis using molecular markers for phosphine resistance gene, \( rph2 \) detected the prevalence of high level of resistance in 32 populations of *Tribolium castaneum* and 12 populations of *Rhizopertha dominica* collected from seven states across Northern India.

**Response of imidacloprid on foraging activities of pollinators.** Seed treatment with imidacloprid 48% FS (Gaucho® 600 FS) @ 5 g a.i./ kg seed was carried out 24 hr before sowing. Cotton crop was visited by nine Hymenopteran pollinators viz., *Apis dorsata*, *Apis florea*, *Apis mellifera*, *Ceratina smaragdula*, *Nomada solitaria*, *Xylocopa* sp., *Megachile* sp. (Hymenoptera: Megachilidae), *Lasioglossum* sp. (Hymenoptera: Halictidae), *Halictus* sp.; one Coleopteran *Oxyceutonia versicolor*; and two Lepidopteran *Spindalis* sp. These pollinators were regular visitors and stay on floral parts for foraging and gathering of pollen. Differences in foraging activities of pollinators on seed treated and untreated crop was not visible in cotton.

Foliar application of imidacloprid 17.8% SL (Confodor®) was carried out @ 20 and 30 g a.i./ ha after flowering on both seed treated as well as untreated seed crops. Number of foragers relatively declined after foliar application of imidacloprid on cotton as compared to pre-spraying period. Residue of imidacloprid was found to be relatively more on seed treatment + foliar treatment as compared to untreated seed + foliar treatment. Absolutely no residue was detected from floral parts of control plot.

### 5.3 NEMATOLOGY

#### 5.3.1 Molecular Approaches for Nematode Management

**Management of Meloidogyne incognita using RNA interference.** Functional validation using *in vitro* RNAi carried out on *Meloidogyne incognita* with two FMRFamide-like peptide genes, *flp-14* and *flp-18*, and a subventral pharyngeal gland specific gene, *16D10* showed that RNAi silencing of each gene reduced the penetration of *M. incognita* at different time intervals both in combination and individually. Silencing of the genes reduced nematode infection by 23-30% and 26.62% reduction in the number of females. In situ hybridisation revealed the expression of *flp-18* in cells associated with the ventral and retro vesicular ganglia of the central nervous system. Quantification of the mRNA levels using qRT-PCR supported the correlation between phenotypic effects of silencing with that of transcript quantification. T_3 generation plants also exhibited about 70% reduction in the nematode multiplication factor showing its utility in reducing the buildup of population pressure on the subsequent crop.

Another set of brinjal transgenics has been developed for host delivered RNAi of an esophageal gland gene *msp18* of *M. incognita*, and authenticated for gene integration in terms of southern blot hybridization, siRNA generation and performance against *M. incognita*. These transgenics were also found to be effective in reducing the nematode multiplication by about 80%. Transgenic tomato lines (cv. Pusa Ruby) were developed with RNAi constructs of cathepsin-L-cysteine proteinase (*Micpl-1*) gene of the root-knot nematode, *Meloidogyne incognita*. Based on the PCR, Southern, northern
wheat and mungbean are the poor hosts of H. oryzae the population didn’t build further.

5.3.4 Screening of Rice Varieties against Rice Root Knot nematode

Out of six rice varieties screened on soilless medium based on pluronic gel, Suraksha and Vanadna were identified highly resistant to M. graminicola. The study revealed delayed and highly reduced penetration in Vandana and Suraksha along with very few eggs indicating resistant nature. This was further confirmed at molecular level by quantifying the expression of eight defense responsive genes by quantitative real time PCR viz.,

Confirmation of siRNAs of msp18 in T1 brinjal plants expressing dsRNA of msp18 by Northern analysis; Lanes - NC: Negative control (Wild type brinjal plant), 1-5: siRNA samples from T1 transgenic brinjal events. PC-Positive control

Effect of crop rotation with Basmati rice (BR)-Wheat (W)-Summer Mungbean (SMB) / summer fallow (SF) on Hirschmanniella oryzae

wheat and mungbean are the poor hosts of H. oryzae the population didn’t build further.

5.3.2 Nematode Genomics

The transcriptome of a major cyst nematode Heterodera cajani infecting most of the pulse crops in India were sequenced and high quality reads were (94.28%) obtained. This filtered library was assembled and a few assembly results were validated. The de-novo sequence assembly of transcriptome of H. indica IJ using velvet showed 18,710 contigs and after filtering out <300bp reads, 13,593 unique transcripts were identified. H. indica transcriptome when was compared with the available parasitic nematode genome sequences, 9906 and 8892 protein matches were observed with plant parasites, Meloidogyne hapla and M. Incognita, respectively.

5.3.3 Management of Rice Root Nematode in Rice

Cropping systems Basmati rice (BR)-Wheat (W)-Summer Mungbean (SMB) / summer fallow (SF) were evaluated for nematode population. BR-W-SMB induced significant reduction (P=0.05) in the total nematode final population. The population of the nematode remained below the threshold level of <1 nematode/cc soil during the wheat season. Since, both

Stained roots of susceptible and resistant rice varieties PB1121, Suraksha and Vandana showing the life cycle of Meloidogyne graminicola
OsMAPK6, OsMPAK5a and OsMPAK20 involved in signaling, AOS2 responsible for Jasmonic acid synthesis, EDS1 and PAD4 associated with Salicylic acid dependent response; WRKY13 and N1H1 involved in transcription. Ten FMRFamide like neuro peptides were cloned from M. graminicola and subjected to functional genomics by in vitro RNAi for their utility in nematode management. It was observed that flp-1 was the most effective followed by flp-18 in reducing the penetration.

5.3.5 Isolation of Indigenous Entomopathogenic Nematodes from Sugarcane and Horticulture-based Cropping Systems

A total of 315 soil samples were collected from sugarcane fields and orchards in Kurukshetra, Panipat, Rohtak, Hisar and Jind districts of Haryana state. The entomopathogenic nematodes (EPNs) were isolated from the soil samples by insect baiting technique using late instar larvae of Galleria mellonella. Out of 315 soil samples, six (1.9%) were found positive for EPNs. Among these, Heterorhabditis sp. was identified from the soil sample of Kurukshetra and Jind.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Chemo and Bio-prospecting for Agrochemicals through Design, Discovery and Development of Novel Processes and Products

5.4.1.1 Lipase catalyzed solvent-free amidation of phenolic acids

A green method was developed for the synthesis of a series of N-alkyl substituted amides, based on various phenolic acids viz., salicylic acid, 3-hydroxy cinnamic acid, p-coumaric acid, caffeic acid, ferulic acid, o-coumaric acid and cinnamic acid, by the condensation of equimolar amounts of phenolic acids with different alkyl amines such as propyl, hexyl, heptyl, undecyl, hexadecyl and octadecyl amine, in presence of Candida antarctica lipase at 60-90°C in 16-20 h. The yields for different compounds varied between 75.6 - 83.5%. The synthesized compounds were characterized using IR and 1H and 13C NMR.

5.4.1.2 Chemical profiling and nematicidal assay of essential oils from Melaleuca bracteata, Chenopodium ambrosioides and Artemisia scoparia

The essential oils extracted and characterised from the leaves of Melaleuca bracteata, suggested that Melaleuca oil contained a total of thirty compounds (96.37%) and methyleugenol was the major constituent (76.84%). Total of twelve (78.42%) compounds were identified from C. ambrosioides and A. scoparia oils, respectively. The C. ambrosioides oil consists of α-terpinen (40.33%), p-cymene (15.25%), ocimene (11.13%) and ascaridol (5.11%) as major components while A. scoparia oil found to be rich in acenaphthene (23.28%) followed by myrcene (21.77%), trans-ocimene (11.54%), γ-terpinen (8.85%), limonene (8.49%), p-cymene (8.39), α-pinene (2.84%), cis-ocimene (2.27%) and geranyl acetate (1.42%). M. bracteata oil showed antagonistic activity against Meloidogyne graminicola as a fumigant.

5.4.1.3 Fungicidal activity of extract of Podophyllum hexandrum

The dried roots of P. hexandrum were extracted with hexane and methanol and the yield of the extract was found to be 0.31 and 19.4%. The crude extract showed antifungal activity against Macrophomina phaseolina.

5.4.2 Innovations in Agricultural Formulations and Application Technology for Safety and Efficacy

5.4.2.1 Development of superabsorbent polymer based micronutrient (Boron) formulation

Hydrogel based formulations with boron and loading efficiency ranging between 67.7 and 92.2% showed water absorption capacity of 35 to 60 g/g of dry gel formulation. Release studies suggested that formulations behaved as slow release micronutrient formulations and predominant mechanism of boron release was Fickian diffusion with diffusion exponent ranging from 0.11 to 0.32.
5.4.2.2 Preparation of starch-clay composites as carrier materials for pesticides

Mixture of soluble corn starch and insoluble potato starch at 70:30 ratio can give better gelation of the composite. This optimized method will be implemented to prepare composites with the modified clays for preparing slow release formulations of imidacloprid.

5.4.2.3 Rheological investigation of boron formulation based on hydrogel composites

The structure, morphology and mechanical stability of the Kaolin and borax reinforced poly (CMC-g-cl-PAam) superabsorbent composites (KBSAPCs) prepared in situ were characterized by which reveals partial hydrolysis of borax to borate ion (BO$_3$$^-$$^3$) during polymerization reaction causing extensive crosslinking of CMC chains and generation of mechanically strong composites. The study release of BO$_3$$^-$$^3$ from KBSAPCs follows Fickian diffusion mechanism and KBSAPCs with higher mechanical strength resulted in slow release of BO$_3$$^-$$^3$.

5.4.2.4 Hydrogel based phosphate formulations

A slow release hydrogel based phosphate formulations with loading efficiency ranging between 80% and 95% showed water absorption capacity of 175g/g of dry gel formulation. The mechanism of phosphate release was Fickian diffusion. The hydrogel based phosphate formulation (25% RDF) showed enhanced phosphate use efficiency in maize as compare to control.

5.4.2.5 Synthesis and characterization of novel encapsulating materials based on functionalized amphiphilic block copolymers

The synthesis and characterization of eight novel poly ethylene glycols (PEG)-based amphiphilic block copolymers was achieved by reacting PEGs of 600, 1000, 1500 and 2000 molecular weights and dimethyl 5-hydroxyisophthalate. The resulting functionalized amphiphilic polymers characterized by $^1$H and $^{13}$C-NMR spectroscopy, when dissolved in water, aggregated to 26.50 to 85.10 nm micelles and molecular weights were in the range of 8.8×10$^3$ to 8.5×10$^4$ kDa. Critical Micelle Concentrations (CMC) of the synthesized polymers was in the range of 115 to 148 mg l$^{-1}$.

5.4.2.6 Development of controlled release nanoformulations of carbendazim and their bio efficacy evaluation against Rhizoctonia solani

Controlled release (CR) nanoformulations of carbendazim (methyl 1H-benzimidazol-2-ylcarbamate) was prepared and The carbendazim release from CR and commercially available 50% Wettable Powder (WP) when showed maximum release on 35$^{th}$ day for PEG-2000 and tetradecyl chain and 10$^{th}$ day for PEG-600 and heptyl chain in comparison to commercial formulation (7$^{th}$ day). The ($t_{1/2}$) values for carbendazim release ranged between 9.5 to 24.2 days, and the period of optimum availability (POA) of carbendazim ranged from 9.2 to 26.6 days.

5.4.3 Food Safety, Risk Assessment of Crop Protection Products and Residue Management

5.4.3.1 Pesticide risk assessment

Persistence of profenofos in/on cauliflower. Residues of profenofos on cauliflower (var. PSBK1) when used as foliar application were below detectable limit (< 0.005 mg kg$^{-1}$) after 10 and 15 days, after application of profenofos @ 500 and 1000 g a.i. ha$^{-1}$. The Codex limits (MRL) (2009) of profenofos on cauliflower are not available; however the UK MRL is 0.01 mg kg$^{-1}$ on cauliflower.

5.4.4 Environmental Fate of Pesticides

5.4.4.1 Effect of elevated CO$_2$ on persistence of chlothianidin

Delhi and Manipur soil treated with chlothianidin (10 µg g$^{-1}$) at different moisture regimes [dry, field capacity (FC) and submerged (SB)] when subjected to different carbon dioxide levels of 550ppm and 750ppm in controlled chambers indicated that in dry ambient conditions $t_{1/2}$ was 301d and 273.6d in Manipur and Delhi soils, respectively, which decreased to 252.8 and 232.5 d at 750 ppm. The half life varied from 231.5-150.2 d in Manipur soil and 167.2-111.4 d in Delhi soil under FC. Significant effect was observed at 750
ppm level under FC and SB condition on dissipation of chlothianidin.

5.4.4.2 Environmental fate behavior of kresoxim methyl

Adsorption-desorption of kresoxim methyl in five different soils, namely, Delhi (Inceptisol), Nagpur (Vertisol), Kolkata (Inceptisol), Kerala (Ultisol) and Almora (Mollisol) revealed moderate to high adsorption with $K_d$ values of 3.72-29.25. Desorption of kresoxim methyl from soils was slower than the adsorption indicating a hysteresis effect. Leaching studies revealed that in column soil >90% of the kresoxim methyl changed into acid metabolite, which showed more leaching potential than the parent molecule. Increasing the organic matter content of the soil by sludge amendment (5%) reduced the leaching potential of both the compounds. Persistence of kresoxim methyl in soil revealed faster dissipation in alkaline inceptisol. Submergence of soil, sludge amendment, light exposure and elevated CO$_2$ level tend to increase the rate of dissipation.

5.4.4.3 Effect of biochars amendment on pyrazosulfuron-ethyl sorption in a sandy loam soil

Effect of wheat (WBC400 and WBC600) and rice (RBC400 and RBC600) biochars on pyrazosulfuron-ethyl sorption in a sandy loam soil studied at 0.1, 0.2 and 0.5% amendment levels showed that Pyrazosulfuron-ethyl was poorly sorbed in the soil (3.5-8.6%). Biochars prepared at 600 °C were more effective in adsorbing pyrazosulfuron-ethyl than biochars prepared at 400°C. Rice biochars were better than the wheat biochars and higher herbicide adsorption was attributed to the biochar surface area/porosity.

5.4.5 Decontamination Studies

5.4.5.1 Remediation of pesticide contaminated water using magnetic nano-composites

Magnetic nano-composites of Fe$_3$O$_4$ coated with alumina, clay (bentonite), chitosan and PEG were prepared and used as adsorbent for the removal of eight pesticides namely lindane, $\alpha$-endosulfan, $\beta$-endosulfan, endosulfan sulfate, $op$-DDT, $pp$-DDT, pendimethalin and chlorpyrifos from aqueous solution. Results revealed that removal efficiencies of composites prepared with alumina, clay and PEG were 13.6-87.8%, 7.8-82.7% and 7.5-73.6% for different pesticides and is similar to the removal efficiency of magnetic nano Fe$_3$O$_4$ particle (9.1-94.7%).

5.4.5.2 Degradation of atrazine/metabolites in effluent using atrazine degrading enrichment culture

An atrazine degrading enrichment culture was used to degrade atrazine/metabolites in the industrial wastewater at different initial concentrations of the contaminants [wastewater-water (v/v) ratio: T1 - 1:9, T2 - 2:8, T3 - 3:7, T4 - 5:5 and T5 - undiluted effluent]. The initial concentrations of atrazine, cyanuric acid and biuret ranged between 5.32–53.92, 265.6–1805.2 and 1.85–16.12 µg ml$^{-1}$, respectively. The enrichment culture was able to completely degrade atrazine, cyanuric acid and biurat up to T4 treatment, while no appreciable degradation of contaminants was observed in the undiluted effluent (T5).

5.4.5.3 Removal of major dissolved organic contaminants from sewage water by eco-friendly Horizontal sub surface flow (HSSF) and vertical sub surface flow (VSSF) treatment plants of IARI

The study was undertaken to monitor the selected PAHs, PCBs and surfactants in influent and effluent water of the two eco-friendly sewage water treatment plants Horizontal sub surface flow (HSSF) and vertical sub surface flow (VSSF) present in IARI farm. The analysis of influent sewage water showed the presence of all the selected compounds except PCB 44 with concentrations ranging from 18.42-32.18, 4.0-7.70, 2.37-5.46 µg/l and 6.19-8.47 µg/l of naphthalene, phenanthrin, pyrene and benzo (a) anthracene, respectively; 3.91-8.73 µg/l of PCB 52 and 151.9-1026.5 µg/ml of SDS
and 889.1-3163.5 µg/ml of SDBS. Both the sewage water treatment systems were found to remove these contaminants from sewage water. In VSSF, the removal varied from 16-99% whereas in HSSF system, the removal of contaminants varied from 20-95%. In both the system, higher removal was recorded for naphthalene than other PAHs. Among the surfactant, SDBS showed higher removal than SDS. Both the treatment systems were found to efficient in removing the selected contaminants (four PAHs, one PCBs and two surfactants).

5.4.6 Analytical Methods

5.4.6.1 Optimisation of LC and MS parameters for multi-residue method development for vegetables

LC and MS instrumental parameters were optimized for 50 pesticides commonly used on vegetables using Shimadzu LCMS-8030 instrument equipped with Zorbax Eclipse Plus C-18 column (Agilent) (3 × 100 mm, 3.5 µ), Mobile phase A: 80:20 5mM ammonium formate: MeOH; B: 90:10 MeOH: 5mM ammonium formate. Gradient mobile phase programming from 45% to 100% of mobile phase B, flow rate 0.2 ml min⁻¹, run time 23 min. MS parameters were: Electron spray ionization (ESI) in positive and negative mode, DL temperature 120°C, heat block temperature 300 °C, nebulising gas flow 3L min⁻¹, drying gas flow 15 l min⁻¹. Six point calibration curve for different pesticides was prepared in the concentration range 0.1-200 ppb. Instrument sensitivity of 2-10 ppb with 10 µl injection volume was achieved for different pesticides. The method was validated for cabbage, cauliflower and brinjal at 10 and 50 ppb fortification level with six replications at each level. Even at 10 ppb fortification level the average recoveries were 77-90%, 73-96% and 76-94% with the RSD of <15%. The developed MRM was found to be simple, sensitive, and repeatable and hence can be used to monitor the residues of these pesticides in vegetable samples meant for export/domestic market.

5.4.6.2 Flucetosulfuron herbicide in soil and rice

Residue analysis method for Flucetosulfuron a new post-emergence sulfonyl urea herbicide for the control of broadleaf weeds, some grassy weeds and sedges in rice and cereal crops has been developed. Standardized method gave 92% recovery of herbicide from soil and 73-75% for plant samples (straw and grain). LOD and LOQ of the method for soil were 0.01 and 0.05 µg g⁻¹ while for straw and grains were 0.05 and 0.1µg g⁻¹, respectively.

5.4.6.3 Methods for analysis of PAH, PCB and surfactants in sewage water

Method was standardised for analysis of PAH and PCB using GC-MS and surfactants by LC-MS-MS. Retention time of PAHs Naphthalene, Phenanthrene, Pyrene and Benzo(a)anthracene was 7.72, 15.34, 18.54 and 21.54 min and PCBs code 52 and 44 was 16.87 and 17.24 min, respectively.

5.5 WEED MANAGEMENT

5.5.1 Integrated Weed Management in Conservation Agriculture (CA)-based Direct-seeded Rice-wheat System

Conservation agriculture (CA)-based direct-seeded rice (DSR)-ZT wheat system is a promising alternative to the conventional transplanted rice-wheat system, but encounters heavy weed infestation. The management of weed is very crucial for the success of DSR. Weed control treatments such as pendimethalin 1.5 kg/ha (pre-em) + bispyribac-Na 25 g/ha at 25 DAS + hand weeding (HW) at 45 DAS and pendimethalin 1.5 kg/ha (pre-em) + bispyribac-Na 25 g/ha at 25 DAS resulted in better weed control in rice and higher system productivity than weedy check. Among CA-based treatments, a system of DSR with summer mungbean residue (SMB) - rice residue (RR) retention in ZTW –summer mungbean (SMB) gave significantly higher system productivity than that in TPR- CTW/ZTW. This treatment also recorded highest values of microbial biomass carbon (MBC) in both rice and wheat, which was significantly higher than rest of the treatments.
5.5.2 Weed Management in Chilli (*Capsicum annuum*)

A study on integrated weed management was undertaken in chilli under conventional tillage (CT) and zero tillage (ZT) with residue combined with seven weed control treatments such as pendimethalin 1.0 kg/ha as pre-emergence; pendimethalin 0.75 kg/ha + oxyfluorfen 0.15 kg/ha as tank-mix pre-emergence; pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha as tank-mix pre-emergence; pendimethalin 0.75 kg/ha as pre-emergence followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT; pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAT; weedy check; and weed-free check. Among the tillage practices, zero tillage with residue (ZT) was superior to conventional tillage, reducing weed competition/growth, and increasing chilli yield, net returns, and benefit:cost. The pre-emergence tank-mix application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha resulted in higher weed control efficacy (85.6%), chilli yield, net returns and benefit:cost. This reduces the application cost of pendimethalin and imazethapyr by 50%, and their doses and residues by 25% in agro-ecosystems.

5.5.3 Weed Management in Garlic (*Allium sativum*)

A study on integrated weed management undertaken in garlic under conventional till flatbed (CTFB) and furrow-irrigated raised bed (FIRBS) combined with seven weed control treatments such as pendimethalin 1.0 kg/ha as pre-emergence; pendimethalin 0.75 kg/ha + atrazine 0.75 kg/ha as tank-mix pre-emergence; pendimethalin 0.75 kg/ha + oxyfluorfen 0.15 kg/ha at 30 DAT; pendimethalin 0.75 kg/ha as pre-emergence followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT; pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAT; weedy check; and weed-free check. Among the tillage practices, zero tillage with residue (ZT) was superior to conventional tillage, reducing weed competition/growth, and increasing garlic yield, net returns, and benefit:cost. The pre-emergence tank-mix application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha resulted in higher weed control efficacy (85.6%), garlic yield, net returns and benefit:cost. This reduces the application cost of pendimethalin and imazethapyr by 50%, and their doses and residues by 25% in agro-ecosystems.
imazethapyr 0.075 kg/ha as tank-mix pre-emergence; pendimethalin 0.75 kg/ha as pre-emergence followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT; pendimethalin 0.75 kg/ha + oxyfluorfen 0.2 kg/ha as tank-mix pre-emergence; weedy check; and weed-free check, showed that pre-emergence tank-mix application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha was superior to all herbicide treatments, reducing weed density and dry weight and the uptake of N, P and K by weeds.

5.5.4 Weed and Nitrogen Management in Conservation Agriculture-based Maize-Wheat System under Zero-till Residue Retention Conditions

A field experiment was undertaken in the CA-based maize-wheat system under zero-till residue retention conditions with treatments comprised of four N treatments [N1 (100% N basal application); N2 (50% + 25% + 25% N-Green Seeker (GS)-guided N application); N3 (50% + 50% N GS-guided N application); N4 (80% + 20% N-GS-guided N application)] and three weed management treatments [W1(weedy check); W2 (pendimenthalin + atrazine); W3 (brown manuring)]. The results showed that the split application of N guided by Green Seeker (GS) and brown manuring weed management strategy resulted in an efficient N and herbicide use economy. The brown manuring significantly suppressed weed growth and a 27-45% lower weed dry matter was observed in the GS-guided (N3 and N2) treatments. An increase in maize yield to the tune of 17-45% achieved in the GS-guided 50% N (basal) + 25% N (broadcasts 30 DAS) + 25% N (GS-guided foliar spray) at various weed management options, when compared with 100% basal N. The soil structural quality index as a function of reduced bulk density was significantly greater in GS-guided N management, which signifies increase organic matter accumulation. This CA-based practice showed a greater prospects of reducing fertilizer N and herbicide applications in CA system with greater productivity, improved soil structural quality and suppressed weed limiting effects on maize crop.

5.5.5 Effect of Pre and Post-emergence Herbicides on Seed Productivity and Quality of Pigeonpea

The major weeds present in experimental field were Commelina benghalensis, Trianthema portulacustrum, Digeria arvensis (broadleaf weeds) followed by grasses and sedges like Dactyloloxiaceae aegyptiacum and Cyperus rotundus, respectively. All the pre and post emergence herbicides followed by (fb) one hand weeding and sequential application of pre-emergence pendimethalin fb post emergence imazethapyr and quizalofop recorded significantly higher seed yield compared to weedy check and at par with weed free treatment.

5.5.6 Effect of Integrated Weed Management on Seed Productivity and Quality of Lentil

Seed crop of lentil is infested heavily by broadleaf and grassy weeds. It demands special attention due to its shorter height and slow initial growth. Significantly lower weed density and weed dry weight were recorded in pre emergence Pendimethalin @ 1.0 l/ha followed by hand weeding at 45DAS both at 30 and 45 days after sowing, respectively. There was reduction of 66.2, 65.1 and 64.3% in seed yield under uncontrolled weedy conditions compared to weed free, Pendimethalin @ 1.0 l/ha fb Imazethapyr 75 g/ha and Pre emergence Pendimethalin @ 1.0 l/ha fb hand weeding at 45DAS. Both these herbicidal treatments recorded higher seed yield due to their higher weed control efficiencies. Seed germination was not affected by the application of different herbicides, hence can be used for weed control in lentil seed crop.
6. BASIC AND STRATEGIC RESEARCH

The basic and strategic research at IARI during this year focused identification of novel genes and mapping of QTLs for biotic and abiotic stress tolerance and quality in various crops by using various genomics tools. Genes for rust resistance were mapped in wild relative of wheat and transferred to cultivated wheat. Significant progress has been made in combining QTLs for drought and heat tolerance by marker assisted recurrent selection (MARS) and genomic selection for drought tolerance. Genes for quality traits such as pro-vitamin A, mineral content and processing quality have been mapped in different crops. Transcriptomics and functional genomics studies led to the identification of miR430 involved in heat tolerance of wheat, oxygen sensing mechanisms under waterlogged conditions in maize and ABA receptor gene involved in drought tolerance of rice. Transgenic soybean with reduced phytate content was developed to enhance the nutritive value of soybean. Studies on natural resources characterization mitigation studies on climate change, development of remote sensing and GIS techniques for assessment and management of crops and natural resources have made significant progress. This section briefly covers some of the significant achievements in these areas.

6.1 GENOMIC AND MOLECULAR BIOLOGY

6.1.1 Gene Discovery and Genomic Analyses

6.1.1.1 Identification of miR430 as a regulator of heat tolerance in wheat

Heat stress drastically affects wheat yield in India. Small RNA transcriptome analysis of thermotolerant wheat cv. HD 2985 led to the identification of heat stress regulated micro RNA 430 which regulates small heat shock proteins (HSP 17 and HSP 26) and protein kinases (CDPK and MAPK). Significant variation in expression of miR430 was observed in root, stem and spike tissues under control and heat stress. A negative correlation between the expression of miR430 and its target genes was observed in different tissues of wheat under heat stress.

6.1.1.2 Expression analysis of starch biosynthesis pathway genes in wheat

Starch biosynthesis is highly sensitive to heat stress in wheat. The key enzymes of starch synthesis namely AGPase, soluble starch synthase (SSS) and starch branching enzyme (SBE) have many isoforms in different crops. However these gene families have not been fully characterized in wheat. Transcriptome comparison of leaf and spike of wheat cultivars (HD 2985, heat tolerant) and HD 2329 (heat susceptible) under controlled and heat stressed conditions resulted in the identification of 5 putative AGPase, 12 putative SSS and 8 putative SBE transcripts. Real-time PCR analysis of these genes showed that heat stress mediated decrease in the expression of AGPase and SSS is smaller in heat tolerant cultivar than that is experienced in the susceptible genotype.

6.1.1.3 Epigenetic variation in contrasting wheat genotypes under salt stress

High-affinity potassium transporter (HKT) genes show differential regulation in salt-tolerant (Kharchia 65 and KRL 10) and salt-sensitive (HD 2329 and WH 542) wheat genotypes under salt stress. To understand molecular basis of genotypic differences in gene regulation, global methylation status was analyzed. Salt stress caused up to 18% increase in cytosine methylation over the control in roots of Kharchia 65, while in roots of salt sensitive HD 2329 showed only 1% increase in cytosine methylation under salt stress as compared with control.
6.1.1.4 Understanding the oxygen sensing mechanisms under waterlogged conditions in maize

To understand the mechanism of waterlogging tolerance, whole-genome RNA sequencing assay was carried out in HKI 1105, a tolerant maize genotype. Tissue samples from shoot and root of the stress and control were collected from HKI 1105 for RNAseq. This analysis identified genes for aeranchyma formation including ethylene synthesis (ACC synthase and ACC oxidase), N-end rule pathway (ERF VII, Methionine aminopeptidase, Arginyl-tRNA-protein transferase, E3 ubiquitin ligases, 26S proteasome, cysteine oxidases) and programmed cell death (Plant aspartic protease A3, SOMBRERO/ANAC033 TF, Respiratory Burst Oxidase Homolog, Metallothionein). ERF VII pathway is considered as an important pathway for oxygen sensing mechanisms. Further, several genes for aerobic and anaerobic metabolism were regulated by waterlogging.

6.1.2 Functional Validation of Genes for Nutritional Quality and Abiotic Stress Tolerance

6.1.2.1 Enhancing nutritional quality of soybean by reducing seed phytate content

Reduction of seed phytate content is a promising approach for increasing mineral and protein bioavailability from soybean and rice. RNAi cassette for silencing MIPS gene and overexpression of phytase gene using seed specific promoters were prepared and transgenic soybean lines were developed. Stable integration of the transgenes, down regulation of MIPS gene and up regulation of phytase gene in transgenic soybean (T1-T4) were confirmed by molecular analyses. Upton 40% reduction in phytic acid content was observed in seeds of transgenic (T4) soybean co-transformed with phytase and MIPS cassettes. Transgenic soybean seeds with reduced phytate content showed improved bioavailability of iron (increased by 19.1%), zinc (9.9%) and calcium (11.7%). No negative effect was observed on seed germination or emergence in any of the transgensics.

6.1.2.2 Overexpression of ABA receptor gene enhances drought tolerance in rice

Genes encoding the hormone abscisic acid (ABA) receptors (ABARs) were selected as candidate genes to identify their role in water use efficiency (WUE) and drought stress tolerance of rice. Rice transgenics overexpressing OsABAR6 under transcriptional control of under stress inducible AtRD29A promoter were developed and confirmed by molecular analysis. Five independent events of $P_{AtRD29A}::OsABAR6$ transgenic lines were evaluated for their drought tolerance at vegetative stage under transgenic greenhouse conditions. Sixty days old plants grown in the same pot were subjected to drought stress till the soil matric potential reached to -90 kPa, and then the plants were recovered by rewatering. The ABAR6 transgenic rice plants maintained better relative water content, membrane stability, chlorophyll content and photosynthesis under drought stress as compared with WT plants, and showed better drought tolerance.
6.2 BIOCHEMISTRY

6.2.1 Off-flavour Reduction in Soybean

6.2.2.1 Use of biotic elicitors for off-flavour reduction

Seeds of soybean genotypes with contrasting off-flavour generation potential (SL 525 and EC 109514) treated with biotic elicitors (jasmonic acid, chitosan and salicylic acid) significantly reduced the off-flavour components like LOX activity, TBA number and protein oxidation. Jasmonic acid treatment was observed to be the best treatment and EC 109514 genotype showed best response. The residual phospholipid content showed direct correlation with TBA number. Chitosan and jasmonic acid treatments significantly reduced the levels of residual phospholipid and TBA number. Thus, treatment with biotic elicitor may be an important strategy to reduce of-flavour generation in soymoal.

6.2.2.2 Role of oleosin proteins in off-flavour generation

Poly-unsaturated fatty acids (PUFAs) are considered to be the principal contributors to off-flavour generation in soybean and its products. However soymeal containing low level of PUFAs produces significantly high levels of off-flavour. Two low molecular weight (18 kDa and 24 kDa) oleosin proteins with phospholipase A2 activity were isolated from oil bodies of soybean seeds and found to be involved in off-flavour generation.

6.3 PLANT PHYSIOLOGY

6.3.1 Phenotyping of Rice Genotypes for High Temperature Stress Tolerance

Rice is highly sensitive to high temperature stress at flowering as compared to vegetative stage. High temperature reduces yield due to reduced pollen viability and spikelet fertility. Thirty six rice genotypes drawn under normal conditions were shifted to greenhouse (day temperature 38.3±0.47°C) at booting stage, and were analyzed for pollen viability and spikelet fertility under high temperature stress. Pollen viability was analyzed using fluorescent microscopic images. Genotypes with contrasting tolerance to heat stress were identified.

In addition to day temperature, increase in night temperature also causes adverse effect on rice production. To quantify the impact of night temperature variation on rice physiology, 18 rice cultivars were phenotyped for tolerance to moderate increase in night temperature, i.e. 1.5°C higher temperature over 24°C mean minimum temperature during the growing season. High night temperature (HNT) resulted in manifold increase in flag leaf night respiration rates accompanied by reduction in biomass in all the cultivars. Genotypes like Nerica L44 showed 14% increase in yield under HNT followed by Pusa Sugandh 5 (11%) and Nagina 22 (8%), while 11-37% decrease in seed yield/plant was observed in sensitive cultivars.

6.3.2 Root System Architecture for Enhancing Drought Tolerance in Wheat

Genotypic variation in root growth in wheat was studied by trench profile wall method after anthesis
stage in 33 wheat genotypes. In the deep soil zone (31-50 cm), HI 1500, Raj 3765, HD 2687, HUW 468, HD 2932, HI 1531 and WH 730 showed higher root density as compared with other genotypes. Analysis of seminal root angle in the agar gel media revealed wider variability in the seminal root angle from 25° to 87°. The relatively drought tolerant genotypes viz., N 59, HD 2985, DBW 14 and C 306 showed narrow root angles as compared to the genotypes bred for irrigated conditions e.g. HD 2967, HD 2643, HD 2285 and HD 2824.

6.3.3 Molecular Characterization of Stay-green Trait under Drought Stress in Wheat

To understand the association of cytokinin accumulation and its association with staygreen trait under drought stress in wheat, expression profiling of genes associated with Cytokinin biosynthesis TalPT5 (Isopentenyl transferase 5) and TalPT9 (Isopentenyl transferase 9), and degradation CKX (Cytokinin oxidase/dehydrogenase) gene were analysed in wheat genotypes with functional staygreen trait and fast senescence. Drought induced reduction in transcript levels of TalPT5 and TalPT9 were minimal in functional staygreen genotypes as compared with non staygreen drought susceptible genotypes. Expression analysis of CKX homologs in two functional staygreen (HW 2041 and CHIRY A7) and two non-staygreen drought susceptible genotypes (HW 2033 and CBW38) genotypes revealed that staygreen genotypes maintain the threshold level of cytokinin under drought stress by maintaining expression IPT genes and lower expression of CKX genes.

6.3.4 Plant Growth Regulators Improve Abiotic Stress Tolerance in Wheat and Chickpea

Foliar application of salicylic acid (SA, 0.7 mM) and Benzyl amino purine (BAP, 10 µM) at anthesis in wheat crop grown under drought and irrigated conditions significantly mitigated the deleterious effect of moisture-deficit stress and enhanced growth characteristics, RWC, membrane stability index, contents of chlorophyll, proline and ascorbic acid, and antioxidant enzymes viz. SOD, catalase and peroxidase. Wheat genotypes HI 8731, HI 1581, C 306, NI 5439, and RAJ 4083 showed better response to both the treatments.

To analyze the protective role of SA in alleviating high temperature stress, wheat plants at crown-root initiation stage were treated with 0.25 mM of SA, and then were subjected to heat stress (39 ± 2°C) for 36h. SA treated wheat plants maintained higher chlorophyll content, antioxidant enzyme activities, PSII yield, and net photosynthetic rate and exhibited enhanced expression of TapsbA (D1 protein), TapsbO (oxygen evolving complex) and TarbcS (Rubisco SSU) genes under heat stress as compared with that of plants heat stressed

RT-PCR expression analysis of TapsbA, TarbcS and TapsbO genes in wheat leaves. Lane-1, 100bp DNA marker; Lane-2, control 25±2°C; Lane-3, heat stress 39 ±2°C; lane -4, heat stress+foliar spray of SA 0.25 mM
without SA treatment. These results suggest that SA can protect the PSI complex from photo-damage through enhanced ROS detoxification and expression of \textit{TapsbA} and \textit{TapsbO} genes in wheat under heat stress.

Paclobutrazol (PBZ)-mediated amelioration of drought stress was studied in Pusa 362 (Desi) and Pusa1108 (Kabuli) genotypes of in chickpea. PBZ-treated (foliar spray 60 ppm/ drenching 120 ppm) plants maintained higher RWC, MSI, photosynthetic activity, photosynthetic pigments and antioxidant enzymes activity and thus maintained the integrity of chloroplast structure under drought stress.

### 6.3.5 Physiology of N and P Use Efficiency

Previously we cloned high affinity nitrate transporter \textit{NRT2.1} from mustard. To validate the function, plant transformation construct was developed (\textit{pBI121-35S::BjNRT2.1}). Tomato plants cv. Pusa Ruby was transformed with this construct and T1 plants expressing \textit{BjNRT2.1} were obtained. The overexpression of 35S::BjNRT2.1 in tomato plants is showing typical symptom of severe Fe deficiency which was restored after foliar spray of 0.2% FeSO\textsubscript{4}, thus confirming that it is Fe deficiency. To confirm the N and P stress tolerance of maize inbreds (CM137, CM138, HKI 1105 and HKI 323), reciprocal crosses were made. The \textit{F\textsubscript{1}} plants were phenotyped under low-N, low-P and low-NP and control in hydroponics conditions. All \textit{F\textsubscript{1}} hybrids maintained biomass comparable to that of control under NP deficiency.

### 6.4 GENETICS

#### 6.4.1 Wheat

##### 6.4.1.1 Combining QTLs for drought and heat tolerance by marker assisted recurrent selection (MARS)

Four MARS populations were generated from four biparental crosses and a total of about 750-800 \textit{F\textsubscript{3}} families were obtained which were subsequently used for interfamily matings. Elite genotypes were selected after multi-location evaluation under drought and restricted irrigation regimes. The crosses were advanced to \textit{F\textsubscript{5}} generation. MARS was exercised for drought and heat tolerance by conducting multi-location phenotyping at four target locations (IARI, New Delhi, ARI, Pune, JNKVV, Powarkheda and PAU, Ludhiana) under rainfed and irrigated conditions. During crop season, individual intermated progenies, single crosses, double crosses and base MARS populations were screened under rainfed and restricted irrigated conditions. Data was recorded according to the trait dictionary of CIMMYT for early vigour, days to heading, flag leaf emergence, CC values at vegetative and reproductive stage, canopy temperature at vegetative and reproductive stage, NDVI, chlorophyll fluorescence, flag leaf area, yield and related traits. The polymorphic markers linked to desirable QTLs putatively mapped were used to confirm the introgression of QTLs. New QTLs were also identified among the \textit{F\textsubscript{4}} base populations by employing marker-trait associations. The best progenies were selected on the basis of multi-location data and SSR markers linked to stress adaptive traits. In these MARS populations, the single nucleotide polymorphism (SNP) genotyping is being carried out for enabling the identification of QTLs with higher resolution.

##### 6.4.1.2 Introgression of QTLs into high-yielding wheat cultivars through backcross breeding

Elite Indian varieties HD 2733 and GW 322 from North-eastern plains zone and Central zone, and still covering a major share of breeder’s seed indent, are targeted for introgression of QTLs for drought and heat tolerance. High-yielding recurrent parent background selection was carried out using SSR markers. Marker-assisted foreground selection was carried out by tracking QTLs linked to physiological traits and agronomic traits for drought and heat tolerance. Backcross populations were advanced to BC\textsubscript{1}/BC\textsubscript{2} \textit{F\textsubscript{2}} after tracking QTLs for fore-ground selection. The lines with more than 90% recurrent parent background recovered in BC\textsubscript{1} \textit{F\textsubscript{1}} and BC\textsubscript{2}
F₁ progenies were selfed and carried forward for development of homozygous lines. The selfed BC₁F₂ and BC₂F₂ homozygous lines were advanced for seed multiplication and homogeneity phenotyping.

6.4.1.3 Mapping and marker assisted transfer of rust resistance genes

About 5100 plants in different generations (BC₁F₁, BC₂F₁, BC₃F₁, BC₄F₁, BC₂F₂, BC₂F₃, BC₂F₄) of interspecific crosses involving T. militinae, Ae. markgrafii, Ae. speltoides, Ae. geniculata, Ae. variabilis, T. timopheevii and T. spelta were screened against leaf rust pathotype 77-5. Mapping populations from interspecific derivatives viz., ER1, ER9 (Ae. markgrafii), Sel.2427 (Ae. speltoides) were phenotyped for rust resistance. Genetic analysis of Ae. markgrafii derivative ER9 revealed a single dominant gene for leaf rust resistance at seedling stage. A novel recessive gene LrSel.G12 for leaf rust resistance was mapped in T. timopheevii derivative “Selection G12”. This gene was mapped to chromosome 3BL linked to two microsatellite markers Xgwm114 and Xgwm547 with distances of 28.3cM proximal and 6cM distal to the gene, respectively. Work was initiated to reduce the alien segment size of Secale chromosome carrying Lr45 in translocation 2A.2RS-2RL. Nine nullisomic plants were identified from 5B monosomic plants carrying Lr45 and backcrossed with bread wheat.

Plants with multiple rust resistance genes were selected in genetic background of elite cv. HD 2733, HD 2932 and HD 2967. Rust resistance genes Yr10 and Yr15 were transferred in genetic background of HD 2851. Leaf rust resistance gene Lr45 is being transferred in several genetic backgrounds using molecular markers developed by IARI.

6.4.1.4 Wheat grain quality

A biparental mapping population (WH 542/T.dicoccom PI94624/Ae.squarrosa (409)//BCN) consisting of 286 RILs grown in six environments was phenotyped for grain micronutrients. Grain Zn and Fe concentration traits were significantly associated (r²=0.67) with each other. Out of the 910 SSRs screened, only 138 showed a Mendelian segregation in the sub-set of 286 RILs. Linkage analysis led to the identification of 10 QTLs for iron and zinc of which six were found to be common to iron and zinc traits and were stable over environments. As many as 47 markers linked to QTLs for Zn and 27 markers linked to Fe concentration have been reported in wheat. 39 SSR markers linked to the QTLs were used for validating them in a set of 96 lines. Only six of the markers linked to QTLs for Fe and Zn could be validated. Eighteen molecular markers related to gluten strength eg. High and Low-molecular weight glutenin subunit and those for puroindoline genes (controlling grain hardness) were validated. These markers are being used for screening a set of 180 lines known for specific end-use quality. The results showed that the Indian wheat varieties do not have the right allelic combinations of the HMW-, LMW-GS and puroinoline alleles for optimum end-use quality. Initial crosses for MAS based development of superior quality wheat have been made in 2015.

6.4.2 Genetic Analysis of Resistance to Bakanae Disease in Rice

The genetic analysis of resistance to rice Bakanae disease caused by Fusarium fujikuroi was carried out under artificial inoculation condition in the cross between the highly susceptible variety Pusa Basmati 1121 and resistant genotype Pusa 1342 showed that the resistance to Bakanae is governed by a single recessive gene.
6.4.3 Maize

6.4.3.1 Understanding the effect of opaque16 allele on endosperm modification

The F1s of single crosses divergent for different opaque alleles with O2o2/O16o16 and O2O2/O16o16 combinations of inbreds parents received from Guizhou Institute of Upland Food Crops, Guizhou Academy of Agricultural Sciences, China were selfed to generate F2 generation. F2 seeds were scored for endosperm modification, and it suggested that opaque16 alone does not affect any kernel modification.

6.4.3.2 Genomic selection for drought tolerance

Data generated from a set of 240 maize subtropical lines phenotyped for seven agronomic traits at three locations under drought stress conditions were used in genomic selection (GS) models. Predictive abilities of seven models–ridge regression, LASSO, elastic net, random forest, reproducing kernel Hilbert space, Bayes A and Bayes B have been tested at 30,000 SNP loci across the maize genome. Bayes B had outperformed other six GS models with highest prediction accuracy of 0.97 and eventually selected for further analysis. A set of top 100 SNPs were selected from seven different traits at three locations to understand their marker contribution from Bayes B model. This exercise produced a total of 1053 unique SNPs with higher marker effects for the respective traits, of which 77 SNPs mapped ten drought-responsive transcription factors in their vicinity. These transcription factors were associated with different physiological and molecular functions – stomatal closure, root development, hormonal signaling and photosynthesis. The result of the experiment is important for predicting hybrid performance under drought stress.

6.4.4 Pearl Millet

6.4.4.1 Stability for iron and zinc over years

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. It may be because of reduced seed set in selfed grains leading to accumulation of nutrients in them. Stable genotypes which showed more than 70 mg/kg iron content are HHVB 15, PPMI 605, PPMI 275, TPR 11, PPMI 662 and NPMIE 2. Stable genotypes which showed more than 60 mg/kg zinc content are PPMI 708, PPMI 484, TPR 11, PPMI 699, PPMI 724 and WGI 8. Six mapping populations for mapping genes/ QTLs for downy mildew resistance, high grain iron and zinc and thick spike characters were advanced which are at different stages in RIL development ranging from F5 to BC2F3.

6.4.4.2 Fertility restoration for A1 cytoplasm in pearl millet

Inheritance of fertility restoration of the A1 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). The F1 plants of all the six crosses were selfed to produce F2 seed and simultaneously crossed to their corresponding genotypes to produce backcross generations.
A lines to produce BC₁F₁ seeds in summer 2013 at ICRISAT, Hyderabad. The parents, F₁, F₂ and BC₁F₁ populations were planted in 2013 rainy season at Delhi and in summer season 2014 at Delhi and Dharwad. Crosses 576A/IPC 1518, 411A/IPC 1518, 576A/ICMR 06111 and 411A/ICMR 06111 showed a segregation ratio of fertile: semi-fertile: sterile as 9:3:4 and 1:1:2 in F₂ and BC₁ generations, respectively, for pollen fertility, indicating involvement of the digenic supplementary or an epistasis with recessive gene action for these crosses. In the other two crosses, where a different restorer HTP 94/54 was crossed with the same CMS lines 576A and 411A as earlier, different digenic ratios of fertile: sterile of 9:7 and 1:3 in F₂ and BC₁ generations, respectively, were obtained for pollen fertility, indicating involvement of two genes interacting in complementary manner. Data of summer season Delhi 2014 did not fit any ratio, probably due to the high temperatures and low humidity caused reduction in the pollen fertility thereby distorting the ratios. Thus, fertility restoration of A₁ CMS system in pearl millet was governed by two major genes but with different types of epistatic interactions in different genetic backgrounds.

6.4.5 Brassica

6.4.5.1 Tagging of white rust resistance gene

Using a F₇ RIL mapping population derived from cross Varuna x Bio-YSR, an SSR marker BRMS006 was tagged at a distance of 10.2cM from the gene of interest governing white rust resistance. Mapping populations for white rust resistance were advanced for developing RILs which are in different stages from F₆ to F₈.

6.4.5.2 Genetics of abiotic stress 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. Three mapping populations for mapping genes/ QTLs for drought tolerance were advanced for developing RILs which are in F₆ to F₈ stages.

6.4.5.3 Molecular marker selection for double low/ single low traits

For introgression of low glucosinolates in two low erucic acid varieties, out of 3703 single plants selected on morphological resemblance to their respective recurrent parents during 2013-14, 150 single plants of two BC₄F₄ (LES-39 x EC 597325 and LES-1-27 x EC-597325) and BC₃F₄ generated through marker assisted backcross breeding (MABB) were selected based on genotypic and phenotypic data. These lines were raised as single plant progenies under net conditions along with their recurrent parents in augmented design. Phenotypically uniform progenies have been bulked and superior progenies with double low traits will be further evaluated in replicated trials.

For identifying low erucic acid and double low genotypes from various breeding populations, maintenance breeding of double and single low varieties and advance lines and for various genetic studies, a large number of single plants and bulks are phenotyped through biochemical analysis. Total 4885 single plants/bulks from quality breeding programme were screened for fatty acid profile of which 4366 were found to be having less than 2% erucic acid. 4571 single plants with low erucic acid (<2%) among which 622 plants were possessing <30 ppm glucosinolate, which were carried forward as double zero selections.

6.4.6 Soybean

6.4.6.1 MAS for KTI-free genotype

To develop trypsin inhibitor free soybean, MABB approach was used to introgress the null allele of Kunitz trypsin inhibitors (kti) from PI 542044. Four advanced breeding lines have been developed which showed phenotypic resemblance to the recurrent parent DS 9712 and the seeds were found to be free from KTI peptides.
6.4.6.2 Genetics of maturity duration

An extra-early genotype (Exo148) was crossed with a late-maturing (120 days) genotype (DS 9712). The F₁ plants exhibited intermediate duration of maturing (90-100 days). However, in the F₂ generation, the plants segregated from early maturity (64 days) to late maturity (120 days) indicating it to be controlled by more than one gene. Mapping of this trait with SSR marker is in progress.

6.4.7 Pulses

To identify QTLs associated with grain Fe and Zn concentration in lentil through association mapping, genotyping with 495 SSR markers were used to analyze the genetic diversity of 336 accessions. A single dominant gene conferring drought tolerance in PDL-2 based on seedling survivability identified. Transcriptome analysis of drought tolerant (PDL 2) and drought sensitive genotypes (JL 3) is under progress.

Genetic diversity in 86 accessions of six species of genus Lens was assessed using 12 genomic and 31 EST-SSR markers. Genomic SSRs exhibited higher polymorphism in comparison to EST SSRs. GLLC 598 produced 5 alleles with highest gene diversity value of 0.80. Among the studied subspecies 43 SSR detected maximum number of alleles in L. orientalis. Based on Nei’s genetic distance cultivated lentil L. culinaris subsp. culinaris was found to be close to L. orientalis. The Prichard’s structure of 86 genotypes distinguished different subspecies.

A set of 251 simple sequence repeat (SSR) primers was developed from 9531 EST sequences downloaded from National Centre for Biotechnology Information Database. PCR primers were designed from 106 sequences and evaluated on 73 genotypes of different Lens species. Of these, 29 (27.5%) primer pairs produced polymorphic amplification and detected 99 alleles. Based on UPGMA cluster analysis all the genotypes were grouped in three clusters at similarity level of 0.30. The high level of polymorphism of EST-SSRs and their transferability to related wild species indicate promise for their application to molecular mapping, comparative genomic studies and marker assisted selection.

6.4.8 Cauliflower

6.4.8.1 Black rot and downy mildew resistance

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 validated for black rot resistance in segregating generations of cauliflower.

For introgression of black rot resistance gene from alien species in to cauliflower, evaluation of Brassica species showed that B. juncea (Pusa Bold and Pusa Vijay), B. nigra (BNR IC 56072, IC 247, EC 289661, IC 560690 and Sangam), B. oxyrhina and B. carinata (NPC 9) were resistant to black rot disease (Xcc C1) on artificial inoculation. The BC₁ generated from B. carinata (NPC 9) using embryo rescue technology showed morphological variations for vegetative and floral characters. Giant pollen, most likely formed from unreduced gametes, was more viable than normal pollen in F₁ hybrid of Cauliflower x Ethiopian mustard (NPC 9). Inter-specific crosses were attempted with cauliflower to alien Brassica species viz., B. nigra (IC 56072) and B. juncea (Pusa Vijaya) to transfer black rot resistance. The advancing of the crosses is in progress through embryo rescue technique.

Two flanking SSR markers BoGMS1330 193/183 and BoGMS1322 26/116 were found to be linked to downy mildew resistance gene Ppa3 at 4.3 and 8.6 cM distance, respectively.
6.4.8.2 Alien sterile cytoplasm introgression in cauliflower

F₁ inter-specific plants were developed through embryo rescue technique involving cauliflower in crosses with *Trachystoma balli*, *Diplotaxis sifolia*, *Diplotaxis catholica*, *Moricandia arvensis* and *Erucastrum canariense* in order to transfer sterile cytoplasm from these alien species into cauliflower.

6.4.8.3 Enhancing \( \beta \) carotene content in cauliflower by introgressing native Or gene

Elite horticulturally desirable events with introgressed ‘Or’ gene obtained in early (Pusa Meghna, CC 14 & DC 41-5) and mid (Pusa Sharad, CC 35 & DC 18-19) maturity Indian cauliflower background in B₃C₂F₂/BC₃F₁. Out of 900 SSR markers screened for background selection, 125 were found to be polymorphic across six different genetic backgrounds of Indian cauliflower. For foreground selection, SCAR marker SA4 was used. Twelve codominant markers, namely BoSF2304b, BoGMS0662, FITO095, BoSF460, OLIH06, BoGMS 0624, OL10D08, BoSF 1245, BoSF2564, CB10534, BoSF2371 and BoGMS0793 were developed which are linked to Or locus present on chromosome 9. \( \beta \)-carotene rich desirable elite events were developed in early (~12ppm) and medium (~10ppm) maturity groups of Indian cauliflower.

6.4.9 Gynoeciousness in Bitter Gourd

Sex determination in bitter gourd is controlled by a single recessive gene (gy-1). The 1-aminocyclopropane-1-carboxylic acid synthase (ACS) catalyses a rate limiting step in ethylene biosynthesis in plants. ACS expression was analysed in a gynoecious line DBGy 201 sprayed silver thiosulfate @ 6mM on female floral buds which turned into hermaphrodite. Results revealed that there was sudden decrease in expression of McACS2 gene after three days of first spray of silver thiosulfate (6mM). After second spray, expression of McACS2 increased during the formation of hermaphrodite buds but its expression was less in modified (hermaphrodite) buds than the female buds. Ethylene was found to be less in hermaphrodite buds as compared with female buds. These results demonstrated that McACS2 mediated biosynthesis of ethylene in individual flower buds is associated with the differentiation and development of female flowers.

6.4.10 Mapping of QTLs for Nutraceuticals in Carrot

Four parental lines viz. IPC 126, IPC 122, Pusa Meghali and White Pale rich in anthocyanin, lycopene, betacarotene and lutein, respectively, were crossed in the following fashion: White Pale × IPC 126, White Pale × IPC 122, White Pale × Pusa Meghali raised F₁s and derive F₂s and backcross (B₁ and B₂) mapping populations from each of the crosses to develop molecular markers linked to each of the nutraceutical trait. A total of 439 SSR markers (114 ESSRs, 156 GSSRs, 144 BSSRs, 8 DCM and 17 SSRs) were screened in carrot for parental polymorphism. Out of these 56 polymorphic markers were evaluated for different colours viz., Black/purple, red, orange and cream. Twenty polymorphic SSR markers were specific to anthocyanin content, 26 for \( \beta \)-carotene, 24 for lycopene and 30 for lutein which were assessed in four parental lines, 12F₁ and 10F₂ plants. Twenty polymorphic SSRs were used in 288 F₂ plants of a cross White Pale X IPC 126 for anthocyanin content and nine SSRs (SSR-89, SSR-1-12T, DCM-2, GSSR-93, ESSR-58, ESSR-59, GSSR-154, GSSR-134 and GSSR-124) were found tightly linked to anthocyanin locus.

6.4.11 Tomato

Validation of Ty 1, 2 and 3 genes was done in resistant lines using sequence based molecular markers. Validation of late blight resistance genes *Phl3* was done in resistant lines using CAPS as well as SSR based molecular markers.
6.4.12 Onion

In order to standardize protocol for haploid induction using flower buds in onion cv. ADR, various media combinations were tried and some of the combinations resulted in induction of gynogenetic embryos which have led to plant formation. These plants will be tested cytologically for their haploid status.

Molecular markers reported for male sterile cytoplasm (S/N) and Ms locus were tested in the male sterile and maintainer lines developed at IARI. It was observed that markers cob and orf725 were able to detect normal (N) and sterile (S) cytoplasm. For Ms locus, markers OPT, PsaO and jnurfl3 were validated for identification of Ms locus in both male sterile and maintainer lines. It was observed that in male sterile and maintainer line, frequency of Msms locus was more as compared to MsMS and msms loci. Several sterile and maintainer plants were identified with the help of these two markers in the short day tropical onion for development of onion hybrids.

6.4.13 Development of Haploids in Brassica Vegetables

Haploid plants were regenerated in different Brassica vegetables like cabbage, cauliflower and Brussels sprouts through isolated microspore culture at Katrain station. This technique will be very useful in rapid development of homozygous inbred lines in highly cross-pollinated crops like cabbage and cauliflower for their use in hybrid breeding.

6.4.14 Drosophila Genetics

The DWnt4 proteins are secreted glycoproteins involved in cell signaling and regulate diverse cellular and developmental processes. They play important role in cell mobility, ovarian morphogenesis and cancer. Further, the biological functions of DWnt6 and DWnt10 remain elusive. Hence a molecular genetic analysis was carried out to understand the functions of these DWnt proteins. DWnt4 AL7 homozygotes die at late embryonic stages. Cuticle preparations of DWnt4 AL7 homozygotes revealed the reduced denticle size of 6 rows. There was no change in polarity or orientation of denticle rows. To study the possible functions of DWnt6 and DWnt 10 genes these genes were overexpressed in DWnt4 AL731. The denticles of DWnt4 AL731 homozygotes revert to the wild type size in the DWnt6 and DWnt10 overexpression lines. A loss of function mutant wg RF7 was isolated, which showed the classical wg phenotype as that of lawn of denticles with naked cuticle loss in ventral epidermis of embryos. Overexpression of DWnt6 in wg RF7-UASDWnt6-daGal4 rescued the cuticle phenotype of the embryos, while DWnt10 overexpression in wg RF7 background did not rescue the cuticular phenotype but the embryo showed formation of denticle rows which were polarized in anterior to posterior direction.

The wg1 mutant was selected to see the effect of knockdown of DWnt6 or DWnt10 on the cuticle phenotype. The wg1 mutation showed normal wild type cuticle pattern of embryos. wg1-UAS-DWnt6RNAi-daGal4 embryos showed loss of segments, reversal of polarity of the denticles and reversal of polarity of entire denticle belt in opposite direction. Overexpression of DWnt4 using Gal4 driver lines in wild type background resulted in extra denticles
during ventral epidermis patterning of the embryos. Wings also showed abnormal polarity of wing hairs, ectopic or missing wing veins. These phenotypes manifests predominantly when *DWnt4* was over expressed using either *en* or *ptcGal4* lines.

Gal4 driven knockdown of *DWnt4* resulted in loss of denticle either in terms of denticle size or rows or loss of entire denticle segments from ventral epidermis of developing embryos. These phenotypes were observed in 20-30% of embryos for *hs* and *ptcGal4* lines. *enGal4* showed 30-40% mortality but cuticle phenotype manifested only 5-10% of the dead embryos. It may be possible that engrailed is selector gene which expresses earlier than *DWnt4* during embryo development, when *DWnt4* was knocked out using *enGal4*, the initial transcript of *DWnt4* is absent from embryos and hence most of the embryos dies at early stages and a very few are able to make cuticles. Another phenotype which predominantly observed was wing size. These effects of knockdown of *DWnt4* transcript were not reported earlier and need to be validated further by studying interaction of *DWnt4* with genes involved in abdominal bristle patterning.

6.5 AGRIcuLtuRAl PHYSIcS, MEtEo-ROLoGY And EnVIRonMEnt

6.5.1 Soil Physics

6.5.1.1 Effect of chiseling on roots and water availability in a soybean-wheat rotation

The residual chiseling (chiseling in 2010) produced higher yield of soybean (1988 kg ha⁻¹) followed by repeated chiseling (once in 2010 and another in 2013). Both fresh (chiseling in 2013) and no chiseled plots had less yields (1372 and 1383 kg ha⁻¹, respectively). The residual chiseling showed higher water use efficiency (WUE) and yield. Root length density in wheat was higher in freshly chiseled plots. The average diameter of roots was also lower, indicating development of finer roots in sub-surface through chiseling. Similarly, the water use and WUE in wheat had no effect suggesting that chiseling effect may diminish after two years. Overall, chiseling moderates soil water fluxes, encourages water retention and lesser drainage down the profile. This also improves root development at subsurface in both soybean and wheat crops.

6.5.1.2 Predicting soil moisture, grain and biomass yield of wheat through Aquacrop

A field experiment was conducted with three irrigation levels (I 5: CRI, tillering, jointing, flowering and grain filling, I 3: CRI, jointing and flowering and I 2: CRI and Flowering) and two nitrogen levels (N160: 160 kg N/ha and N40: 40 kg N/ha) with wheat cv. HD 2967 to evaluate the performance of Aquacrop crop growth model. The model predicted grain and biomass yield satisfactorily with R² of 0.79, RMSE of 571 kg/ha and NRMSE of 13 % for grain yield and with R² of 0.79, RMSE of 1188 kg/ha and NRMSE of 10 % for biomass yield.

<table>
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<th>Treatment</th>
<th>R²</th>
<th>RMSE (mm)</th>
<th>NRMSE (%)</th>
<th>D index</th>
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6.5.1.3 Effect of crop residue mulching, irrigation and nitrogen management on soil hydrothermal regime, productivity and input use efficiency of wheat

A field experiment was conducted on a Typic Haplustept at the Indian Agricultural Research Institute, New Delhi during Rabi seasons of 2013-14 in a split-split plot design with two levels of irrigation (2 irrigations and 4 irrigations at critical growth stages), under two levels of mulching (with or without maize stover mulch @ 5t/ha) and three nitrogen doses (0, 60 and 120 kg N/ha) to study the effect of irrigation, mulching and nitrogen interactions on soil hydrothermal regime, yield and water and nitrogen use efficiency of wheat (cv. PBW 502) in maize-wheat system. Significant increase in the soil moisture storage due to application of crop residue mulch was observed. Application of 120 kg N/ha registered significantly lower soil moisture storage in the profile than that with control due to higher evapo-transpiration demand in the former treatment.

Application of maize stover mulch in wheat caused lower soil temperature than the no mulch treatment on the surface soil while the difference in soil temperature on 5 and 10 cm soil depth due to mulching was not significant. The surface soil temperature in cropped field was less than the bare soil irrespective of mulching. However, in the lower soil layers the difference in the soil temperature between bare field and the cropped field was not prominent. The grain yield of wheat increased significantly by 16.5% due to application of 4 irrigations as compared to 2 irrigations at critical growth stages. The grain yield of wheat increased significantly due to N application but there was no significant difference in the grain yield of wheat due to 60 and 120 kg N/ha. Though there was increase in the grain yield of wheat by 4.4% due to mulching, the effect was not statistically significant. The WUE was not influenced significantly due to irrigation level or mulching but increased due to N application. The Agronomic N use efficiency (ANUE) was not influenced significantly by irrigation and mulch treatment but decreased significantly at higher N level. These results suggest that wheat may be grown with four irrigation at critical growth stages and 60 kg N/ha with maize stover mulch @ 5t/ha to attain better hydrothermal regime, and achieve higher water and nitrogen use efficiency without any significant reduction in crop yield in Inceptisols of Delhi region.

6.5.2 Remote Sensing, GIS and Modeling

6.5.2.1 Kharif rice yield prediction modeling from satellite remote sensing

A study was taken to predict rice yield in Kharif season for hot sub-humid dry ecoregion (AER-9) using time series of remote sensing images. The study used MODIS Terra-EVI time-series dataset from 2000-2014 having spatial resolution of 500 m and temporal resolution of 16 days. The dataset was filtered and pixel wise crop phenology parameters were extracted from time-series data using TIMESAT 3.11 and aggregated into district level for 2000-2014 period. The important phenology parameter like amplitude (peak crop growth) was derived and correlated district wise historic yield data to develop regression model for yield prediction. For this purpose rice mask has been prepared and the study area covering AER-9 has been delineated using ArcGIS. The linear regression analysis was employed to develop Kharif rice yield model for AER-9 using historical district yield data from 2000-01 to 2009-10 and EVI amplitude. The zonal regression model have $R^2$ of 0.7 and was statistically significant with p value <0.001. The regression models were validated with 2010-11 yield data. The root mean

Temporal variation in soil temperature at the surface and 10 cm depth as influenced by mulching
square error (RMSE) of district wise predicted yield values was about 450 kg/ha for AER-9 which account average 17% error as percentage of zone. The district wise prediction was then aggregated into AER level and a yield forecast was made for AER-9 for 2014. The forecasted average yield value for AER-9 is 2.46 t/ha which shows decrease in average yield over the earlier year.

6.5.2.2 Cropping System Analysis using time series remote sensing data

Time series MODIS satellite - EVI (Enhanced Vegetation Index) product of 250m was used for the agricultural calendar, May 2012 to April 2013 at 16 days. Routine pre-processing of the time series data was conducted and analyzed to retrieve cropping system based on temporal EVI profile of each cropping system which were identified and mapped based on ground survey data of the study region.

6.5.2.3 High throughput measurement of leaf area index from digital colour image in wheat crop

Leaf area index (LAI) is an important physiological trait that determines solar radiation interception and thus biomass. In this study, LAI was estimated from vertical gap fraction derived from top-of-canopy digital colour photography of wheat canopies. An improved vegetation index, Excess Green minus Excess Red (ExG-ExR) was compared to the commonly used Excess Green (ExG), Excess Red (ExR) and normalized difference (NDI) indices. A histogram-based threshold technique was used to separate green vegetation tissues from background soil in order to derive the canopy vertical gap fraction. LAI derived from the ExG-ExR, ExG indexed image was comparable to the LAI measured using the commercial plant canopy analyzer (LAI-2200, LI-COR Inc., USA) (R² = 0.68 and 0.66 for ExG-ExR and ExG, respectively) with RMSE of 0.63 and 0.79, respectively. However, NDI was overestimated while ExR was found to be under estimated LAI as compared with that measured using the commercial plant canopy analyzer (R² = 0.47 and 0.35 for NDI and ExR, respectively) with RMSE of 4.09 and 2.19, respectively. Thus, digital photography based ExG-ExR method can be used as low cost, non-destructive high throughput method for assessing LAI, early vigour and gap fraction of wheat and potentially other cereal crops.

6.5.2.4 Prediction model for agricultural drought from remote sensing data

A study was carried out to predict Agricultural Drought using long term satellite remote sensing data. Multi-temporal SPOT VGT NDVI (Normalized Difference Vegetation Index) data (at 10 days interval) of 15 years (1998-2012) for Kharif season was used to develop a model for predicting agricultural drought through a remote sensing derived drought index called vegetation condition index (VCI). Year 2008 is taken as drought event year for developing the prediction model and its validation. Four districts from different agroecological conditions were considered for the study. Mewat of Haryana and Ganjam of Odisha are taken as rainfed districts and Dhar of Madhya Pradesh and Raigarh of Maharashtra as partly rainfed
and partly irrigated. The study revealed that relative deviation between actual and predicted drought increased with time interval and was found lowest while predicting ten days prior. Prediction model worked very well for rainfed regions like Mewat and Ganjam.

6.5.2.5 High throughput non-destructive phenotyping of plant water status in rice using hyperspectral remote sensing

A study was carried out to develop a non-invasive spectroscopy based method to access plant water status in rice under drought stress and capture differential behavior different rice genotypes. Excised leaves of 11 rice genotypes grown in field experiments were allowed to undergo water loss in laboratory condition. Relative water content (RWC) and spectral measurements were done at 10 different stress levels and spectral analysis was done to understand differential behavior of genotypes to water stress and corresponding effect on spectral reflectance and derived water sensitive spectral index (e.g. NDWI, Normalized Difference Water Index). Spectral reflectance of a rice leaf differ at different stress levels which indicates water sensitive spectral regions and their corresponding reflectance at different relative water contents.

NDWI was computed from spectral reflectance values for all the genotypes for different stress levels and change in NDWI for different stress levels revealed differential growth response of the genotypes to water stress. Prediction models were developed for quantitative estimation of relative water content (RWC) of rice crops and validated.

6.5.2.6 Web-based crop model InfoCrop-Wheat to simulate the growth and yield of wheat

Demand for crop simulation studies is growing rapidly at national and international level because of its vital role in characterizing the crop growth and simulating the crop yields to predict the impacts of climate change, abiotic stress and crop management practices. A web based application of crop simulation model InfoCrop -Wheat has been designed and
developed at IARI, New Delhi, India. Web InfoCrop is a web based crop simulation model that simulates the wheat crop growth on daily basis based on weather, soil, variety and management practices and facilitates the simulation of wheat crop growth and yield. Web InfoCrop -wheat has been developed using Visual Studio Express, SQL Server, NET framework 4.0 and hosted at http://InfoCrop.iari.res.in. System has been designed using modular approach and has separate modules for input variable, management conditions and output – results. Registered users (no fee is required) have the right to insert, edit/update and delete data within their private domain. System manager only has the administrative right to add data to the public domain. General users have the flexibility to run and simulate the growth of a wheat crop and get information on the crop fertilizer dynamics, environmental impact, crop growth and yield, pest damage, soil nitrogen dynamics, water balance and weather at a single day interval or as defined by the user.

6.5.3 Agricultural Meteorology

6.5.3.1 Increase in atmospheric CO\textsubscript{2} modifies solar radiation utilization by chickpea

The response of chickpea (cv. Pusa 1105) in utilizing solar radiation under elevated CO\textsubscript{2} condition (580 ± 20 ppm) in open top chamber experiments was monitored. The LAI increased largely with no change in fractional intercepted photosynthetically active radiation. Significant reduction (18.5%) in canopy extinction coefficient was recorded, indicating more erect canopy structure under elevated CO\textsubscript{2}. This along with a 24% increase in radiation use efficiency resulted in 27.3% higher crop biomass. Higher specific leaf nitrogen content and water soluble carbohydrate concentration in leaves suggest greater C assimilation. No change in harvest index was recorded, indicating increase in biomass under elevated CO\textsubscript{2} is translated into similar increase in economic yield, but larger C:N in grains implies reduction in the quality of grains.

6.5.3.2 Effect of soil temperature on biophysical parameters of wheat crop

Soil temperature is one of potential parameters that determine the crop growth and productivity. A field experiment was conducted to measure soil temperature at different depth and its effect on biophysical parameters of wheat crop under variable weather conditions. Two varieties of wheat were sown on three different dates for creating different weather condition at different phonological stages of the crop. Biomass, LAI and soil temperature was measured at weakly interval. Soil temperature was measured at different depth 0-5 cm, 5-10 cm and 10-15 cm. Results showed that air temperature had statistically positive and strong relationship with the soil temperature both at morning (R\textsuperscript{2} = 0.76 to 0.89) measured at 7.21AM and afternoon (R\textsuperscript{2} = 0.72 to 0.82) measured at 2.21PM under different weather conditions. There was positive correlation between biophysical variables and cumulative surface soil temperature. Linear regression analysis showed that in biomass 87 to 95 % variation in production and for leaf area index 79 to 96% variation in production in wheat crop under different weather conditions could be explained through the soil temperature. Therefore soil temperature could be used for estimating the biophysical parameters of wheat more accurately and hence can be used as input for dynamic crop simulation model for improving its accuracy.
6.5.3.3 Gramin krishi mausam sewa-Delhi Unit

Agro-met advisory bulletins were prepared on every Tuesday and Friday based on the past weather data, current weather data and weather forecast received for next five days on different weather parameters viz., maximum and minimum temperature, rainfall, cloud cover, wind speed and wind direction from Regional Meteorological Centre, India Meteorological Department, Agro met Advisory Unit, Safdarjung, New Delhi. The agromet advisory bulletin contains summary of previous week's weather, value added medium range weather forecast information (for the next 5 days), crop management which is based on decision tools and weather forecast, giving timely warning to farmers on rainfall variation, its amount and other weather variables including pest/disease problems, etc. so that farmers can decide about crop management, application of nutrients, irrigation scheduling, sowing, harvesting, etc. During 2014-15, a total of 105 agro-advisory bulletins were prepared in Hindi as well as in English and more than 1.5 lakhs SMS were sent to the farmers through farmers Kisan portal. These advisories are sent to IMD for preparation of national bulletins and uploaded on the IMD website (www.imdagrimet.gov.in) in both Hindi and English. The bulletins are also sent to ATIC, KVK Shikohpur, KVK Ujawa, IKSL, NGO, ATMA, State Agriculture, e-choupal, Krishi Darsan, All India Radio and local Hindi newspaper through E-mail for
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6.6 PHYTOTRONICS

The controlled environmental facilities of the National Phytotron Facility (NPF) was largely used by scientists and students from IARI and other ICAR institutes including University of Delhi South Campus, The Energy Research Institute (TERI) to conduct critical experiments related to climate change, transgenic crops, gene expression and regulation, physiology of nutrient use efficiency, plant-pathogen interaction, biochemical and genetic interventions for crop improvement, etc. During this year, 176 new experiments were accommodated along with a few previous on-going experiments. Bulks of these experiments were from the in-house projects of ICAR institutes (32.39%), post-graduate researches (54.54%) and the paid experiments from out-funded projects and non-ICAR institutes (13.07%). During 2014-15, an amount of ₹ 14,90,622 was collected at NPF as users’ fee. The NPF was visited by a number of domestic and foreign visitors including the delegates from the USA (University of Nebraska, and USDA-ARS), Australia, Tanzania, and Argentina. The Phenomics facility established within NPF aroused immense interests among the visitors.

Delegates from Agriculture Ministry, Tanzania visiting the NPF
7. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

Economic evaluation of development of the agrarian economy is highly essential for providing proper planning of ongoing research activities and quantification of the progress in various issues related to progress of agriculture and rural economy. During the early stage of planning the capital needs of Indian agriculture sector in India were deemed to be low. Today, Indian agriculture is capital intensive and is more explicit for attaining sustainable growth and feeding the burgeoning population, as also making due contribution to earning foreign exchange through exports. Researches in agricultural economics have been focused to address the issues of investment in agriculture, energy requirement in agriculture, agriculture market reforms & changing scenario of trade, and innovation in access to credit. The agricultural extension and technology transfer and assessment programmes concentrated on the demonstrations and evaluation of the technology generated, especially the new varieties of various crops developed by the Institute and also on developing innovative models for technology transfer including post-office linkage extension model and model village programmes. Under the National Extension Programme (NEP), collaborative programmes have been established with selected ICAR institutes and state agricultural universities, besides partnership with reputed voluntary organizations spread across various states of the country. An effective mechanism of linkages with various agencies and farmers groups have also been developed to boost seed production in villages to meet the growing demand for quality seed. Rural women and youth have been trained to take up alternative vocational employment and to become entrepreneurs themselves along with the extension initiatives like information and farm advisory services, on-farm testing, trainings, field days, exhibitions, feedback mechanisms, publication of farm magazines and extension literature, etc.

7.1 AGRICULTURAL ECONOMICS

7.1.1 Investments in Indian Agriculture in the Post Liberalization Period

The study on public and private investments at all India level examined trends in agricultural investments and its inter-relationships with other macro-economic variables. The trends in private investment (mainly by farm households and corporate sector) showed an upward momentum during the nineties and the 2000s, enabling total investment (public and private) to grow at the rate of 11 per cent during the period 1991-2010. Annual private investment (including both farm households and corporates) for agriculture was twice of the public investment in Triennium Ending (TE) 1995 and the former grew much faster as its size expanded to four times of the latter during TE 2010. This has accelerated over the past three five year Plans and averaged 15.6 per cent of agricultural GDP in the first four years of the eleventh Plan. However, inspite of consistent increase in the private investment (which includes both investments by farm households as well as corporate), the total trends in growth of agricultural capital stock and agricultural workers: all India
accumulated investment by farmers, as measured by the value of agricultural capital stock, did not show the commensurate increase.

The on-farm net aggregate capital stock (ACS) grew by 1.3 percent annually during the 1980s and 1990s, followed by a modest fall to one percent during the period 2000-07. This suggested an increased growth of corporate investments in sunrise sectors like food processing which also has strong backward and forward linkages in promoting growth. Of the five categories of agricultural capital, land improvement claimed the highest share (40%) in total net capital stock followed by livestock (18%), machine and implements (8%), plantation crops (6%) and livestock structures (3%) in 2007. Growth in net capital stock of farm machinery and implements was impressive (6%) among all the five components during 1980-2007. Agricultural capital stock per agricultural worker (capital-labour ratio), an important indicator of labour and land productivity suggests that growth in agricultural workers was significantly higher than that of net capital stock during the eighties and the nineties resulting in negative growth in capital-labour ratio. During the nineties, there was slight reversal in the trend, not as a result of an increased growth in capital, but because of a rapid decline in the agricultural workers. The aggregate net capital stocks per agricultural worker grew at a growth rate of - 0.3 per cent.

7.1.2 Energy Use in Indian Agriculture

The study estimated the long-run and causal relationship among agricultural growth, investment and energy-use in Indian agriculture using auto-regressive distributed lag (ARDL) bounds testing approach. The order of integration for each variables was tested using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The analysis showed that after differencing the variables once, all the variables were confirmed to be stationary. The optimal lag structure for the regression was obtained as lag 1 using Schwartz Bayesian Criterion. The ARDL test indicated that there exists single robust long-run relationship when energy consumption is the dependent variable while productivity and investments are explanatory variables. The presence of a co-integration relationship between the variables suggests that all variables tend to move towards an equilibrium relationship in the long run. The causality was examined through the significance of the coefficient of the lagged error-correction term and joint significance of the lagged differences of the explanatory variables using the Wald test. The empirical investigation indicated that there is strong uni-directional Granger causality running from total energy consumption to productivity and from productivity to investment. This implies that energy conservation policies may have adverse effects on agricultural growth. Further analysis revealed that energy-use increases productivity which in turn lead to the private investment.

The energy requirement of the total food processing sector, both organized and unorganized, of India has shown a rapid growth. To reach the level of 4.37 million tonnes of oil equivalent (MTOE) in the year 2010-11, it more than tripled from 1.20 MTOE during 2005-06. Coal was found to be the major source of energy in the organized sector contributing 1.60 MTOE followed by petroleum products (0.99 MTOE) and electricity (0.67 MTOE). The industry manufacturing vegetable and animal oils and fats used more than 40 per cent of the total coal and 17 per cent of the total petroleum products used in organized food processing industry. The industry manufacturing grain mill products and starch products lead in the use of electricity.

7.1.3 Agrarian Change, Resource Use and Productivity in Rice-Wheat System

Productivity growth in agriculture is important for development of Indian economy. India has made impressive strides on agricultural production front. However, after 1990's, there has been a deceleration in productivity growth, which continues to remain a concern. Rice-wheat cropping system (RWCS) is the major cropping system in the Indo-Gangetic Plains (IGP) of India, which contributed significantly to the success of green revolution. Districts with high
productivity were pre-dominant in Punjab and Haryana states whereas, low productivity districts were more in Bihar and Uttar Pradesh during 1980-2010. Very low yield and higher instability of rice and wheat crop was witnessed in middle and lower Gangetic plains during 1990-2010. During the same period, the Instability Indices have shown that wheat production in Punjab and Haryana states were stable. High instability in rice production was observed in Bihar state. Seeds were over-utilized in Haryana and Bihar states whereas fertilizer and labour resources were under - utilized during this period. There has been increase in growth of total factor productivity (TFP) in Haryana, Bihar and West Bengal except Punjab and Uttar Pradesh in rice in 2001-2010. In case of wheat, insignificant growth of TFP has been noticed in two decades 1990-2000 and 2001-2010.

7.1.4 Impact of Domestic Market and Trade Reforms in Indian Agriculture

A study was undertaken to ascertain the trend in the export of agricultural commodities from India and the impact of regional and free trade agreements. Overall, the trend analysis indicated that India’s agricultural trade has witnessed compositional change over years in terms of increased share of meat and meat products, cereals, guargum 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 of rice accounts for 71 per cent of total cereal export; among various rice items, the share of basmati rice increased by close to 25 per cent points to reach 68 per cent by 2012-13, at a growth rate of 27.6 per cent. Export of vegetables has shown higher prospects; it grew at the rate of 15 per cent per year during the decade ending 2012-13. In case of fruits, highest export prospect is noticed in case of mango (growth rate 12 per cent) which constitutes highest share among fruits. Spice export doubles almost every four year. Significant change is observed in the composition of spices- major commodities are chilli (with a share of 35 % and growth of 27%) and cumin (share of 12.6% with a growth of 36%). The export competitiveness analysis through comparative advantage indicated that cashew nuts, coffee, cotton, egg, maize, mangoes, onion, sugar, tea and rice are competitive.

It was noted that regional and multi-lateral trade agreements foster faster growth of both import and export. India’s exports to ASEAN region has increased by 536 per cent during the decade 2001-11. The impact of the bilateral agreements has been examined by using the trade intensity and sectoral Hirchman Index. Among the individual partner countries, the intensity of India’s trade with Sri Lanka is increasing. The Sectoral Hirchman Index of diversity indicated that the bilateral and multi-lateral trade agreements tend to favour specialisation rather than the diversification. It was noted that the future export prospects lies in the country’s ability to increase agricultural production through yield improvement. Technology bears great role in this case.

7.1.5 Innovations in Credit Delivery and Farmer’s Access to Institutional Credit

The institutional credit has played a pivotal role in the agricultural development of India. A number of innovations have taken place in credit delivery in India. The Kisan Credit Card (KCC) Scheme is one the major programmes that has impacted large number of farmers. The study shows that the costs incurred on legal documentation, commission agents and the opportunity cost of time spent in the process of procuring loan from the banks together makes up for the transaction cost of borrowing. Thus, for the net income realized by KCC beneficiary and non-beneficiary farmers (T/ha)
taking loan from formal sources of finance, farmers have to bear transaction cost on legal documentation, commission agents, travel cost on visits to the bank, etc. The average transaction cost on taking loan was found to be much lower for KCC beneficiary farmers (₹ 247/-) than non-beneficiaries (₹ 839/-).

The cost and return analysis of beneficiary and non-beneficiary farmers has revealed that the cost of cultivation per hectare for all the five major crops (paddy, maize, wheat, potato and groundnut) was higher for beneficiary than non-beneficiary farmers. It was due to application of higher amount of purchased inputs facilitated by the borrowed money. The net return per ha was higher for all the crops and it was the highest in potato. The constraints faced by farmers in the use of KCCs have been ranked using Garrett’s ranking technique. Most of the KCC beneficiary farmers have reported the lengthy and tedious paper work to be the major problem (74 %). The insufficient credit limit (67 %), non-availability of loan on time (60 %), and inflexibility in the number of withdrawals (55 %) were other major constraints faced by the farmers. The existing credit limit under KCC needs to be increased to meet the credit needs of farmers for production process. Similarly, reduction in the existing rate of interest, incorporation of consumption loan along with crop loan, provisioning of ATMs and flexibility in the use of bank branches could attract more farmers towards the scheme.

7.1.6 Rural Non-farm Employment in India—Trends and Determinants

The process of structural transformation of the rural employment in different states was analysed by changes in the composition of states in different clusters. It was found that although in 1999-2000, more number of states belonged to the low RNFE cluster(<25%RNFE), after a decade the picture had changed, gradually the states had moved in to the medium cluster and from medium (26-40%) to the high cluster (>40%). The low level of RNFE cluster had witnessed a continuous decline in the number of states, whereas just reverse was true in the case for high level cluster. Interestingly, medium cluster was the largest cluster and its strength peaked in 2004-05 and declined in 2009-10. Kerala and Haryana belonged to the high level cluster in 1999-00 and this cluster was joined by Punjab, and Jammu and Kashmir in 2004-05 and by West Bengal in 2009-10. Uttar Pradesh, Tamil Nadu and Himachal Pradesh dwelled in the medium cluster; not moved to high cluster during the reference period despite improvement in RNFE.

The determinants analysis of rural non-farm employment revealed that the Agricultural Gross State Domestic Product (AgGSDP) had a positive influence on the expansion of non-farm activities and on an average, if farm income increase by ₹ 10,000/ ha, it would lead to expansion of states’ RNFE share by 3.7 percentage points, keeping all other factors at constant. It implies that the higher income received from agriculture led to demand for other non-farm activities and also acted as a demand pull factor for RNFE. The relationship between average land holding-size and RNFE per cent share was positive, if average land holding-size increases by one ha, RNFE share of the state would increase by 3.6 percentage points. This means that if the farm-size increases above certain level, it shall increase the capacity to undertake non-farm activities due to better access to credit and other resources and the economic stability of the households supports them to enter into non-farm activities.

The percentage share of SC and ST population in rural areas had negative and significant effect on RNFE status. On an average, if SC and ST population share increases by one per cent, RNFE share would decline by 0.38 percentage points. It implies socio-economic background of rural populations had determined the selection of occupation and confirms existence of caste-based occupation in rural India. Other important variable, infrastructure development comprising per capita electricity consumption and road density has strong and positive effect on the growth of RNFE indicating that infrastructure-led growth of RNFE was the strongest. If the index is increased by one point, RNFE share of the state would increase by 14.7 percentage points.
7.2 AGRICULTURAL EXTENSION

7.2.1 Development of Innovative Agricultural Extension Model

The IARI Post Office Linkage 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 fifty five districts of 14 states covering 110 branch post offices. The model has been found effective in dissemination of farm information to the remotely located farmers and successful means of making improved agricultural technologies available in the rural areas in relatively lesser time and cost. Trainings for farmers and branch post masters were organised at Sheopur district of Madhya Pradesh and Sirohi district of Rajasthan during 2014-15. Capacity building of branch post masters helped in benefitting the farmers of the area. Interaction Meet of the partner KVKs were organised at Zonal Project Directorate of all the five zones during the year. The interaction meets were organized to discuss the project rationale with the identified KVKs involved in the project in order to receive their feedback and discuss the project activities to be implemented.

During 2014-15, total 9 tonnes of wheat seeds (HD 3086, HD 2967, HD 2733, HD 2985, HD 2932 and HD 2851), 0.19 tonnes mustard seeds (Pusa Mustard 26 and Pusa Mustard 28), 0.41 tonnes paddy seeds (PB 1121, PB 1509, P 2511, P 44) were sent to the post masters and KVKs in the project locations. Seeds of mungbean (Pusa Vishal), bottle gourd (Pusa Naveen), okra (Pusa A4) and marigold (Pusa Narangi Gainda) were also sent to the project locations. The wheat variety HD 2967 performed well with average yield of 5.5 t/ha. The farmers reported low lodging problem under recent rainfall in HD 2967 variety. The performance of Pusa Mustard 28 variety was also satisfactory with an average yield of 1.5 t/ha. The paddy variety Pusa 1509 was preferred by majority of the farmers in Uttarakhand. In Sheopur district of Madhya Pradesh, the crop stand of HD 2967 was better than the other wheat varieties and farmers were expecting a bumper yield. Performance of Pusa 44 was better (15%) compared to the prevailing variety (Saryu 52, MTU 7029). Performance of fine grained rice (P 2511) was better than local fine grained (Indrasan, Gobindobhog and Sambha Mansoori). The variety P 2511 performed well in Rajasthan, West Bengal, M.P. and U.P. Farmers preferred the variety for less duration and less water requirement.

Survey of Mewat and Gurgaon districts revealed change of variety, agronomic adjustments, multiple cropping, non-farm activities, and crop diversification as the preferred strategies for climate change adaptation. About 28 per cent of the farmers reported using short duration varieties of pearl millet if there is delayed monsoon or first seeding is spoiled due to lack of rainfall and high temperature. Nearly 23 per cent of them practiced multiple cropping like growing sesame, pigeonpea, maize, besides the main crop of
pearl millet to distribute the risk of climatic events and secure some income. Nearly one-fourth of the farmers adopted agronomic adjustments like early or delayed sowing, reducing the area under cultivation and fertilizer dosages, increasing the frequency of irrigation, fallow with dust mulching, intercropping, etc.

A bench mark survey of mobile phone usage behaviour of the farmers was conducted in Badarpur Said village. For catering to information need of farmers, content was developed for Paddy (var. Pusa Basmati 1121) for mobile agro advisory to farmers in the form of text SMS.

7.2.2 Maximising Farm Profitability through Entrepreneurship Development and Farmer Led Innovations

Prioritisation of IARI technologies for agri-enterprise ventures uptake were identified based on location and farmers’ needs in a participatory mode. Selection of six villages for the project interventions - two villages in NCR Delhi, two in Madhya Pradesh and two in Himachal Pradesh were done. Focus Group Discussions for taking up specialty agriculture production, value addition of selected fruits and vegetable 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. Documentation of Farmer Led Innovations (FLIs) for two cases was done and the characterization in terms of type, strength, communicability and policy suitability of innovation. The triggers, catalysts and sparks have been identified. One model training course entitled ‘Extension strategies for upscaling farmers innovation of eight days duration with 20 participants across the country was conducted to sensitize regarding FLIs. For the purpose of development of the scalability criterion for Farmer led Innovations, collection of items for developing an objective criterion for selection was done.

7.2.3 Enhancing Nutritional Security and Gender Empowerment

A pilot survey was conducted in two villages of Baghpat district of Uttar Pradesh in the context of household level nutritional security (consumption trend, awareness and knowledge about nutrient elements, nutrition programmes, cooking methods, food habits, kitchen and personal hygiene and water and food safety, etc.) through a structured interview schedule. The preliminary results suggest that average household income of the respondents was about Rs. 10,000/- per month. Out of this, two-third portion of their income was spent on food. Majority of the farmers were following sugarcane-wheat; sugarcane-rice; wheat-sugarcane-mustard-jowar cropping pattern. The food habits suggest that 98 per cent of them were pure vegetarians. About 65 per cent of them had two meals per day and the rest of them had 3 meals per day. Their staple foods were wheat and rice. Apart from this, in their diet they included vegetables like potato, green peas, cauliflower, cabbage, palak, methi, tomato, brinjal, potato, carrot, radish, beet root, onion, bottle gourd, ridge gourd; fruits like banana, guava and mango which are seasonal; pulses like red gram, lentil and black gram; milk and milk products like butter milk, curd and ghee. For vegetables and fruits, they had to rely on local markets. About 80-85 per cent of the vegetables were procured from local markets. Fruits consumption was very less as they had to buy from nearby market and it was costly too. The per capita consumption of milk was 0.6 l/day. It is
because households were having livestock like cows and buffaloes.

The knowledge and awareness level of the respondents were assessed by using set of questions related to food sources of nutrients; functions of nutrients; nutrients for pregnant women; importance of breast milk and about IARI and its crop varieties. It indicates that although they are aware of the importance of having diversified foods like combination of cereals, pulses, vegetables and fruits, their knowledge score was very low. There was no gender bias in food distribution at household level. Even though they were growing IARI varieties, 98 per cent of them did not know about IARI. Nearly 90 per cent of them knew about mid-day meals programme, which is the major nutrition oriented programme in our country.

7.2.4 Developing Agricultural Entrepreneurs in Vegetable Seed Production

The availability of quality seeds to farmers reduced the stress faced by the farmers because of the problem of poor access and availability. Enterprise development resulted into enhanced income of farmers. Also replication effect was seen among the non adopted farmers and in the neighbouring villages after success of the project farmers. A number of small holder farmers were associated in the project activities for seed production. The emphasis was on the process of developing expertise, skills for entrepreneurial venture so that it can be upscaled later on. The main aim was on motivating farmers, their capacity building and skills upgradation for entrepreneurial venture. The 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 Seeds Corporation) with the farmers for turning them into farm entrepreneurs was designed, tested and found effective as an innovative approach. The process of converging strengths of respective agencies for developing Rural Farmers as Seed Entrepreneurs was standardized and can be up scaled in larger field areas and varied regions of the country to present a viable solution to the problem of inadequacy of quality seeds availability to our farmers.

7.2.5 National Initiative for Climate Resilient Agriculture

Twenty five training programmes were organized to upgrade the knowledge and skills of the farmers in areas of method and principles of direct seeded rice (DSR) and zero-till wheat cultivation systems; management of nematode, weeds and nutrient management in DSR, Insect pest Management (IPM) in paddy and vegetables, Use of leaf colour chart in paddy and wheat, use of bio fertilizers in DSR and use of mKRISHI for mobile based advisory. More than 460 demonstrations on climate resilient technologies like zero-tillage in wheat, direct seeded rice, bio- fertilizers, green manuring, raised bed and protected system for vegetables, etc were laid out in NICRA villages for educating the farmers. Field days (15) and kisan gosthies (10) were also organized to resolve the queries of farmers.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Technology demonstrated</th>
<th>Area (ha)</th>
<th>No of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Zero-till wheat</td>
<td>88</td>
<td>220</td>
</tr>
<tr>
<td>2.</td>
<td>Direct seeded rice</td>
<td>21.6</td>
<td>63</td>
</tr>
<tr>
<td>3.</td>
<td>SRI</td>
<td>2.8</td>
<td>7</td>
</tr>
<tr>
<td>4.</td>
<td>Summer <em>moong</em> in rice--wheat system</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td>5.</td>
<td>Green manuring</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>6.</td>
<td>Raised bed, drip and plastic mulching in vegetables</td>
<td>2.5</td>
<td>7</td>
</tr>
<tr>
<td>7.</td>
<td>Low and walk-in tunnel, net house nursery</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>8.</td>
<td>Pheromone traps</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>9.</td>
<td>Laser levelling</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10.</td>
<td>Bio-fertilizers</td>
<td>20</td>
<td>60</td>
</tr>
</tbody>
</table>
Though the demonstrations on DSR were affected due to delayed monsoon, the farmers realized that the paddy var. Pusa 1509 helped in saving irrigation water (3-4) due to its short duration.

7.2.6 Validation and Promotion of Bio-pesticides (IPM technology and SinPV), for Crop Management in Paddy-Vegetable Agro-ecosystem in District Faridabad

The IPM Module for rice and vegetables crops was applied at the adopted farmers’ field in both the villages. Twenty farmers were imparted bio-pesticide production training at Institute of Pesticide Formulation Technology (IPFT), Gurgaon. Two workshops were arranged at the project site for demonstration of IPM techniques to the farmers and popularization of IPM practices. A data base information was developed regarding the comparative study between the IPM and non IPM practices including the yield of the produce for both the crops as well as the constraints faced by farmers in way to IPM adoption.

7.3 TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Assessment and Promotion of Agricultural Technologies and Developing Market-led Extension Models

This Project (2009-2014) was implemented in four villages of NCR, namely, Badarpur Said in Faridabad, Rajpur in Sonipat, Dhani Kumbhawas in Gurgaon districts and Soodana in Hapur district with the purpose to develop these villages through integrated agricultural development which will act as model villages for surrounding area. The productivity of different crops and income of farmers have been enhanced significantly through adoption of IARI technologies. Further, IARI technologies have also been diffused to neighbouring villages. Under this programme during Rabi 2013-14, 360 demonstrations were conducted on wheat, mustard, chickpea, lentil, cauliflower, onion, carrot, tomato, palak, pea, brinjal, sarson sag, bottle gourd and broccoli in an area of 147.65 ha. During Kharif 2014, 169 demonstrations were conducted on varieties of paddy, pigeon pea, bhindi, bottle guard, pearl millet and tomato covering an area of 116.50 ha in all the four adopted model villages. Some of the major experiences of technology diffusion in these villages were as follows:

- Spread of latest released IARI wheat and paddy varieties up to 90 per cent in the project areas and its neighbouring villages.
- Large scale adoption and enhanced profitability through vegetable and fruit varieties such as carrot variety (Pusa Rudhira), bottle gourd, (Pusa Naveen) and muskmelon, (Pusa Madhuras).
- Capacity building on use of biofertilizers, bio-control agents like Pheromone traps, agricultural machinery, drudgery reduction, post harvest processing and compost preparation from household waste, etc.
- Entrepreneurship development on production and use of Trichoderma, protected cultivation, preparation of decorative products using dry-flowers, etc.

7.3.2 Outscaling Agricultural Innovations for Enhancing Farm Income and Employment

The project 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 agro-ecosystem analysis was conducted to identify the resources and agricultural related problems in the area. The analysis of farmer’s categories based on size of their land holding revealed that in Khajurka, maximum farmers (39.9%) are marginal, having landholding less than one hectare followed by 31.6 per cent landless. in Kuthbi, 26.6 per cent farmers are marginal followed by 25.53 per cent medium farmers (2-5 ha) and 26 per cent were small farmers (1-2 ha); and in Rajpur village, maximum farmers are marginal farmers (34.23%). Only 0.77 per cent were big farmers, and 28.46 per cent medium
7.3.3 Technology Integration and Transfer to Strengthen Farming System in Partnership Mode

The project is being implemented in partnership with selected ICAR Institutes / SAUs/VOs in different parts of the country.

7.3.3.1 Collaborative programme with ICAR institutes and SAUs

During Rabi 2013-14, a total number of 306 demonstrations were conducted covering an area of 73.92 ha across 15 locations on wheat, mustard, lentil, chick pea, pea, spinach, carrot and brinjal.

Wheat

- Wheat variety HD-2733 was highly accepted by the farmers due to its high yield, dwarf height, medium early maturity (130-135 days) and resistance to leaf rust and leaf blight (BAU, Ranchi).
- Wheat variety HD 2733 resulted in highest yield of 4.67 t/ha followed by HD 2967 (3.62 t/ha) and HD 2985 (3.47 t/ha) resulting in 44.07 per cent higher yield over local check (HUW 234). This variety had more number of tillers and has capacity to replace the existing varieties (IIVR, Varanasi).

Agro-ecosystem analysis and cropping patterns in the project villages

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Khajurka village (Haryana)</th>
<th>Kuthbi Village (U.P.)</th>
<th>Rajpur Village (U.P.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil type</td>
<td>Silty soil in lowland and sandy loam in upland</td>
<td>Sandy loam</td>
<td>Silty soil in lowland and sandy loam in upland</td>
</tr>
<tr>
<td>Topography</td>
<td>Two types of topographies; Upland and lowland</td>
<td>Single topography</td>
<td>Two types of topographies; Upland and lowland</td>
</tr>
<tr>
<td>Major crops grown</td>
<td>a. Kharif, Paddy, mungbean, sorghum, pigeon pea</td>
<td>Sugarcane, bajra, paddy, Forage sorghum, mungbeen</td>
<td>Paddy, bajra, maize, pigeon pea, sorghum, cotton</td>
</tr>
<tr>
<td></td>
<td>b. Rabi, Wheat, carrot, radish, fenugreek</td>
<td>Wheat, mustard, barley, berseem, oats</td>
<td>Wheat, potato, mustard, berseem</td>
</tr>
<tr>
<td></td>
<td>c. Zaid/Vegetable, Ashgourd, cucumber, kachri, mungbean, bottle gourd</td>
<td>Cauliflower, okra, cabbage, bottlegourd, brinjal</td>
<td>Cucurbits, watermelon, muskmelon</td>
</tr>
</tbody>
</table>
Farmers liked varieties HD 2967 and HD 2987 due to higher yields and bold grain size over local check. The var. HD 2967 was found better (MPUAT, Udaipur).

**Mustard**

- Mustard variety Pusa Jagannath was appreciated by the farmers due to its more branching, more number of siliqua, good yield (2.15 t/ha) and better oil recovery.
- Mustard variety NPJ 113 in Jammu region was found to be suitable under multiple cropping systems.
- The average yield of mustard variety Pusa Vijay was 1.83 t/ha in comparison to 1.52 t/ha of local check (IVRI, Izatnagar).

**Lentil**

- Farmers preferred Lentil variety L 4076 due to more number of branching, medium grain size and higher yield.
- Lentil variety Pusa Shivalik was reported as resistant to diseases and pests and suitable in maize-lentil, maize-toor-lentil cropping system in Jammu.
- Pusa Shivalik variety of lentil demonstrated using rhizobium culture and PSB gave an average yield of 1.81 t/ha compared to the local check (1.4 t/ha) (IVRI, Izatnagar)

**Carrot**

- Farmers were satisfied with new varieties of carrot when compared to local varieties as they recorded more yield (23.80 -26.52t/ha compared to local variety (19.8 t/ha) with high net returns. Farmers accepted new varieties for attractiveness, color, yield, sweetness and fibrous roots. The average length of each carrot ranged from 15 to 19.8 cm (UAS, Dharwad).
- Farmers are producing seeds of carrot, var. Pusa Rudhira in Bharatpur (Rajasthan) and selling in local as well as distant markets.

During Kharif 2014, a total of 332 demonstrations on paddy, moong, pigeonpea, bajra, bottle guard, tomato, chilli and okra covering an area of 103.72 ha were conducted at ICAR Institutes/SAUs. All demonstrated IARI varieties showed significantly higher yield in comparison to local varieties at all locations except one or two instances.

**Paddy**

- PB 1509: Farmers were satisfied with crop stand, tillering quality, yield and market price of the var. PB 1509 variety. This is a short duration variety and fits well in the cropping system and even under poor rainfall situation, it performed very well. The crop yield was found significantly higher than the local check.
- Pusa Basmati 1121: It has potential to replace local variety Sharbati (IVRI, Bareilly). Most of the farmers showed interest in paddy var. PB 1509 as it is resistant to lodging, high yielding and aromatic (SKUAS & T-J). This variety performed better as compared to Indrayani (MPKV, Rahuri). Good grain size, aroma, higher yield, and suitability for cutting by combined harvester were the best traits of the variety (NDRI, Karnal).
- P 2511: Farmers liked it due to its grains quality, aroma and taste (IIVR, Varanasi).
- PRH 10: Appreciated by the farmers due to its quality, duration and yield in comparison with local check (IVRI, Bareilly and IIVR, Varanasi). Performance was very good in upland conditions due to short duration and tillering than other hybrids. It was found suitable for rice-potato/vegetable pea/mustard cropping system (IIVR, Varanasi). At IVRI, Bareilly, farmers also appreciated physical and cooking quality of grains and tolerance of pests and diseases. PRH 10 was also liked by the farmers due to high yield potential and quality of rice (MPUAT, Udaipur). Paddy farmers are demanding PRH 10 variety due to its high yield, aroma and good quality (NAU, Navsari).
Pusa 44: It has good quality grains and good performance in DSR than transplanted.

Pigeonpea
- Better performance of pigeon pea variety Pusa 2002 was observed as compared to Narendra Arah 1. (IIVR, Varanasi)
- Pusa 2002 gives net profit on the higher side and the variety can fetch good market price due to better grains quality and the variety has high potential to replace the existing short duration pigeon pea variety UPAS 120. Quality of cooked dal was also found good (IVRI, Bareilly).

Okra
- Okra variety A 4 was liked by farmers due to its small, tender and dark green colour pods. Yellow vein mosaic virus was major disease observed in the variety during rainy season (IVRI, Bareilly).

Bottlegourd
- Pusa Naveen variety was liked by the farmers as it is small in size and market friendly (IIVR, Varanasi).
- Farmers liked Pusa Naveen as its character and shape resembled to popular variety Varad (MPUAT, Udaipur).

Green Gram (Moong)
- Farmers liked moong variety Pusa Vishal for its bold grain and yield potential. (MPUAT, Udaipur).
- Pusa 9531 is good in yield, synchronous in maturity and resistant to yellow mosaic virus diseases (SKUAST-Jammu).

Mustard
- Mustard variety Pusa Vijay performed better after harvesting of rice PRH 10. Farmers were very much impressed with this hybrid due to more branching and high yield (IIVR, Varanasi).

Spinach
- Crop performance of spinach variety All Green was rated good by the farmers due to fast sprouting, free from pests and diseases, potential for adoption, acceptability, consumer preference and, high value in market (UAS, Dharwad).

7.3.3.2 Collaborative programme with Voluntary Organizations

In collaboration with 32 Voluntary Organisations during Rabi 2013-14, a total of 1461 demonstrations covering an area of 432 hectares, over 26 locations on wheat, mustard, lentil, pea, spinach, onion, chick pea, bottlegourd, carrot, cauliflower, brinjal, paddy and marigold were conducted. The feedback from farmers is as follows:
- Wheat variety HD 2967 performed better than other varieties in terms of production (3.45 t/ha) and net return. Chick pea varieties P-1053 and P-1108 gave better production and net return (DRI, Chitrakoot).
- Wheat variety HD 2967 outperformed all other varieties and gave an average yield of 4.83 t/ha. (ITC, Uttar Pradesh).
- Wheat variety HI 1563 yielded better in West Bengal (4.53 t/ha) followed by Bihar (4.37 t/ha) in comparison to UP (3.35 t/ha).
- Performance of wheat variety HI 1544 was rated good as compared to GW 496. No lodging occurred during heavy rain and wind (ClnI – Collective for Integrated livelihood initiative, Gujarat).
- Wheat variety WR 544 was found suitable for late sowing and could be sown after harvesting of sugarcane (FARMER, Ghaziabad).
- During Rabi 2013-14, 10 t of foundation seed and 30 t of certified seed was also produced by one farmer (PRDF, Gorakhpur, UP).
- Spinach variety Pusa Bharti as seasonal vegetable is very good for the Rabi season as farmers started...
to grow vegetables in this area and earned more money for their household livelihood. (MVS, Bilaspur, H.P).

- Farmers were satisfied using bio-fertilizer in the wheat crop and reported the application of bio-fertilizers resulted in dark green leaves, bold grain and long head and healthy crop. Through the use of bio-fertilizers they could save on fertilizer cost (1 bag per acre) thus reduced cost of production and gain profit (more than 10%). They felt confident to convert their fields into organic fields. (PRDF, Gorakhpur, UP).

- Application of bio-fertilizer mixed with FYM has shown some impact in increasing crop yield. (FARMER, Ghaziabad).

  During Kharif 2014, 931 demonstrations were conducted on 23 varieties of 10 crops, namely, paddy, pigeon pea, moong, bajra, bottle gourd, tomato, okra, cowpea, carrot, cauliflower, and chilli covering an area of 285 ha at 24 VOs locations.

Paddy

- P 1612: Crop matures in 115-120 days and hence, it saved irrigation and gave the best results, both from the yield as well recovery after milling and sale price (JEEVANIA, Lucknow).

- Paddy varieties P 1121 and PB 1509 showed resistance to rice gandhi bug and brown spot (HESCO, UK).

- PRH 10 demonstrated at all locations is well accepted by the farmers as it yielded significantly higher yield and exhibited better quality in comparison to local varieties. It is short duration variety and requires less irrigations thereby enabling the farmers to plant the subsequent crops in time. However, due to non-availability of seed, the spread of variety is limited.

- P 44: High yield, bold grain as compared to local Gurjari variety (CInI, Gujarat). However this variety was not found suitable at Hazaribagh, Ranchi due to its lower duration and higher water requirement and grain size (Holycross KVK, Hazaribagh).

- P 2511: High yield, long grain size, fragrance, very good taste and high price (Gujarat). P 2511 still continues to be a good choice by many farmers as they have found it consistent in yields and market rate that it fetches. (JEEVANIA, Lucknow).

Green Gram (Moong)

- Moong variety Pusa Vishal gave better return as 80 per cent pods mature at the same time. Farmers could take early vegetables in the same field (Hazaribagh, Ranchi).

Pigeonpea

- Varieties P 2002 and P 992 were preferred by farmers for higher yield and good taste. (HESCO, UK).

Bottle gourd

- Variety Pusa Naveen was found more market friendly due to its higher yield and good taste.

Okra

- Pusa A 4 variety was preferred for its yield potential and strength of plants. (STD, Mandi and HESCO, Uttrakhand).

Bio-fertilizers

- Use of BGA in Paddy, Azospirillum + PSB in pearl millet & maize and Azatobactor + PSB in wheat increased yield by 7 to 10 per cent at a very nominal cost and have a very good farmer’s acceptance, but availability of reliable bio-fertilizer culture is a serious constraint (ITC, UP).

- Application of BGA (Blue Green Algae) in 20 ha area on rice crop in Kharif 2014 resulted in healthy crop, slipper soil surface, moisture retention for longer time, and withstand plant not lodging till late. (PRDF, Gorakhpur)

7.3.4 Participatory Seed Production of Improved Varieties of IARI

Under participatory Seed production of improved varieties of IARI during Rabi 2013-14, seeds of wheat varieties, namely, HD 3059 (1.5t), HD 2932 (1.24t), HD 2733 (15 t), HD 2967 (5 t) and HD 2851 (0.84t) was
produced at PRDF Gorakhpur; and 115.9 t seed of wheat var. HD 2967 was produced at YFAP, Rakhra (Patiala).

During Kharif 2014, 45.4 t of PB 1509, 35 t of P 1612, 68 t of Pusa 44, 48.5 t of Pusa 1401, 27.5 t of Pusa 1121, and 12 t of Pusa 1460 varieties of paddy were produced at YFAP, Rakhra, Patiala.

7.3.5 Front Line Demonstrations on Wheat (in Collaboration with IWBR)

During Rabi 2013-14, 23 FLDs on wheat at Samoli, Dabal and Rampur villages of Muzaffarnagar district (UP) were conducted on newly released wheat variety HD 2967, and use of bio-fertilizer (Azotobacter + PSB).

Performance of FLD – IWBR (Wheat) during Rabi 2013-14

<table>
<thead>
<tr>
<th>Technology</th>
<th>Variety</th>
<th>No. of dem.</th>
<th>Area (ha)</th>
<th>Yield (t/ha)</th>
<th>Av. yield of check</th>
<th>% increase over check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly released Variety</td>
<td>HD 2967</td>
<td>10</td>
<td>4.00</td>
<td>7.87</td>
<td>3.75</td>
<td>5.33</td>
</tr>
<tr>
<td>Use of Bio-fertilizer</td>
<td>HD 2967</td>
<td>13</td>
<td>6.00</td>
<td>7.50</td>
<td>4.50</td>
<td>5.47</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>23</td>
<td>10.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.3.6 Pusa Krishi Vigyan Mela-2015

The Institute organised its annual Krishi Vigyan Mela on the theme “IARI Technologies for Inclusive Growth” from March 10-12, 2015. The mela was inaugurated by Shri Siraj Hussain, Secretary, Department of Agriculture & Cooperation, Ministry of Agriculture, Govt. of India. Dr. J.S. Sandhu, DDG (Crop Science), Dr. A.K. Singh, DDG (Extn.), ICAR were the Guests of Honors on this occasion. During the mela, a total of 285 exhibitors participated and displayed their technologies. Farm technologies developed by the Institute for inclusive growth were displayed in the 48 stalls of different Divisions of the Institute and in the 6 stalls of IARI Regional Stations. Besides, 30 ICAR Institutes, 15 SAUs, 4 KVKs, 5 CGIAR, 77 private companies, 5 media agencies, 25 NGOs and 29 public sector undertakings also participated in the mela to demonstrate their technologies / products for display and sale. In addition to this, 50 progressive farmers from extension operational areas of the Institute also put up their stalls for display and sale of their farm produce. Farmers were provided free of cost agricultural consultancy services at the mela site by various agricultural experts. Four technical sessions were organised for Farmers-Scientist-Industry interface on different themes, namely, An Innovative Farmer’s Meet was held on March 12, 2015 under the chairmanship of Dr. S.A. Patil, former Director, IARI. Twenty eight progressive farmers from different states of the country participated and shared their experiences about their innovations in agricultural production during this event. The mela ended with valedictory function wherein Honourable Minister of State for Agriculture and Food Processing Industries, Dr. Sanjeev Kumar Balyan was the Chief Guest and Dr. S. Ayyappan, Secretary, DARE & DG, ICAR, presided over the function. Twenty eight progressive farmers from different states of the country were honoured for their innovations in the field of agriculture. The Chief Guest addressed the farmers and gave away the prizes and certificates to various participating organizations and farmers. On this occasion, eight publications, namely, Mela Souvenir, Prasar Doot, Champion Kisano Ka Sankshipt Parichaya, Shaktiya Beej Utpadan Dwara Krishi Udhaymiyo Ka Vikas, Samekit Keet Prabandhan, Agronomic Interventions for Sustainability of Major Cropping Systems of India, Sasya VigyanSsambhag Ki Naveentam Sasya Prodyogikiyon and Integrated Farming Systems: A Key Driver for Farmers’ Prosperity were released.
In recognition of the outstanding contribution in technology development and dissemination in partnership with IARI, three farmers were bestowed with ‘IARI fellow’ award.

7.3.7 Off-campus Exhibitions

The Centre for Agricultural Technology Assessment and Transfer (CATAT) and Agricultural Technology Information Centre (ATIC) of the Institute actively participated and organized 14 off-campus exhibitions in Delhi as well as other states of the country. The technologies and products developed by the Institute and the services provided were showcased in these exhibitions.

1. IInd Rajasthan Science Congress from May 1-3, 2014 at K.N. Modi University, Tonk Road, Rajasthan.

2. “10th International Agricultural and Horticultural Expo, 2014” organized by NNS Media Group from July 25 - 27, 2014 at Pragati Maidan, New Delhi. ICAR, Ministry of Agriculture, Govt. of India. IARI stall was awarded the first prize for excellent achievement and best display.

3. “Special Convocation” convened to confer the Doctor of Science degree to Dr. Jose Graziano da Silva, Director General, FAO, organized by IARI, New Delhi at NASC Complex, New Delhi on September 8, 2014.

4. “All India Farmers’ Fair and Agro-industrial Exhibition” at SVBPUA&T at Meerut from October 16-18, 2014. IARI stall received first prize.


6. Central India’s Agri-summit “6th Agro-vision” organized by Agrovision and MMACTIV, held from December 4-7, 2014 at Reshimbag ground, Nagpur (MS).


8. 7th Vibrant Gujarat Summit held from January 11-13, 2015 at Mahatma Mandir, Gandhinagar, Gujarat.

9. ASC India Expo during 12th Agricultural Science Congress 2015 on the theme “Sustainable livelihood security for small holder farmers” held from February 3-6, 2015 at NDRI, Karnal.

10. Exhibition during Inter-session meeting of consultative committee of the Ministry of Agriculture on February 17, 2015 at KVK, Shikohpur, Gurgaon (Haryana).

11. Exhibition on occasion of Annual General Meeting on February 18, 2015 at NASC, New Delhi.


14. ‘Regional Agriculture Fair for the Northern Zone’ during March 17-20, 2015 organized by ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly (UP).

7.3.8 Agricultural Technology Information Centre (ATIC)

A total number of 30,120 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. Maximum number of farmers visited ATIC to purchase/enquire seeds/varieties (15,235), this was followed by horticultural and medicinal plants related information (6010), plant protection (1450), Agro-based enterprises (1465), farm literature (5135), dairy (145), agricultural implements (798), visitors at ATIC stall (8265) and others (1055). Majority of the farmers visited ATIC from U.P. (28 %) ranked first followed by Haryana (20%), Delhi (15 %), Rajasthan (15%), Punjab (08) and others (14%). Besides, 8172 farmers/entrepreneurs 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). Purpose wise maximum calls were made by the farmers related to seed availability (3210) followed by production technology (2418), plant protection (1320), agro-based enterprises (690), farm literature (745), biofertilizer (380) and others (895). Pusa seeds of worth ₹46,51,388 and farm publication for ₹4,19,660 were sold to the farmers during the year.

ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators. More than 50 farmers and others got farm advisory services through letters/emails. 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 to the information needs of the different stakeholders. Six issues of farm magazine “Prasar Doot” were published by the centre. 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.

The ATIC laid out live demonstrations of paddy varieties, Pusa Basmati 1, PB 1121 (PS 4), Pusa Sugandh 5 (PS 2511), Pusa 1401 (PB 6), Pusa Basmati 1509, maize varieties, Pusa Composite 3, Pusa Composite 4, *moong* var. Pusa Vishal during *Kharif* season. Live demonstrations of wheat varieties, namely, HD 2733, HD 3086, HD 2851, HD 2967, HD 2894, HD 2932 and HD 3059; mustard varieties, Pusa Vijay and Pusa Mustard 26, Pigeonpea var. Pusa 992 were organized during *Rabi* season. In summer season demonstrations on vegetables, namely, pumpkin (Pusa Vishwas) okra (Pusa A 4), *lobia* (Cowpea) (Pusa Sukomal), cucumber (Japanese Long Green), onion (Pusa Red), *bathua* (Pusa Bathua-1), sponge gourd (Pusa Sneha), brinjal (Pusa Uttam), bottle gourd (Pusa Naveen), *palak* (Pusa Harit) Chilli (Pusa Sadabahar), tomato (Pusa Gaurav), *Amaranthus* (Pusa Kiran). In winter season demonstrations on vegetables such as cauliflower (Pusa Hybrid 2), broccoli (KTS 1), radish (Hybrid 1), beet. (Crimson Globe), *knol khol*. (W. Vienna), tomato (Pusa Rohini), *methi* (PEB, Pusa Kasuri), and flowers like gladiolus (Shabnam, Sinayana, Srijan, Kiran and Cidushi), and marigold (Pusa Narangi Gainda) were conducted. Medicinal garden, nutrition garden and fruit orchard were also maintained.

Drip irrigation system was demonstrated for fruit orchard and nutrigarden in crop cafeteria for the benefit of the visitors. Also a demonstration of pigeonpea under drip irrigation system was laid out in crop cafeteria. The result of the demonstration plot was encouraging (yield 2.30 t/ha). High density fruit trees orchard has been planted with lemon
(Kagzi Kalan), mango (Amrapali), guava (Lucknow-49, Allahabadi Safeda and Lalit), ber (Banarasi Karaka and Gola). For awareness of farmers, herbal block was developed in crop cafeteria which includes medicinal plants like Turmeric, Aloevera, Ashwagandha, Satavar, Coleus, Giloe, Mushkdana, Sadabahar, Konch, Mint, Tulsi (Basil), Lemon grass, Java citronella, etc.

New initiatives undertaken by ATIC. For termite management (IPM) Push Pull technique demonstration by sowing of three lines of wheat var. HD-2932 and 3059 between two lines of Kharif maize stubbles have been laid out during the Rabi 2014-15 season. Its results are encouraging.

1. Drip irrigation system has been installed in ATIC crop cafeteria for demonstrating water saving technology to the visiting farmers.
2. ATIC conference hall has been strengthened for facilitating interaction of farmers with experts.
3. Two Touch Panel Kiosks to access latest IARI technology through computer for visitors have been installed in the corridor of ATIC building.
4. Nineteen illuminated posters having farmer friendly information about the IARI technologies have been put up in the ATIC building corridor.

7.3.9 Krishi Vigyan Kendra, Shikohpur, Gurgaon (Haryana)

7.3.9.1 On-farm testing

Twelve on-farm trials were conducted on different field/farm based problems. Two trials on animal based problems were also conducted.

On farm testing conducted

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the On-Farm Testing</th>
<th>No. of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Integrated weed management (IWM) in rice</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Leaf blight management in marigold</td>
<td>3</td>
</tr>
</tbody>
</table>

7.3.9.2 Front line demonstrations

A total of 354 frontline demonstrations (Rabi 2013-14 & Kharif-2014), covering an area of 123.50 ha on oilseeds, pulses, cereal and vegetable crops under different schemes were organized.

Front line demonstration on wheat var. HD 2967
### Results of FLDs organized at the farmers' fields during Rabi 2013-14

<table>
<thead>
<tr>
<th>Name of programme/scheme</th>
<th>Crop</th>
<th>Variety</th>
<th>No of demonstrations</th>
<th>Area (ha)</th>
<th>Yield (t/ha)</th>
<th>Increase in yield (%)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Demonstration</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>(A) FFLDs on cereals, oilseeds, pulses, and vegetables (Under KVK Scheme)</td>
<td>Mustard</td>
<td>Pusa Vijay</td>
<td>60</td>
<td>24.00</td>
<td>2.14</td>
<td>1.67</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>Mustard</td>
<td>RH 0749</td>
<td>05</td>
<td>2.00</td>
<td>2.18</td>
<td>1.64</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>HD 2967</td>
<td>36</td>
<td>14.5</td>
<td>7.25</td>
<td>5.34</td>
<td>6.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VL 829</td>
<td>02</td>
<td>0.80</td>
<td>4.27</td>
<td>4.04</td>
<td>4.16</td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td>BH 902</td>
<td>10</td>
<td>4.00</td>
<td>6.26</td>
<td>4.88</td>
<td>5.43</td>
</tr>
<tr>
<td></td>
<td>Gram</td>
<td>Pusa 547</td>
<td>15</td>
<td>0.40</td>
<td>1.84</td>
<td>1.62</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>Garden Pea</td>
<td>Azad P 3</td>
<td>28</td>
<td>6.00</td>
<td>7.82</td>
<td>6.39</td>
<td>8.53</td>
</tr>
<tr>
<td></td>
<td>Carrot</td>
<td>Pusa Rudhira</td>
<td>04</td>
<td>2.00</td>
<td>30.50</td>
<td>24.80</td>
<td>26.20</td>
</tr>
<tr>
<td></td>
<td>Onion</td>
<td>Pusa Madhvi</td>
<td>03</td>
<td>0.80</td>
<td>34.05</td>
<td>28.40</td>
<td>31.640</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>163</td>
<td>58.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(B) FFLDs under NEP scheme (Model village)</td>
<td>Wheat</td>
<td>HD 2967</td>
<td>24</td>
<td>9.60</td>
<td>6.24</td>
<td>5.52</td>
<td>5.87</td>
</tr>
<tr>
<td></td>
<td>Mustard</td>
<td>Pusa Vijay</td>
<td>14</td>
<td>5.60</td>
<td>2.22</td>
<td>1.81</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>Spinach</td>
<td>Pusa Bharti</td>
<td>06</td>
<td>0.40</td>
<td>11.54</td>
<td>8.52</td>
<td>10.30</td>
</tr>
<tr>
<td></td>
<td>Onion</td>
<td>Pusa Madhvi</td>
<td>02</td>
<td>0.40</td>
<td>34.00</td>
<td>29.50</td>
<td>31.75</td>
</tr>
<tr>
<td></td>
<td>Carrot</td>
<td>Pusa Rudhira</td>
<td>05</td>
<td>0.80</td>
<td>30.40</td>
<td>25.200</td>
<td>26.96</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>51</td>
<td>16.80</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Result of FLDs on Kitchen Gardening (Nutrition)**

No. of demonstrations : 05, Area (ha): 0.20

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cauliflower</th>
<th>Fenugreek leaves</th>
<th>Spinach</th>
<th>Garden pea</th>
<th>Brinjal</th>
<th>Bottle gourd</th>
<th>Turnip</th>
<th>Radish</th>
<th>Mustard</th>
<th>Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>Pusa Meghna</td>
<td>Pusa early bunch</td>
<td>All Green</td>
<td>Pusa Pragati</td>
<td>Pusa Utam</td>
<td>Pusa Naveen</td>
<td>P. Purple white</td>
<td>Pusa Himani</td>
<td>Pusa Sarson Sag 1</td>
<td>Sel. 2</td>
</tr>
<tr>
<td>Yield (kg)</td>
<td>28.4</td>
<td>4.2</td>
<td>12.8</td>
<td>10.3</td>
<td>14.6</td>
<td>13.2</td>
<td>9.0</td>
<td>13.6</td>
<td>8.6</td>
<td>6.8</td>
</tr>
</tbody>
</table>
## Result of FLDs on Drudgery Reduction

<table>
<thead>
<tr>
<th>Crop</th>
<th>No. of demo.</th>
<th>Area (ha)</th>
<th>Parameter</th>
<th>Farmer's practice</th>
<th>Use of CIAE wheel hand hoe</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustard</td>
<td>05</td>
<td>5.00</td>
<td>Man power /ha</td>
<td>20</td>
<td>10</td>
<td>50% saving in all three parameters</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Man hrs/ha</td>
<td>160</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Expenditure on labour (₹)</td>
<td>5000/-</td>
<td>2500/-</td>
<td></td>
</tr>
</tbody>
</table>

## Results of FLDs organized at the farmers' fields during Kharif 2014

<table>
<thead>
<tr>
<th>Name of programme/scheme</th>
<th>Crop</th>
<th>Variety</th>
<th>No of Demo</th>
<th>Area (ha)</th>
<th>Yield t/ha</th>
<th>Increase in yield (%)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Demonstrations</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>(A) FLDs under KVK scheme</td>
<td>Paddy</td>
<td>PB 1509</td>
<td>30</td>
<td>12.00</td>
<td>4.71</td>
<td>3.64</td>
<td>4.08</td>
</tr>
<tr>
<td>Arhar</td>
<td>Pusa 2002</td>
<td>30</td>
<td>10.00</td>
<td>1.83</td>
<td>1.64</td>
<td>1.66</td>
<td>1.54 (Manak)</td>
</tr>
<tr>
<td>Moong</td>
<td>Pusa Vishal</td>
<td>05</td>
<td>1.60</td>
<td>0.80</td>
<td>0.58</td>
<td>0.76</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>SML 668</td>
<td>05</td>
<td>1.60</td>
<td>0.85</td>
<td>0.61</td>
<td>0.81</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Pusa 672</td>
<td>07</td>
<td>1.60</td>
<td>0.88</td>
<td>0.63</td>
<td>0.82</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>MH 421</td>
<td>05</td>
<td>1.60</td>
<td>0.87</td>
<td>0.59</td>
<td>0.85</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>P. Ratna</td>
<td>05</td>
<td>1.60</td>
<td>0.86</td>
<td>0.62</td>
<td>0.80</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>87</td>
<td>30.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cowpea</td>
<td>P. Sukomal</td>
<td>07</td>
<td>1.50</td>
<td>3.95</td>
<td>3.68</td>
<td>3.83</td>
<td>3.62 (Mahesh)</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>P. Naveen</td>
<td>09</td>
<td>2.00</td>
<td>29.67</td>
<td>2.64</td>
<td>2.79</td>
<td>2.54 (Kirti)</td>
</tr>
<tr>
<td>Sponge gourd</td>
<td>P. Sneha</td>
<td>04</td>
<td>1.00</td>
<td>10.04</td>
<td>6.08</td>
<td>8.14</td>
<td>7.27 (Nutan)</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>P. Meghna</td>
<td>05</td>
<td>2.00</td>
<td>11.08</td>
<td>8.84</td>
<td>10.66</td>
<td>9.87 (Kuvari)</td>
</tr>
<tr>
<td></td>
<td>P. Kartik S</td>
<td>04</td>
<td>2.00</td>
<td>12.16</td>
<td>9.08</td>
<td>11.53</td>
<td>-do-</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>8.50</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total (A)</td>
<td>116</td>
<td>38.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B) FLDs under NEP scheme (Model Village)</td>
<td>Paddy</td>
<td>PPB 1509</td>
<td>05</td>
<td>2.00</td>
<td>4.20</td>
<td>3.58</td>
<td>3.89</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>HHB 197</td>
<td>06</td>
<td>2.40</td>
<td>3.01</td>
<td>2.525</td>
<td>2.72</td>
<td>2.54 (Pioneer)</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>P. Naveen</td>
<td>01</td>
<td>0.10</td>
<td>27.60</td>
<td>—</td>
<td>27.60</td>
<td>25.00 (Kirti)</td>
</tr>
<tr>
<td>Bhindi</td>
<td>Pusa A 4</td>
<td>02</td>
<td>0.40</td>
<td>11.450</td>
<td>10.750</td>
<td>11.10</td>
<td>9.650 (H. Unnat)</td>
</tr>
<tr>
<td>Total (B)</td>
<td>14</td>
<td>4.90</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Grand Total (A+B)</td>
<td>130</td>
<td>43.40</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
7.3.9.3 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community, the KVK organized/ participated in 1290 events and activities in the villages and at KVK campus.

Organisation/participation in various extension events and activities

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Programme</th>
<th>No. of programmes</th>
<th>No. of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Field Days</td>
<td>24</td>
<td>749</td>
</tr>
<tr>
<td>2.</td>
<td>World food day</td>
<td>01</td>
<td>69</td>
</tr>
<tr>
<td>3.</td>
<td>Women in agriculture day</td>
<td>01</td>
<td>40</td>
</tr>
<tr>
<td>4.</td>
<td>Honey day</td>
<td>01</td>
<td>38</td>
</tr>
<tr>
<td>5.</td>
<td>Farmers visit at KVK for FAS</td>
<td>—</td>
<td>1119</td>
</tr>
<tr>
<td>6.</td>
<td>Field visit of SMSSs in farmer's fields</td>
<td>172</td>
<td>3298</td>
</tr>
<tr>
<td>7.</td>
<td>Farm Advisory Service on Telephone</td>
<td>—</td>
<td>2986</td>
</tr>
<tr>
<td>8.</td>
<td>Radio &amp; TV talk</td>
<td>23</td>
<td>—</td>
</tr>
<tr>
<td>9.</td>
<td>Lectures delivered by SMS of KVK in farmers trainings/ meetings organized by line department/ NGOs</td>
<td>30</td>
<td>1800</td>
</tr>
<tr>
<td>10.</td>
<td>Method Demonstration</td>
<td>18</td>
<td>194</td>
</tr>
<tr>
<td>11.</td>
<td>Kisan Gosthi</td>
<td>02</td>
<td>69</td>
</tr>
<tr>
<td>12.</td>
<td>Group Meetings/ Discussion</td>
<td>39</td>
<td>449</td>
</tr>
<tr>
<td>13.</td>
<td>Popular articles</td>
<td>03</td>
<td>—</td>
</tr>
<tr>
<td>14.</td>
<td>Camp /campaign (Agriculture)</td>
<td>06</td>
<td>425</td>
</tr>
<tr>
<td>15.</td>
<td>Camp /campaign (Animal)</td>
<td>04</td>
<td>594 animals diagnosed and treated</td>
</tr>
<tr>
<td>16.</td>
<td>News letter (quarterly)</td>
<td>04</td>
<td>500 copies of each issue were distributed to the farmers</td>
</tr>
<tr>
<td>17.</td>
<td>Diagnostic service (Animal) at KVK</td>
<td>11</td>
<td>30 Milk and fecal samples analyzed</td>
</tr>
<tr>
<td>18.</td>
<td>Soil &amp; water samples analyzed</td>
<td>726</td>
<td>587 (Soil samples) 139 (Water samples)</td>
</tr>
<tr>
<td>19.</td>
<td>Exhibitions</td>
<td>04</td>
<td>—</td>
</tr>
<tr>
<td>20.</td>
<td>Exposure visit of farmers &amp; farm women</td>
<td>03</td>
<td>185</td>
</tr>
<tr>
<td>21.</td>
<td>Press releases</td>
<td>22</td>
<td>—</td>
</tr>
<tr>
<td>22.</td>
<td>Extension bulletins (pamphlets) published</td>
<td>28</td>
<td>—</td>
</tr>
<tr>
<td>23.</td>
<td>SMSs sent to the farmers through Kisan Mobile services</td>
<td>168</td>
<td>Sent to 1128 farmers of the district</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1290</td>
</tr>
</tbody>
</table>

Front line demonstration on cauliflower var. Pusa Meghna

Exhibition stall being visited by Hon’ble Union Minister of Agriculture, Shri Radha Mohan Singh at KVK, Shikohpur
7.3.10 Transfer of Technology through IARI Regional Stations

7.3.10.1 Regional Station, Pusa (Bihar)

**Wheat frontline demonstrations.** Fourteen frontline demonstrations (FLDs) were laid out in Mohmmadpur village of Muzaffarpur district of Bihar. The demonstrations conducted were: Use of bio-fertilizers on K 1006 and HD 2967 wheat varieties (4) *Azatobactor* and PSB (4), zero-tillage technology (4) and new improved wheat variety (6). The performance of different demonstrations conducted was very encouraging. The FLD on wheat variety CBW-38 gave mean yield of 4.85 t/ha against mean yield of local checks 4.14 t/ha (HD 2733) and 3.73t/ha (UP 262). The overall yield increase of wheat variety CRW 38 was 17.23 to 29.96 per cent over local checks. A field day was organized on 30th March, 2015 in the village Mohammadpur-Damodar, (the adopted FLD village). About one hundred farmers participated in the discussions on the performance of the two latest wheat varieties and future plans of diffusion.

Under the IARI Outreach Programme during Kharif 2014, paddy seed were distributed among eighteen KVKs of Bihar, two KVKs of West Bengal and two KVKs of Jharkhand to popularize IARI varieties among the farmers. A paddy trial of three different varieties (Pusa 44, PNR 381 and Pusa Sugandh 5) was laid out involving 220 farmers. The response of farmers was very encouraging for the scented varieties of paddy, especially for Pusa Sugandh 5. Seed for 40 demonstrations of pigeonpea (var. Pusa 9) was distributed in four districts of Bihar. In Rabi 2014-15, seed for 919 demonstrations of wheat was distributed to 17 KVKs of Bihar, two each in West Bengal, Jharkhand, and four NGOs (Parivartan Siwan, Sathi Godda, Gramin Vikash Kendra, Nalanda and Welfare Creation Society Muzaffarpur).

About 840 minikit demonstrations of eight wheat varieties were laid out in farmers’ fields under the close supervision of KVKs in Bihar, Jharkhand and West Bengal in Rabi 2013-14. In Kharif 2014, 220 minikit demonstrations of three varieties of paddy were laid out in farmers’ fields in Bihar, Jharkhand and West Bengal. The mean yields of late sown wheat varieties recorded in Bihar were HD 2733 (3.65t/ha), HD 2824 (3.07 t/ha), HD 2967 (3.60 t/ha). The overall increase in mean yield was observed to be 39 to 65 per cent against the state average of 2.21t/ha. The results of mean yields of late sown wheat varieties in Bihar obtained were HD 2985 (3.12 t/ha), HI 1563 (3.08 t/ha), HW 2045 (2.96 t/ha), and the yield increase was 33 to 41 per cent over the local checks.

In the case of timely sown varieties of wheat in West Bengal, the mean yields obtained were HD 2733 (2.77 t/ha) HD 2824 (3.29 t/ha), HD 2967 (2.64 t/ha) and HI 1544 (2.56 t/ha) which indicated yield increase of 8 to 17 per cent against the state average of 2.80 t/ha. On the other hand, the mean yield of late sown wheat varieties obtained in West Bengal were HD 2985 (2.83 t/ha), HI 1563 (3.02 t/ha), HW 2045 (2.78 t/ha) thereby registering yield increase of 1 to 7 per cent over the local controls. In Jharkhand state, the mean yield of timely sown varieties of wheat were HD 2733 (3.92t/ha), HD 2824 (3.61 t/ha), HD 2967 (3.42 t/ha) and HI 1544 (2.69 t/ha) thereby indicating the yield increase of 43 to 109 percent, against the state average of 1.88 t/ha.

In the case of late sown wheat varieties, the mean yields recorded in West Bengal were HD 2985 (2.66 t/ha), HI 1563 (2.63 t/ha), HW 2045 (2.20 t/ha), which showed the overall yield increase of 17 to 42 per cent over the local checks. The results of mean yields obtained under paddy demonstrations in Kharif 2014 were Pusa 44 (3.59 t/ha), PNR 381 (3.18 t/ha), and Pusa Sugandha 5 (3.67 t/ha).

**Organization/participation in Kisan mela and other extension events**

- Participated in the Regional Agricultural Fair for Eastern Region organized at Central Potato Research Station, Patna (Bihar) during Feb. 19-21, 2015.
- Participated in one day Siwan Kisan Mela organized on March 2, 2015.
- Organized a Kisan Mela on the theme “Changing Climate: Appropriate Scientific farming” in the campus of IARI Regional Station Pusa (Bihar) on March 2, 2015. About 2000 farmers attended the Kisan Mela.
- Participated in the Kisan Mela organized by Rajendra Agriculture University, Pusa (Bihar) from March 14-16, 2015.

### 7.3.10.2 Regional Station, Indore (MP)

**Wheat FLDs.** A total of 38 demonstrations of eight wheat varieties were conducted in 16.35 hectares area in eight villages of Dewas, Dhar and Khargone districts of M.P. following recommended package of practices. Overall increase in yield was 2.30 t/ha (66 %) in these demonstrations compared to local check varieties grown with farmers' conventional cultural practices. The overall yield increase of durum wheat varieties were HI 8713 (82.2%), HI 8663 (77%) over the local check varieties.

### 7.3.10.3 Regional Station, Shimla (HP)

**Frontline demonstrations.** Five front line demonstrations (FLDs) on wheat variety HS 542 and five FLDs on barley variety BHS 400 were organized in different villages of Himachal Pradesh for popularizing the cultivation of new varieties among the farmers.

### Participation in Extension Events

- Farmers’ field days were organized at Kangru and Nihri villages of H.P.
- State Council for Science, Technology and Environment, H.P., Shimla sponsored training programme on “Nursery Production of Temperate Fruits” organized on 21.11.2014 at Horticultural Research Farm, Dhanda under IARI, R.S. Shimla.
- Kisan Mela at Darlaghat, Solan (HP) on 17/2/2015

### 7.3.10.4 Regional Station, Wellington (Tamil Nadu)

**Frontline Demonstrations.** Recently released high yielding multiple disease resistant wheat varieties HW 5216, COW 2 and COW 3 for Southern Hills Zone and HW 1098 for all dicoccum growing areas were popularized under front line demonstrations (FLDs) programme of DWR/MOA.

Fifteen wheat FLDs were sucessfully conducted in the districts of Vellore, Dharmapuri, Krishnagiri, Tiruvannamalai, Nilgiris of Tamil Nadu and Mandya of Karnataka and Parbhani of Maharashtra. Two wheat field days were also conducted to motivate the farmers to take up wheat as alternate viable and choice crop.

### 7.3.10.5 Regional Station, Katrain, Kullu (HP)

Fifty field demonstrations of different vegetables were conducted at the farmer’s fields and the varieties/hybrids resulted 10-16 per cent more yield over local check in Kharif 2014. Fifty field demonstrations on different vegetables were also organized in Rabi 2014-15. Twenty four groups of farmers, students, trainees, etc. visited the regional station.

### 7.3.10.6 Regional Station, Karnal (Haryana)

Seed village scheme sponsored by DAC, Ministry of Agriculture, GOI was continued during Kharif 2014 and Rabi 2014-15 for farmer-to-farmer horizontal spread of seeds of popular varieties of different crops. During Kharif 2014, 38.4 ha area was covered under paddy cv. PB 1509 and during Rabi 2014-15, 38.4 ha area was covered under wheat HD 2967 and 6.4 ha area under berseem seed production for increasing the availability of quality seeds in the concerned villages itself. Under seed village programme, resource poor farmers and farm women were given training at the regional station as well as at farmer’s field on various aspects of quality seed production.
Under participatory seed production programme, during *Rabi* 2013-14, seeds of wheat var. HD 2967 (99.76 t), berseem var. BL 42 (0.62 t), gram cv. BG 1103 (0.672 t) and garden pea var. Arkel (0.58 t) were produced. During *Kharif* 2014, seeds of improved varieties of paddy Pusa 44 (93.82 t), PB 1121 (51.52 t), PB 1509 (58.13 t) and PB 1 (3.12 t) were produced.

Hundreds of quintals of IARI Seed (Pusa Beej) of different varieties of wheat, gram, mustard, berseem, garden pea, paddy, etc. were sold to thousands of farmers as minikits. Farmers who visit our station for purchase of seeds were given proper guidance on various aspects of crop/seed production. More than 6000 seedlings of fruit plants like mango, guava, lemon and others were also sold from the station.

**Organisation of Extension Events**

- Field Day on September 23, 2014 at Brass village under the farmers participatory seed production programme.
- *Beej Bikri Divas* on March 12, 2015 in which seeds of popular IARI varieties of *basmati* paddy viz., PB 1509, PB 1121 and non-*basmati* variety, Pusa 44 was sold to thousands of farmers from Haryana, Punjab and Western UP.
Rural women have assumed an increasingly vital role in agricultural activities and household management. Their contribution to the farm based activities, particularly the animal production and management is widely recognized. They have immense potential to deliver significantly to increase farm output and enhance family income and well being. In this context, the empowerment of women through capacity building and trainings in farm and non-farm alternative occupations holds a key towards realizing their full potential to realize the intended goals of sustainable food, nutritional and livelihood security. A number of interventions were planned and undertaken to address the women empowerment and gender issues for creating awareness about scientific farming; enhancing nutritional security; and promoting entrepreneurial orientation among rural women and girls in order to enable them to undertake need-based employment and income-generating activities.

8.1 ENHANCING NUTRITIONAL SECURITY AND GENDER EMPOWERMENT

A pilot survey was conducted in two villages of Baghpat district of Uttar Pradesh in the context of household level nutritional security (consumption trend, awareness and knowledge about nutrient elements, nutrition programmes, cooking methods, food habits, kitchen & personal hygiene and water & food safety, etc.) through a structured interview schedule. The preliminary results suggest that average household income of the respondents was about ₹ 10,000/- per month. Out of this, two-third portion of their income was spent on food. Majority of the farmers were following sugarcane-wheat; sugarcane-rice; wheat-sugarcane-mustard-jowar cropping pattern. The food habits suggest that 98 per cent of them were pure vegetarians. About 65 per cent of them had two meals per day and the rest of them had 3 meals per day. Their staple foods were wheat and rice. Apart from this, in their diet they included vegetables like potato, green peas, cauliflower, cabbage, palak, methi, tomato, brinjal, potato, carrot, raddish, beet root, onion, bottle gourd, ridge gourd; fruits like banana, guava and mango which are seasonal; pulses like red gram, lentil and black gram; milk and milk products like butter milk, curd and ghee. For vegetables and fruits, they had to rely on local markets. About 80-85 per cent of the vegetables were procured from local markets. Fruits consumption was very less as they had to buy from nearby market and it was costly too. The per capita consumption of milk was 0.6 l / day. It is because households were having livestock like cows and buffaloes.

The knowledge and awareness level of the respondents were assessed by using a set of questions related to food sources of nutrients; functions of nutrients; nutrients for pregnant women; importance of breast milk and about IARI and its varieties. It indicates that although they are aware of the importance of having diversified foods like combination of cereals, pulses, vegetables and fruits, their knowledge score was very low. There was no gender bias in food distribution at household level. Even though they were growing IARI varieties, but 98 per cent of them did not know about IARI. Nearly 90 per cent of them knew about mid-day meals programme, which is the major nutrition oriented programme in our country.
Training needs areas of extension professionals for organizing Gender Empowerment trainings were identified. An analysis of constraints in extension organizations for gender empowerment trainings revealed inadequate transportation, social norms, workload of women and inadequate budget as major constraints in organization of trainings for women. These constraints were assigned I, II, III and IV rank, respectively. Absence of Child Care Centre and Canteen were reported as some of the other constraints specifically for organization of on-campus training programmes for women.

8.2 BIOTECHNOLOGY-LED SOCIO-ECONOMIC EMPOWERMENT OF FARM WOMEN

The project is being implemented in collaboration with two organizations viz., Deen Dayal Research Institute (DRI), Chitrakoot and PRDF, Gorakhpur, UP as non-government organization with lead centre at IARI. The project is under operation in five villages in Tappal block of Aligarh district having different agro ecological conditions. After conducting the participatory analysis of the area, women of these villages were mobilized to form 19 Self Help Groups (SHGs). Interventions on improved cereals, pulses, oilseeds, fodder crop, vegetables, fruits (lemon) and flowers, nutrition garden, soil and water management, protected cultivation and improved implements to reduce drudgery were implemented to address technological needs of the women. Besides, training programmes to motivate and mobilize women farmers for group action, scientific cultivation of crops including protected cultivation, grain storage, processing, baking and nutritional awareness were conducted.

8.3 PARTICIPATION OF FARM WOMEN IN SEED PRODUCTION

Rural women are playing significant role in agricultural development. Women of rural origin have proven to be good managers in all spheres of lives. Fourteen farm women during Kharif 2014 and Rabi 2014-15 from different villages of Karnal district (Haryana) were selected under Seed Village Scheme. They were given training on various aspects of quality seed production of important crops, namely, paddy cv. Pusa Basmati 1509, wheat cv. HD 2967 and berseem cv. BL 42. Through active participation in the trainings, the knowledge of farm women about importance of quality seed has increased significantly.

8.4 EFFECTIVENESS OF SHGs FOR GENDER EMPOWERMENT

The adoption of entrepreneurial activity by the groups, on one hand has helped the rural women in gaining self-confidence through financial independence and on the other hand, it has given them a recognition in the society by attracting awards and appreciations on district, state and national level.

8.5 VOCATIONAL AND FARM TRAINING FOR TECHNOLOGICAL INTERVENTION

The Institute KVK at Shikohpur is playing a vital role in empowering rural women and girls of Gurgaon district (Haryana) by organizing various need based self employment and income generating activities and other extension programmes for creating the awareness about scientific farming and disseminating the technology to wider areas. The important programmes and activities organized for rural women and girls were:

- Vocational training courses for self employment and income generation
- Day long trainings in villages for updating the farm knowledge/skills
- Exposure visit of rural women to agriculture fairs and exhibitions
- Front line demonstrations for disseminating improved farm technologies
- Celebration of “Women in Agriculture Day”
• T.V. talks, advisory services on phone, publication of literature on technical know-how on food processing and dairy management, etc.
• Formation of women Self Help Group in villages and motivating them to start their own enterprise and linking them to market.
• In all, 75 programmes were organized through which 964 rural women and girls of all social classes and income strata were benefited.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of activity</th>
<th>Duration</th>
<th>No. of programmes/activity</th>
<th>Number of beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>A Vocational Trainings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Establishment of Nutri-farm</td>
<td>1 week</td>
<td>02</td>
<td>40</td>
</tr>
<tr>
<td>2.</td>
<td>Dress designing and tailoring</td>
<td>2 months</td>
<td>02</td>
<td>50</td>
</tr>
<tr>
<td>3.</td>
<td>Value addition on soybean and pearl-millet</td>
<td>1 week</td>
<td>02</td>
<td>50</td>
</tr>
<tr>
<td>4.</td>
<td>Preservation of seasonal fruits and vegetables</td>
<td>1 week</td>
<td>02</td>
<td>33</td>
</tr>
<tr>
<td>5.</td>
<td>Participation in other vocational trainings</td>
<td>1 week</td>
<td>04</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td><strong>B Extension activities</strong></td>
<td></td>
<td></td>
<td>191</td>
</tr>
<tr>
<td>1.</td>
<td>Day long training in villages</td>
<td>1 day</td>
<td>33</td>
<td>469</td>
</tr>
<tr>
<td>2.</td>
<td>Day long trainings (On campus)</td>
<td>1 day</td>
<td>06</td>
<td>36</td>
</tr>
<tr>
<td>3.</td>
<td>Participation in different field days</td>
<td>1 day</td>
<td>20</td>
<td>173</td>
</tr>
<tr>
<td>4.</td>
<td>Celebration of Women in Agriculture Day</td>
<td>1 day</td>
<td>01</td>
<td>40</td>
</tr>
<tr>
<td>5.</td>
<td>Exposure visit of rural women to agricultural fairs /exhibitions</td>
<td>1 day</td>
<td>01</td>
<td>45</td>
</tr>
<tr>
<td>6.</td>
<td>Front line demonstrations</td>
<td>–</td>
<td>02</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td></td>
<td><strong>Grand Total (A+B)</strong></td>
<td></td>
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<td>75</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>964</td>
</tr>
</tbody>
</table>

Activity-wise participation of rural women and girls in vocational trainings and extension activities

A vocational training on “Dress Designing and Tailoring”

Vocational training on “Value Addition in Soybean and Pearl Millet”

A vocational training on “Preservation of Seasonal Fruits & Vegetables”
9. POST GRADUATE EDUCATION AND INFORMATION MANAGEMENT

The Indian Agricultural Research Institute has a rich legacy of excellence in research, teaching and extension. The Post Graduate School of IARI continues to provide national and international leadership in Human Resource Development by awarding Post Graduate degrees in 24 disciplines. So far, 3685 M.Sc./M.Tech. and 4468 Ph.D. students have been awarded degrees including 349 international students.

9.1 POST GRADUATE EDUCATION

9.1.1 Admission during the Academic Session 2014-15

The PG School continues to be the most sought destination for the students seeking admission to 24 PG Courses in all five streams of admission, namely, open competition, faculty up-gradation, ICAR in-service nominees, departmental candidates and foreign students. The admissions to the Ph.D. programme are based on national level entrance examination conducted in different parts of the country, followed by an interview and academic track record. While the admissions to the M.Sc. programme are based on an ‘All-India Entrance Test’ conducted by the Education Division of the Indian Council of Agricultural Research. The foreign students are admitted through DARE, Ministry of Agriculture and are exempted from the written test and interview. During the academic year 2014-15, 107 students (including 3 from physically handicapped and 2 from UPS categories) were admitted to M.Sc., 7 M.Tech. and 165 students (including 1 physically challenged, 5 ICAR in service nominee and 3 under faculty upgradation scheme) to Ph.D. courses. In addition 19 international students (12 M.Sc., 1 M.Tech. and 6 Ph.D.) from 8 foreign countries were also admitted.

At present, the total number of students on roll is 894 (240 M.Sc., 15 M.Tech. and 639 Ph.D.) including 44 international students representing 16 foreign countries, namely, Afghanistan, Botswana, Cameroon, Egypt, Ethiopia, Iran, Libya, Nepal, Nigeria, Rawanda, Seychelles, Sudan, Syria, Turkmenistan, Vietnam and Zambia. For the first time, the courses in the disciplines of ‘Horticulture’ and ‘Agricultural Engineering’ have also been started at Indian Institute of Horticultural Research (IIHR), Bengaluru and Central Institute of Agricultural Engineering (CIAE), Bhopal, respectively, as IARI’s outreach programme.
9.1.2 Convocation

The 53rd Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 20, 2015 with Dr. R. Chidambaram, Principal Scientific Advisor, Government of India and Chairman of the Scientific Advisory Committee to the Cabinet as the Chief Guest. Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR presided over the function. Dr. Chidambaram, in his convocation address, emphasized that science and technology–driven growth is essential to become a ‘developed’ country. To achieve global leadership in science (including agricultural science), engineering, technology, and manufacturing, innovations are needed and India’s vast National Agricultural Research, Education and Extension system has created the base today for converting the Indian economy into a knowledge-driven economy. Dr. Chidambaram also mentioned that sensor, sensor networks and related technologies are growing rapidly, which have the potential for use in sustainable Agriculture.

Dr. Ravinder Kaur, Director (Acting) presented her report on the significant research achievements of the Institute during 2014, while Dr. R.K. Jain, Dean and Joint Director (Education) highlighted the significant achievements in the field of education and training activities of the Institute.

On this occasion, the Chief Guest released thirteen varieties of different field and horticultural crops developed by the Institute which include: wheat (2); rice (2); chickpea (1); soybean (1); cauliflower (1); garden Pea (1); ash gourd (1); acid lime (2); marigold (1); and rose (1). The PG School Annual Report 2013-14 was also released during the convocation.

9.1.3 Special Convocation

The Special Convocation of the P.G. School of IARI was held on September 8, 2014 to confer the degree of Doctor of Science (Honoris Causa) on Dr. José Graziano da Silva, Director-General, Food and Agriculture Organization (FAO) of the United Nations for his tangible contributions in the area of food security, rural development, agriculture, and Zero Hunger Programme. Dr. S. Ayyappan, Secretary, DARE and Director-General, ICAR welcomed the Chief Guest, dignitaries and participants of the event. He made an illustrative presentation highlighting recent achievements and future research, education and extension thrusts of the ICAR.

Prof. M.S. Swaminathan, Emeritus Chairman & Chief Mentor, MSSRF and Dr. R.B. Singh, former President, NAAS
addressed the August gathering present on this great occasion. Dr. K. Vijayaragavan, Acting Director, IARI presented the report of the Director. Dr. R.K. Jain, Dean & Joint Director (Education), IARI read out the citation indicating outstanding contributions of Dr. Graziano in the field of food security, agriculture and rural development. Fourteen IARI varieties of different crops and a book entitled ‘Climate Resilient Dryland Farming and Watershed Management’ were released by the Chief Guest.

Dr. Graziano delivered the convocation address. Dr. Graziano complimented ICAR, IARI and the Government of India for according top priority to sustainable development in which the approach of more crop per drop is the foremost one, as water is the critical and limiting resource for agriculture. He emphasized that, simply producing more food is not enough, we need to increase production, sustainably, and ensure access to all. Dr. Graziano was also honored with prestigious Fellowship of the National Academy of Agricultural Sciences (NAAS) which is regarded as think tank of the India on agriculture and related issues. While conferring Fellowship, Dr. R.B. Singh, former President, NAAS highlighted the central role of Dr. Graziano in implementation of Zero Hunger Programme in Brazil which realized unprecedented results.

The convocation was followed by an interactive session, where in scientists from NARS system participated. Shri Arvind R. Kaushal, Additional Secretary, DARE and Secretary, ICAR proposed the vote of thanks.

9.1.4 Special Lectures

Dr. B.P. Pal Memorial Lecture. The 21st Dr. B.P. Pal Memorial Lecture was delivered by Dr. Shivaji Pandey, Special Advisor and Former Director, Plant Production and Protection Division, FAO on May 26, 2014 on the topic ‘Sustainable Agriculture: An Imperative to Feeding People and Protecting Earth’. Dr. Mangala Rai, former Secretary, DARE and Director General, ICAR presided over the function.

Teachers’ Day Lecture 2014. The Teachers’ Day Lecture 2014 was delivered on September 5, 2014 by Dr. S.A. Patil, former Chairman, Karnataka Krishi Mission and former Director, IARI on the topic ‘Role of Teachers in Achieving and Improving the IARI Mandates’. Dr. H.S. Gupta, Director General, Borlaug Institute for South Asia and former Director, IARI presided over the function.

National Agricultural Education Day Lecture. ‘National Agricultural Education Day Lecture’ was organized on November 13, 2014. Dr. Anupam Varma, Adjunct Professor, IARI, New Delhi delivered an impressive and informative lecture on the topic ‘Agricultural Education in India: Imaging Possibilities to Meet Challenges in the Changing Environment’. Shri B.N. Navalawala, former Secretary, Ministry of Water Resources and Advisor to the Hon’ble Chief Minister, Gujarat, presided over the function.

Lal Bahadur Shastri Memorial Lecture. The 45th Lal Bahadur Shastri Memorial Lecture was delivered by Prof. Sudhir K. Sopory, Vice Chancellor, Jawaharlal Nehru University on February 19, 2015 on the topic ‘Glyoxalase Pathway: Role in Stress Adaptation in Plants’. Dr. Manju Sharma, former Secretary, Department of Biotechnology, Govt. of India, presided over the function.
9.1.5 International Recognition

The excellence of IARI is recognized internationally. 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.

The Institute initiated teaching programme for M.Sc. students of ANASTU. A five months Modular Course for 21 M.Sc. Agronomy students of ANASTU, Kandahar (Afghanistan) was organized from March 3 to August 2, 2014. Dr. R.K. Jain, Dean and Joint Director (Edn.), was the Course Director, while Dr. K.S. Rana, Professor and Head (Acting), Division of Agronomy was the Course Coordinator. Six courses, namely, Principles of Crop Production; Agronomy of Vegetables and Fruit Crops; Protected Cultivation and Precision Farming; Agronomy of Fodder and Pasture Crops; Dryland Farming, Watershed Management, Climate Change and its Effect on Agriculture; Basic Agricultural Statistics and Designs; and Basic English Literature and Grammar were covered. The Institute has recently started tele-teaching of a course on “Principles and Practices of Weed Management” (3L+1P) for the students of ANASTU, Kandahar, Afghanistan.

9.1.6 Introduction of Anti-plagiarism Software ‘Turnitin’

To discourage plagiarism and maintain academic integrity, the Institute has provided the faculty and students access to a web-based software ‘Turnitin’, global leader in addressing plagiarism. Turnitin’s comprehensive plagiarism prevention system allows quick and effective checks to all research work in a fraction of the time.

9.2 INFORMATION AND DATABASE

9.2.1 Consortium for e-Resources in Agriculture (CeRA)

The main objective of the CeRA is to provide online access of journal in 143 institutions (including 40 agricultural universities) under the National Agricultural Research System (NARS) for enhancing research capabilities and output. In addition to on-line access, IARI library is providing document delivery services to 143 institutions (including SAU’s) under NARS. The library received 350 job requests and provided 2500 pages of photocopies of articles from its holding.

9.2.2 Statistical Modeling and Informatics

A web based forewarning system for yellow stem borer (YSB) and leaf folder (LF) of rice crop are being developed for Mandya (Karnataka), Raipur (Chhattisgarh), Ludhiana (Punjab), Chinsura (West Bengal), Karjat (Maharashtra) and Aduthurai (Tamil Nadu). The long-term monthly trends along with projections for 2020, 2025, 2030, 2035, 2040, 2045 and 2050 in various meteorological variables for different centers were obtained. The monthly means projected changed in meteorological variables for different locations in different years are also obtained. The patterns were developed on cotton pests population during 2014-15 for thrips, jassid and whitefly in different locations. The patterns over the crop season for cotton pests for different locations were studied through non-linear models taking time as independent parameter.
Scientist database was created to enable the users to dynamically search a scientist based on division, name and employee number. The database is now integrated with new detail table which consists of publications, faculty information, patents, technology/methodology / variety, awards and recognition, etc. Hyper linking was done on photo/name with a PHP page for displaying the scientist details. In addition using PHP 5.4.7 as front end platform and MySql 5.0.10 as backend database an update feature that enables the scientist to update their information was created.

9.2.3 Bioinformatics

Sequence and structural analysis of protein coded by WESR3 gene was carried out using various bioinformatics tools. Three-dimensional modeling was carried out to elucidate its structure and its active site. The Ramchandran plot analysis also showed that all amino acid residues of I-TASSER model lie in the allowed region and thus indicating towards the overall good quality of the predicted model. Seventeen active sites were predicted in the protein bearing resemblance to the Mlo family conserved regions. These results aid to the experimental data and help to build up a complete view of WESR3 proteins and their role in plant stress response.

In silico approach, including secondary structure analysis, detailed signature pattern study, cis-acting regulatory elements survey, evolutionary trends and three-dimensional molecular modeling was used for different chitinase classes of wheat (*Triticum aestivum*). The model structures were further refined by molecular mechanics methods using different tools, such as Procheck, ProSA and Verify3D. The results provide insight into the evolution of the chitinase family, constituting a diverse array of pathogenesis-related proteins. The study also provides insight into the possible binding sites of chitinase proteins and may further enhance our knowledge of fungal resistance mechanism in plants.

9.3 LIBRARY SERVICES

IARI Library is one of the largest and the finest agro-biological libraries in South East Asia housing large collection of publications including books/monographs, journals, reports, bulletins, postgraduate theses and other reference materials. The Library has on its role 2000 member viz., students, scientists and technical staff. It also serves about 2500 visitors every year. The Library functions as the depository of Food and Agricultural Organization (FAO), and Consultant Group of International Agricultural Research (CGIAR) institutes’ publications.

9.3.1 Acquisition Programme

9.3.1.1 Books

During the period under report, the Library procured 425 publications which includes 190 in Hindi and 235 in English costing ₹ 15,01,633. The Library also acquired 159 gift publications and 182 PG Students’ theses from IARI.

9.3.1.2 Serials

The Library procured 2645 journals/serials through subscription, gifts and exchanges. It subscribed to 107 foreign journals (out of which 30 had online access), 180 advances & annual reviews, and 185 Indian journals, advances, and annual reviews. Exchange relationship was maintained with 67 institutions globally and nationally by sending 102 annual reports, ICAR journals and society publications. A total of 311 publications accessioned. One hundred eighty annual scientific/technical reports of different institutions and 94 bulletins were received in the Library during report period. The expenditure on serial acquisition from plan/non-plan and PG strengthening scheme was ₹ 1,78,10,116 for 107 foreign titles and ₹ 15,13,975 for 185 Indian Journals.

9.3.2 Documentation Activities

9.3.2.1 AGRIS Project

IARI Library is declared as an input center for National Agricultural Research Database (NARD)
under AGRIS Project. The Library is assigned the job of scanning articles from 10 most important Indian journals. The input was done in ISO format using AGRIN methodology.

9.3.2.2 Development news in agriculture

Fourteen newspapers were scanned and 85 news items pertaining to IARI as well as ICAR were sent to the Directorate, Principal Scientist (PME) and CATAT.

9.3.2.3 Document processing

In all, 1040 documents consisting of 326 books, 368 IARI post-graduate and RFT theses, 96 old books and 230 Hindi books were processed (classification and cataloguing).

9.3.3 Resource Management

9.3.3.1 Reference, circulation and stack maintenance

Apart from approximately 2000 registered members, the Library served everyday approximately 150 to 200 users, who come from different agricultural universities/ICAR Institutes consulted about 2000 to 2500 documents. During the period under report, 1831 publications were issued and 1828 publications returned to its members. In all, 35 documents were issued under Inter Library Loan System to various institutions. Three hundred sixty two no dues certificate were issued. Payment of ₹ 11,500 for membership of DELNET (Developing Library Network), New Delhi was made for providing Inter Library loan (reference services) to scientific community.

9.3.4 CD-ROM workstation

Three prominent international databases on agricultural aspects were subscribed amounting to ₹47,38,381 to provide CD-ROM services. Ten user terminals were provided to users in CD-ROM workstation of the library. These databases are accessible to scientists/students/users of IARI through LAN. In all, 14,103 references were downloaded by the scientists and students of IARI and research scholars from all over India. The cost based references downloaded were 15669 which generated revenue amounting to ₹ 19,269.
10. PUBLICATIONS

An important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications in the form of research papers in peer reviewed journals, books/book chapters, popular articles, etc. are an integral component of the information system. During the reported period, the Institute scientists brought out quality publications in the form of research papers in peer reviewed journals, books/book chapters, popular articles, etc. both in English and Hindi. Apart from these publications, the Institute brought out several regular and ad hoc technical publications both in English and Hindi. The details of these publications are given below:

### 10.1 PUBLICATIONS AT A GLANCE

<table>
<thead>
<tr>
<th>1. Research/Symposia Papers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Research papers (NAAS rating 6 and above) published in journals</td>
<td>529</td>
</tr>
<tr>
<td>b) Symposia/conference papers</td>
<td>439</td>
</tr>
<tr>
<td>2. Books/Chapters in Books</td>
<td></td>
</tr>
<tr>
<td>a) Books</td>
<td>35</td>
</tr>
<tr>
<td>b) Chapters in books</td>
<td>280</td>
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### 10.2 IN-HOUSE PUBLICATIONS

#### 10.2.1 Regular Publications
- IARI Annual Report 2013-14 (ISSN: 0972-6136)
- IARI NEWS (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly)-12 issues (Available only on IARI website)

#### 10.2.2 Technical Publications (English)
- Advances in Vegetable Agronomy (ISBN 978-93-83168-17-0)
- Seed Technology (TB-ICN:134/2014)
- Hybrid Seed Production Technology of Bitter Gourd (TB-ICN:135/2014)
- Climatic Rises and Strategizing Agricultural Adaptation in Climatically Challenged Regions (TB-ICN:136/2014)
- Agronomic Interventions for Sustainability of Major Cropping Systems of India (TB-ICN:137/2014)
- Valorization of Horticultural and Arable Crops (TB-ICN:139/2014)
- Natural Resource Management for Sustainable Agriculture (TB-ICN:140/2014)
- Avenues in Floriculture for Livelihood (TB-ICN:141/2014)
- Enhancing Crop Productivity with Seed Enhancement Technologies under Less Favourable Environments (TB-ICN:143/2015)
- Seed Production Technology in Important Field Crops (TB-ICN: 144/2015)
- Management of Production Problems of Horticultural Crops for Enhancing Productivity and Quality (TB-ICN: 146/2015)
- Entrepreneurial Technical Information Packages (TB-ICN: 147/2015)

10.2.3 Other Important Packages
- पूर्वांश (वार्षिक)
- वार्षिक रिपोर्ट 2013–14
- पूर्वांश समाचार (वार्षिक)

10.2.4 Other Important Packages
- प्रसार दूत (विमानसेवा)
- सामाजिक (शास्त्रीय) (केन्द्र संचालन की वेबसाइट पर उपलब्ध)

10.2.4 Other Important Packages
- सिंगल क्रास ब्रॉडकास्ट के बीज उत्पादन (ICN: H-141/2014)
- सर्वश्रेष्ठ महत्वपूर्ण स्थानों की शोध आधारित नवीनतम सर्वश्रेष्ठ प्रौद्योगिकियाँ (ICN: H-142/2014)
- समर्थक किट प्रबंधन (ICN: H-143/2015)
- प्रमुख प्रक्षेत्र फसलों में बीज उत्पादन प्रौद्योगिकी (ICN: H-144/2015)
- बदलता ग्रामगल्ला (उपयुक्त वैज्ञानिक खंडी) (ICN: H-145/2015)
- गुणवत्ता सुनिश्चित बीज : हरित क्रांति का महत्वपूर्ण उपादान (ICN: H-146/2015)
- चैनैयन किसानों का संक्षिप्त परिचय (ISBN: 978-93-83168-20-0)
11. IP MANAGEMENT, TECHNOLOGY COMMERCIALIZATION AND AGRIBUSINESS INCUBATION ACTIVITIES

The mission of the Zonal Technology Management and Business Planning and Development (ZTM & BPD) Unit is, “Translating Research into Prosperity” which is achieved by doing IP management, technology commercialization and fostering entrepreneurship through business incubation. During the period, the Unit has organized following activities:

11.1 TECHNOLOGY COMMERCIALIZED

Under lab to land initiative, during 2014-15, 30 innovative technologies from North Zone -1 of ICAR were transferred to 144 industry partners which resulted around ₹ 1.54 crore revenue. Among the technologies commercialized, wheat variety HD 3086 was in great demand and licensed to 109 Industry Partners, creating historical record for ICAR system, followed by wheat vars. HD 3090 & HD 2967; rice vars. PB 1509 & Pusa 1612; mustard vars. Pusa Mustard 25, Pusa Mustard 26, Pusa Mustard 28, Pusa Mustard 29 & Pusa Mustard 30, Nanofertilizer Technology, STFR Meter, VAM Technology, Compost Inoculant, PSB carrier based Biofertilizer, Rhizobium carrier based Biofertilizer, Blue Green Algae (BGA), and Trichoderma Bio Pesticide, etc.

11.2 INTELLECTUAL PROPERTY RIGHTS

A. Patent Application Filed

Six patents applications with six renewals of existing patents were filed, along with two responses to First Examination Report (FER) and one hearing and four amendments. The details are as follows:

<table>
<thead>
<tr>
<th>Patent application filed</th>
<th>Application/ registration no.</th>
<th>Date of filing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Insecticidal formulation of novel strain of Bacillus thuringiensis AK47</td>
<td>2361/DEL/2014</td>
<td>August 20, 2014</td>
</tr>
</tbody>
</table>

Revenue generated through licensing of the technologies during 2009-15
B. Applications for Protection of Plant Varieties under PPV&FRA

Varieties protected under PPV&FRA

1. **Triticum aestivum** L. (wheat) HD 3043
   - REG/2015/325
   - February 19, 2015

2. **Triticum aestivum** L. (wheat) HD 3086
   - REG/2015/326
   - February 19, 2015

---

11.3 AGRIBUSINESS INCUBATION

ZTM & BPD Unit, IARI an Agri Business Incubator incubates new start-up businesses by providing physical space, shared services, business and legal advice and financial and assist them until ‘graduation’. This year following activities were under taken.

A. Agribusiness Incubation Programme

- For the first time, in agribusiness sector, online entrepreneurial ecosystem was created by launching four months “Agribusiness Incubation Program” on 25th April, 2014 for providing a platform for identifying next generation of agri business leaders from India’s emerging agri-business innovation ecosystem, thereby buttressing them to develop and set up viable business models based on innovative ideas in association with ZTM & BPD Unit, IVRI, Izatnagar and BPD units of NDRI, Karnal, BAU, Ranchi, CIPHET, Ludhiana and CIIE, Ahmedabad. Ten business proposals were selected for two months mentorship programme at ZTM & BPD Unit, IARI.

- ZTM&BPD Unit organized “AgriBiz Idol Camp cum Incubation Workshop” on May 9, 2014 at IARI, New Delhi. Ten (out of 32) business plans presented before the selection committee were selected for long term mentoring. Following five proposals/ideas were submitted to MSME for funding:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the project</th>
<th>Name of the incubatee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cotton harvesting machine</td>
<td>Mr. Nitin</td>
</tr>
<tr>
<td>2</td>
<td>Double mustard: commercialization of zero erucic acid mustard (<em>Brassica juncea</em>) for enhancing the competitiveness of domestic edible oil industry in India</td>
<td>Mr. Raju Ram</td>
</tr>
<tr>
<td>3</td>
<td>Instant millets mix for breakfast, soups, shake, etc.</td>
<td>Mr. Abhay Kumar Verma</td>
</tr>
<tr>
<td>4</td>
<td>Hand-held device embedded/installed SAAS (software as service) /an information application with predictive local and regional analytics for animal husbandry</td>
<td>Mr. Umang Aggarwal</td>
</tr>
<tr>
<td>5</td>
<td>Enzys translational research and application centre (enTRAC)</td>
<td>Mr. Amit Kumar Roy</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Trade Mark application filed/renewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. “flexiCFF”</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2. PUSA Trade Mark (Renewal)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

---

5. Nanofabrication of phosphorus on kaolin mineral receptacles
   - 989/DEL/2014
   - Complete specification filed on March 4, 2015

6. Beneficiation of phosphate rock for the segregation of phosphorus containing heavy metal free minerals
   - 1042/DEL/2014
   - Complete specification filed on March 4, 2015

---

Glimpses of AgriBiz Idol camp cum incubation workshop
B. MSME Scheme for Business Incubation

Ministry of MSME, Govt. of India, New Delhi sanctioned a project, for supporting “Startup companies with innovative ideas” to ZTM & BPD Unit. As a result of technical and business mentoring, following five incubates got the grant of ₹ 5.0 lakhs each, which helped them setting up of their viable business ventures.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the project</th>
<th>Name of the incubatee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Production and marketing of high quality hybrid and OP seeds of vegetable and field crops</td>
<td>Mr. L.K. Pandey</td>
</tr>
<tr>
<td>2</td>
<td>Innovations, production and marketing of quality Soya products under brand name of Soya Nutri Nuts</td>
<td>Mr. Kundan Kumar</td>
</tr>
<tr>
<td>3</td>
<td>Manufacturing of bio-fertilizers and bio-pesticides</td>
<td>Mr. Jaideep Pareek</td>
</tr>
<tr>
<td>4</td>
<td>Utilization of waste mango kernel for extraction of rich mango kernel butter and oil</td>
<td>Ms. Tuba Siddiqui</td>
</tr>
<tr>
<td>5</td>
<td>Biscuit-making from nutritionally rich traditional millets in combination with the wheat flour</td>
<td>Mr. Bhopinder Mehta</td>
</tr>
</tbody>
</table>

C. Marketing and Networking Platform

ZTM & BPD Unit provided the Marketing and Networking Platform in *Pusa Krishi Vigyan Mela* to its incubatees and industry partners in ZTM enclosure. Twenty incubates and industry partners participated and showcased their products/technologies, services which were of benefit to the farming community as well as other stakeholders of agricultural development.

11.4 CONSULTANCIES AND CONTRACT RESEARCH PROJECTS

During the year 2014-15, ZTM & BPD Unit facilitated and finalized 17 Consultancy, Contract Research and Collaborative Research Projects worth ₹ 57,57,048, as per the prescribed guidelines from ICAR.

11.5 CORPORATE MEMBERSHIP

Eighty one new corporate members were registered with ZTM&BPD, with thirty seven renewals of existing memberships, generating a revenue of ₹ 5,76,000 during the year under report.

11.6 HANDHOLDING OF ZONAL ITMUs

- **Post NAIP Collaborations**: For commercialization of technologies on which ICAR has IPR Rights and being generated by both non-ICAR Institutes and by ICAR Institutes under consortium mode coming in the catchment area of North Zone, elaborate processes and procedures were established via Agreements with different institutions like IIT Delhi, PAU Ludhiana, BITS, Pilani, etc. Under this mechanism, five technologies in nano fertilizer/nano nutrients were commercialized to Industry Partners, and branding of another technology by trade mark registration was accomplished, which is also under commercialization.

- One to one interaction with ITMU in-charges as well as with concerned scientists was done regarding technologies ready for commercialization, valuation and IP issues in Zonal Institutes like NCIPM, NBPGR, NRCSS, CAZRI and DMR.

- The Unit commercialized Nano technology basket of CAZRI, Jodhpur.

11.7 OTHER ACTIVITIES

A. Technology Promotional Events

(1) Meets Organized

The ZTM & BPD Unit, IARI organized: (1) ‘HD 3086 Wheat Day’ on August 14, 2014 at IARI and during the Day HD 3086 variety was licensed to 26 Seed companies; (2) ‘HD 3086 Industry Partnership Meet’ on September 6, 2014 and exchange of 60 MoA’s between IARI and the Industry Partners in a single day creating historical record for ICAR system; (3) Business Meet with M/s Coromandel International Limited on October 13, 2014 for showcasing ICAR-nano technology basket available for commercialization and seeking avenues for collaboration between IARI and Coromandel International Limited; (4) ‘Induction
Workshop on December 19, 2014 on Business Planning & Development for incubatees to provide mentorship on financial management; and (5) “Mustard Field Day” on March 4, 2015 to showcase ‘Brassica Improvement Program’ developed at Division of Genetics, IARI to prospective 27 industry partners.

B. Marketing Campaign

- During 2014-15, eleven e-marketing campaign for 32 futurististic technologies of IARI and Zonal Institutes i.e., STFR Meter, Biofertilizer Technology, Biopesticides Technology, Agricultural Chemicals Technology, Nano Fertilizer Technology, Cross flow membrane filtration assembly for small processing volume and new varieties of Rice, Wheat and Mustard developed by IARI were launched.
- More than 4236 e-mails despatched to various seed, biofertilizer, biopesticides, chemicals manufacturing and agri-equipments and agricultural machineries manufacturing companies. The campaign received over whelming response from the Industries across India.
- Around 400 Cold calls were made to various agro based companies and corporate members for promotion of new technologies developed by IARI, New Delhi.

C. Collaborations

During the period, the ZTM & BPD Unit, IARI facilitated the collaborations with other institutes as follows:

- Collaboration between IARI and DUVASU, Mathura for Quality Seed Production.
- Collaboration between IARI and Bhabha Atomic Research Centre (BARC), Department of Atomic Energy (DAE), Mumbai for the project on ‘Dynamics of engineered nano-particles (ENPs) in soil and phytotoxicity assessment on food crops’.
- Collaboration between IARI and Bhabha Atomic Research Centre (BARC) for setting up a ‘Radioecology Unit’ at Nuclear Research Laboratory, IARI, New Delhi.
The Indian Agricultural Research Institute has linkages with various national and international institutes/organizations. At national level the Institute has close linkages with almost all annual crop and horticultural crop research institutes, centres, project directorates, coordinated projects as well as a few other selected institutes of the ICAR. Similar linkages exist for natural resource and socio-economic research institutes. Collaboration exists with almost all state agricultural universities (SAUs), selected conventional universities, several of the institutes of the CSIR and departments of Ministry of Science and Technology such as the Departments of Biotechnology, Space Research, Meteorology, and several other ministries/departments/organizations/banks of the Government of India, besides some private organizations/banks.

IARI is the lead centre to coordinate the accelerated crop improvement programme for breeding rust resistant wheat varieties involving 10 centres, improving quality in maize which has enabled several SAUs and ICAR institutes to upgrade and update themselves with new tools and techniques. Under the NAIP and NFBSFARA, IARI is lead centre to develop state of art facilities and infrastructure on food science and phonemics led sciences. The NICRA programme of ICAR performed significantly by developing new genotypes for minimizing the negative impact of climate change in wheat by recombining QTL combinations for drought and heat tolerance apart from documenting the mitigation and adaptation phenomena to changing climate in rice and wheat.

In lieu with the consortia mode of project of ICAR, the Institute has been encouraging linkages and professional collaborations among national institutes to work on major research focus on ‘Molecular breeding’ for improvement of tolerance to biotic and abiotic stress, yield and quality traits in crops, and ‘Hybrid technology’ for higher productivity in selected field and horticultural crops. The Institute also identified some of the priority research areas through other ICAR Consortium Research Platforms as Mega seed platform, Genomics platform, Diagnostic and Vaccines, Energy platform, Water platform, Conservation Agriculture Platform, Farm mechanization and precision farming, etc.

On public private partnership mode, the role and participation of private sector in agricultural services is increasing in different forms and capacities. This underlines the need for ensuring effective public-private partnerships and linkages besides improving the structural and operational efficiency and governance of the institutions to make them farmer-friendly. Keeping this in view, the Institute has planned to forge collaboration with the advanced centres of research in other countries, as well as with some of the private seed sector having strong R&D base and expertise in seed quality enhancement.

The Institute has extended liaison with private companies for commercialization of technologies. Commercialization of many IARI technologies with private and public enterprises has taken place.

The linkage system is being studied for strengthening extension under IARI-NGO Partnership programme as well. Linkage with post offices as a new extension model was developed by IARI. The IARI has initiated an innovative extension programme for technology dissemination in partnership with selected NGOs for feasibility trails and promotion of agricultural technologies in their operational areas.

On Post Graduate Education, the Institute has recently approved a collaborative programme with University of Nebraska from USA for strengthening PG education. Efforts are being made to have such
programmes with more universities on bilateral basis. The Institute is playing a very important role in institution building in other countries, namely, in the establishment of (i) Afghan National University of Agricultural Sciences and Technology, Afghanistan; and Advanced Centre for Agricultural Research and Education at Yezin Agricultural University, Myanmar. Further linkages extend towards establishment of IARI off-campus in selected ICAR Institutes. The classic examples are start of PhD programmes in IIHR, Bangalore and CIAE, Bhopal.

In the arena of training, the centres of excellence at IARI have established linkages with different national institutions through their regular training programmes and also through other programmes offered through Centre of Advanced Faculty Training.

At the international level, the Institute has close linkages with some of the CGIAR’s international agricultural research centres (IARCs), viz., ICRISAT, CIMMYT, IRRI, and ICARDA. It also has linkages with other international organizations, viz., FAO, IAEA, USAID, UNDP, WMO, UNIDO and UNEP. Several bilateral research linkages involving developed and developing countries also exist. These include linkages with USDA, selected universities in USA, Canada, Australia, World Bank, Rockefeller Foundation, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The number of externally funded projects in operation during the period from 1.4.2014 to 31.3.2015 are given below:

<table>
<thead>
<tr>
<th>Name of funding agency</th>
<th>No. of projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within India</strong></td>
<td></td>
</tr>
<tr>
<td>AIREA, CRIDA, Directorate of Horticulture, HPSC&amp;ST, DRDO, MSME, DBT, DST, ICAR, CPRI (Mini Mission - HP), CSIR, NCFA, Ministry of Water Resources, Ministry of Environment &amp; Forest (MOFPI), Bill Melinda Gates Foundation (BMGF), DAC, NABARD, Indian Meteorological Department (IMD), BARC, PPV&amp;FRA, NFBSFARA (ICAR), etc. National Fellow Scheme of ICAR and Niche Area Project</td>
<td>03</td>
</tr>
<tr>
<td><strong>Outside India</strong></td>
<td></td>
</tr>
<tr>
<td>ICARDA, CIMMYT, Harvest Plus Consortium IFPRI, VFRC, IWMI, CIARC, IRRI</td>
<td>10</td>
</tr>
</tbody>
</table>
13. AWARDS AND RECOGNITIONS

The ZTM & BPD Unit, IARI won the Gold in Flame Award-2014, under the category “Agriculture/ Dairy Initiative of the Year” for the campaign “Translating Research into Prosperity” for successful materialization of inventions from lab to land. The award was conferred by the Hon’ble rural marketing goliaths of Rural Marketing Association of India on March 20, 2015.

- Dr. A. K. Singh, Head, Division of Genetics received (i) Rafi Ahmed Kidwai Award for his contribution in Agricultural Sciences (Crop and Horticultural Sciences), (ii) Bharat Ratna Dr. C. Subramaniam Outstanding Teacher Award, and (iii) Recognition Award 2014 of All India Rice Exporters Association.

- Dr. K. Annapurna, Head, Division of Microbiology received Woman Leadership Award, Asian PGPR Society.

- Dr. Rashmi Aggarwal, Head, Division of Plant Pathology awarded (i) K.C. Mehta and Manoranjan Mitra Award and (ii) Fellowship of Society of Biocontrol Advancement.

- Dr. S.V. Sai Prasad, Head, IARI-Regional Station, Indore received Outstanding Achievement Award in Plant Breeding.

- Dr. S.S. Sindhu, Head, Division of Floriculture and Landscaping was elected Fellow, Horticulture Society of India.

- Dr. V.R. Sagar, Head, Division of Food Science & Post Harvest Technology received J.C. Anand Gold Medal Award.

- Dr. P Krishnan, Head, Agricultural Physics received (i) Fellowship of Indian Society of Plant Physiology, and (ii) CICS International Travel Fellowship-2014.

- Dr. Pratibha Sharma, Professor, Division of Plant Pathology received National Crystal Agri Award-2014.

- Dr. Man Singh, Professor and Dr. Manoj Khanna, Principal Scientist, Water Technology Centre received Indian Society of Agricultural Engineers Team Award.

- Dr. H. Pathak, Professor, CESCRA was elected (i) Fellow, Indian National Science Academy, and (ii) DARE/ICAR’s Coordinator for climate negotiations in the UNFCCC.

- Dr. M. Sivasamy, Principal Scientist, Dr. P. Jayaprakash, Senior Scientist and Dr. Vikas V.K., Scientist, IARI-Regional Station, Wellington received Silver plaque for the development of *Dicoccum* variety, HW1098.

- Dr. Zakir Hussain, Principal Scientist, Division of Vegetable Science awarded Best Scientist Award of Hi-Tech Horticultural Society.

- Dr. Shelly Praveen, Principal Scientist, Division of Plant Pathology was elected Fellow, National Academy of Agricultural Sciences.

- Dr. G.P. Singh, Principal Scientist, Division of Genetics was elected (i) Fellow, National Academy of Agricultural Sciences, (ii) Fellow, Society of Advancement of Wheat Research, and (iii) received V.S. Mathur Memorial Award.
- Dr. Sujata Vasudev, Principal Scientist and Dr. Naveen Singh, Senior Scientist, Division of Genetics were elected Fellow, Indian Society of Genetics and Plant Breeding.
- Dr. C. Bharadwaj, Principal Scientist, Division of Genetics was elected Fellow, Indian Society of Pulses Research and Development.
- Dr. Shiv K. Yadav, Principal Scientist, Division of Seed Science & Technology was elected Fellow, Society of Extension Education.
- Dr. V.K. Pandita, Principal Scientist, IARI-Regional Station, Karnal received Achiever Award - 2014 of Society for Advancement of Human and Nature.
- Dr. Anuja Gupta, Principal Scientist, IARI-Regional Station, Karnal received Commendation Certificate from Town Official Language Implementation Committee, Karnal.
- Dr. M. Sivasamy, Principal Scientist, IARI-Regional Station, Wellington was elected Fellow, Society for Advancement of Wheat Research.
- Dr. A.K. Dubey, Principal Scientist and Dr. Manish Srivastav, Senior Scientist, Division of Fruits and Horticultural Technology were elected Fellow, Horticulture Society of India.
- Dr. T.K. Behera, Principal Scientist, Division of Vegetable Science was elected (i) Fellow, National Academy of Agricultural Sciences, and (ii) received Fulbright-Nehru Academic and Professional Excellence Fellowship.
- Dr. Kanwar Pal Singh, Principal Scientist, Division of Floriculture and Landscaping received Horticulture Society of India Gold Medal in Floriculture.
- Dr. Ram Asrey, Principal Scientist and Dr. Shalini G. Rudra, Scientist, Division of Food Science & Post Harvest Technology received Young Scientist Award.
- Dr. A.K. Saxena, Principal Scientist, Division of Microbiology was elected Fellow, Indian Academy of Microbiological Sciences and received Distinguished Scientist Award, Asian PGPR Society.
- Dr. V.K. Baranwal, Principal Scientist, Division of Plant Pathology was elected Fellow, Indian Phytopathological Society.
- Dr. Anupama, Principal Scientist and Dr. Dhruba Jyoti Sarkar, Scientist, Division of Agricultural Chemicals were awarded 5th National Award for Technology Innovation in various Field of Petrochemicals and Downstream Plastic Processing Industry.
- Dr. V.K. Sharma, Senior Scientist, Division of Soil Science and Agricultural Chemistry received (i) Young Scientist Award, and (ii) Fellowship of Indian Society of Salinity Research Scientists.
- Dr. V. Shanmugam, Senior Scientist, Division of Plant Pathology was elected Fellow, Society for Biocontrol Advancement.
- Dr. T. Nepolean, Senior Scientist, Division of Genetics received Eminent Scientist Award of the National Environmental Science Academy.
- Dr. M.K. Dhillon, Senior Scientist, Division of Entomology was elected Fellow of the Academy of Environmental Biology.
- Dr. Sachin S. Suroshe, Senior Scientist and Dr. P. Shashank, Scientist, Division of Entomology received DST-Young Scientist award.
- Dr. Kolla Sridevi, Senior Scientist, Division of Entomology received HTHS Gold Medal.
- Dr. Renu Pandey, Senior Scientist, Division of Plant Physiology received (i) JJ Chinoy Gold Medal Award, and (ii) Fellowship of Indian Society for Plant Physiology.
- Dr. Dhruba Jyoti Sarkar, Scientist, Division of Agricultural Chemicals received Jawaharlal Nehru Award of ICAR for outstanding doctoral thesis research.
- Dr. Shankarganesh, Scientist, Division of Entomology was elected Fellow, Society of Biological Control.
- Dr. P. L. Saran, IARI-Regional Station, Pusa (Bihar) received Young Scientist Fellowship Award.
- Dr. Veda Krishnan and Dr. Sweta Kumari, Scientists, Division of Biochemistry received Young Scientist Award.

In addition, a large number of our scientists were recognized by their peer groups by electing/nominating to the various positions in the societies and governmental and inter-governmental committees.
# 14. BUDGET ESTIMATES

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E.) for the year 2014-15 and Budget Estimates for 2015-16 under Plan

## PLAN BUDGET ESTIMATE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grants for creation of Capital Assets (CAPITAL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Works</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A) Land</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B) Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. Office building</td>
<td>1000.00</td>
<td>83.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii. Residential building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii. Minors Works</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Equipments</td>
<td>1045.00</td>
<td>159.64</td>
<td>50.00</td>
</tr>
<tr>
<td>3</td>
<td>Information &amp; Technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Library Books &amp; Journal</td>
<td>250.00</td>
<td>250.00</td>
<td>250.00</td>
</tr>
<tr>
<td>5</td>
<td>Vehicles &amp; Vessels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Furniture &amp; Fixtures</td>
<td>70.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Total- CAPITAL (Grants for creation of Capital Assets)</td>
<td>2365.00</td>
<td>492.64</td>
<td>300.00</td>
</tr>
</tbody>
</table>

## Grants in Aid-Salaries (REVENUE)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establishment Expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A) Salary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. Establishment charges</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii. Wages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii. Overtime allowance</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total-Establishment Expenses (Grants in Aid-Salaries)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

## Grants in Aid-General (REVENUE)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pension &amp; Other Retirement Benefits</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Traveling Allowance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Domestic/Transfer T.A.</td>
<td>100.14</td>
<td>102.00</td>
<td>120.00</td>
</tr>
<tr>
<td></td>
<td>B. Foreign T.A.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total-Traveling Allowance</td>
<td>100.14</td>
<td>102.00</td>
<td>120.00</td>
</tr>
<tr>
<td>3</td>
<td>Research &amp; Operational Expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Research Expenses</td>
<td>600.00</td>
<td>404.12</td>
<td>696.00</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td>B. Operational Expenses</td>
<td>400.00</td>
<td>400.00</td>
<td>435.00</td>
</tr>
<tr>
<td></td>
<td>Total Res. &amp; Operational Exp.</td>
<td>1000.00</td>
<td>804.12</td>
<td>1131.00</td>
</tr>
<tr>
<td>4</td>
<td>Administrative Expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Infrastructure</td>
<td>225.00</td>
<td>210.00</td>
<td>200.00</td>
</tr>
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<td>C. Repair &amp; Maintenance</td>
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</tr>
<tr>
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<td>i. Equipments, Vehicles &amp; Others</td>
<td>200.00</td>
<td>100.00</td>
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<tr>
<td></td>
<td>ii. Office building</td>
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<td></td>
<td>iii. Residential building</td>
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<tr>
<td></td>
<td>iv. Minor Works</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D. Others (exc.TA)</td>
<td>223.93</td>
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<td>648.93</td>
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</tr>
<tr>
<td></td>
<td>A. HRD</td>
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<td>B. Other Items (fellowships)</td>
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<td>C. Publicity &amp; Exhibitions</td>
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<tr>
<td></td>
<td>D. Guest House-Maintenance</td>
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</tr>
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<td>E. Other Miscellaneous</td>
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<td>Total - Miscellaneous Expenses</td>
<td>334.93</td>
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<td>Total Grants in Aid-General</td>
<td>2084.00</td>
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<td>B</td>
<td>Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)</td>
<td>2084.00</td>
<td>1408.64</td>
<td>1855.00</td>
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<td>TOTAL (CAPITAL + REVENUE)</td>
<td>4449.00</td>
<td>1901.28</td>
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<td></td>
<td>* Tribal Sub Plan Expenditure</td>
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<td></td>
<td>* NEH Expenditure</td>
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<td>GRAND TOTAL</td>
<td>4664.00</td>
<td>1901.28</td>
<td>2290.00</td>
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</table>

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E.) for the year 2014-15 and Budget Estimates for 2015-16 under Non-Plan

**NON-PHAN BUDGET ESTIMATES** ₹ in lakhs

<table>
<thead>
<tr>
<th></th>
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<td><strong>Grants for creation of Capital Assets (CAPITAL)</strong></td>
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<td>1</td>
<td>Works</td>
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<tr>
<td></td>
<td>(A) Land</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B) Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. Office building</td>
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<tr>
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<td>ii. Residential building</td>
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<td></td>
<td></td>
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<td></td>
<td>iii. Minors Works</td>
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<td>Equipments</td>
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<td>3</td>
<td>Information &amp; Technology</td>
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<td>Library Books &amp; Journal</td>
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<td>5</td>
<td>Vehicles &amp; Vessels</td>
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<td>17.33</td>
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<tr>
<td>6</td>
<td>Livestock</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
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<td>7</td>
<td>Furniture &amp; Fixtures</td>
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<td>8</td>
<td>Others</td>
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<td>A</td>
<td>Total- CAPITAL (Grants for creation of Capital Assets)</td>
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<td>Grants in Aid-Salaries (REVENUE)</td>
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<td>Establishment Expenses</td>
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<tr>
<td></td>
<td>(A) Salary</td>
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<td></td>
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<tr>
<td></td>
<td>i. Establishment charges</td>
<td>14530.00</td>
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<td>ii. Wages</td>
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<td></td>
<td>iii. Overtime allowance</td>
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<td>Total-Establishment Expenses (Grants in Aid-Salaries)</td>
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<td>15001.62</td>
<td>15414.00</td>
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<td>Grants in Aid-General (REVENUE)</td>
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<td>1</td>
<td>Pension &amp; Other Retirement Benefits</td>
<td>9700.00</td>
<td>11200.00</td>
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<td>Traveling Allowance</td>
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<td>A. Domestic/Transfer T.A.</td>
<td>33.00</td>
<td>43.00</td>
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<td></td>
<td>B. Foreign T.A</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total-Traveling Allowance</td>
<td>33.00</td>
<td>43.00</td>
<td>40.00</td>
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<tr>
<td>3</td>
<td>Research &amp; Operational Expenses</td>
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<td></td>
<td></td>
</tr>
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<td>A. Research Expenses</td>
<td>220.00</td>
<td>255.00</td>
<td>230.00</td>
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<td></td>
<td>B. Operational Expenses</td>
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<td>320.00</td>
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<td>Total Res. &amp; Operational Exp.</td>
<td>490.00</td>
<td>575.00</td>
<td>510.00</td>
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<td>Administrative Expenses</td>
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<td>A. Infrastructure</td>
<td>1600.00</td>
<td>2085.00</td>
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<td></td>
<td>B. Communication</td>
<td>40.00</td>
<td>47.00</td>
<td>50.00</td>
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<td></td>
<td>C. Repair &amp; Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. Equipments, Vehicles &amp; Others</td>
<td>170.00</td>
<td>209.00</td>
<td>175.00</td>
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<td></td>
<td>ii. Office building</td>
<td>300.00</td>
<td>844.00</td>
<td>600.00</td>
</tr>
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<td></td>
<td>iii. Residential building</td>
<td>300.00</td>
<td>478.25</td>
<td>450.00</td>
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<td>iv. Minor Works</td>
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<td>D. Others (exc.TA)</td>
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<td>Total-Administrative Expenses</td>
<td>3300.00</td>
<td>4745.90</td>
<td>3925.00</td>
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<td>5</td>
<td>Miscellaneous Expenses</td>
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<td>A. HRD</td>
<td>1.00</td>
<td>11.50</td>
<td>6.00</td>
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<td>B. Other Items (fellowships)</td>
<td>275.00</td>
<td>341.58</td>
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<td>C. Publicity &amp; Exhibitions</td>
<td>20.00</td>
<td>14.50</td>
<td>20.00</td>
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<td>D. Guest House-Maintenance</td>
<td>50.00</td>
<td>50.09</td>
<td>50.00</td>
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<td>E. Other Miscellaneous</td>
<td>200.00</td>
<td>179.91</td>
<td>200.00</td>
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<td>Total-Miscellaneous Expenses</td>
<td>546.00</td>
<td>597.58</td>
<td>626.00</td>
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<td>Total Grants in Aid-General</td>
<td>14069.00</td>
<td>17161.48</td>
<td>15601.00</td>
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<tr>
<td>B</td>
<td>Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)</td>
<td>28603.00</td>
<td>32163.10</td>
<td>31015.00</td>
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<td>TOTAL (CAPITAL + REVENUE)</td>
<td>28673.00</td>
<td>32296.18</td>
<td>31085.00</td>
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<td>(C) Loan &amp; Advances</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
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<td></td>
<td>GRAND TOTAL</td>
<td>28733.00</td>
<td>32356.18</td>
<td>31145.00</td>
</tr>
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## 15. STAFF POSITION
(As on 31.03.2015)

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of posts</th>
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<tr>
<td></td>
<td></td>
<td>Sanctioned</td>
<td>Filled</td>
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<tr>
<td><strong>A. SCIENTIFIC STAFF</strong></td>
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<tr>
<td>1) Research Management Personnel</td>
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<td></td>
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</tr>
<tr>
<td>2) Principal Scientist</td>
<td>65</td>
<td></td>
<td></td>
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<tr>
<td>3) Senior Scientist/Scientist (S.G.)</td>
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<td></td>
<td></td>
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<tr>
<td>4) Scientist</td>
<td>337</td>
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<tr>
<td><strong>Total</strong></td>
<td>578</td>
<td></td>
<td><strong>440</strong></td>
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<tr>
<td><strong>B. TECHNICAL STAFF</strong></td>
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<td>1) Category III</td>
<td>23</td>
<td></td>
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<tr>
<td>2) Category II</td>
<td>294</td>
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<td></td>
</tr>
<tr>
<td>3) Category I</td>
<td>381</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Auxiliary</td>
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<tr>
<td><strong>Total</strong></td>
<td>698</td>
<td></td>
<td><strong>546</strong></td>
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<td><strong>C. ADMINISTRATIVE STAFF</strong></td>
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<td>1) Group A</td>
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<td>2) Group B</td>
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<td>3) Group C</td>
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<tr>
<td><strong>Total</strong></td>
<td>457</td>
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<td><strong>329</strong></td>
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<tr>
<td><strong>D. SKILLED SUPPORT STAFF</strong></td>
<td>1301</td>
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<td>889</td>
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</tbody>
</table>

**Note:** * For scientific staff, the figures shown out of parentheses represent the number of scientists working in particular grade (assessment/direct recruitment/induction). The figures shown in the parentheses represent the number of scientists initially appointed by direct recruitment/induction in the grade (i.e., excluding assessment)

**Two vacancies are excess filled, i.e., Sr.F & AO, and Security Officer**
16. POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLEDF PERSONS

16.1 POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLEDF PERSONS

The decisions and activities undertaken for the benefit of the differently abled persons are as follows:

- The benefits to the differently abled candidates in service matter as per instructions of ICAR/DOPT. Govt. of India as the case may be are followed.
- Three per cent of the total number of seats in each scheme of admission open to Indian nationals are reserved for differently abled candidates subject to their being otherwise suitable as per the norms of ICAR/Govt. of India. During the year 2014-15, two students each in M.Sc. and Ph.D. were admitted against the reserved seats for differently abled candidates. However, in the event of there being no eligible suitable differently abled candidates in the earmarked discipline, to fill up the mentioned number of seats, such unfilled seats shall be transferred to other disciplines, where eligible suitable differently abled candidates are available for filling these seats.

16.2 NUMBER OF BENEFICIARIES AND THEIR PERCENTAGE IN RELATION TO TOTAL NUMBER OF BENEFICIARIES

The number of beneficiaries with disabilities and their percentage in relation to total number of beneficiaries as on 31.3.2015 are as follows:

<table>
<thead>
<tr>
<th>Number of beneficiaries with disability</th>
<th>Total number of beneficiaries</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>329</td>
<td>2.73%</td>
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</tbody>
</table>
17. OFFICIAL LANGUAGE (RAAJ BHASHA) IMPLEMENTATION

According to Article 343 of the Constitution, Hindi shall be the Official Language of the Union Government. To implement the objectives in letters and spirit, IARI is making consistent progress in the use of OL in agricultural research, education, extension as well as in administration.

17.1 OFFICIAL LANGUAGE IMPLEMENTATION COMMITTEE

An Official Language Implementation Committee (OLIC) was constituted by the Institute under the chairmanship of Joint Director (Research) and the Committee ensures compliance of policy and rules of O.L. Act 1963 and O.L. rules of 1976. All the Joint Directors, Head of Divisions and Comptroller are ex-official members of OLIC and Deputy Director (OL) is its member-secretary. During the period under report, the meeting of this Committee was organized regularly in each quarter and necessary suggestions and instructions were given for promoting the use of Hindi in various official/research activities and the effective implementation of Official Language. To ensure follow up action on the decisions taken in these meetings, sub-committees were also constituted in different Divisions, Regional Stations and the Directorate.

17.1.1 Inspection of Progressive Use of Official Language

To achieve the targets fixed in the annual programme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, and as per the recommendations of the Institute Official Language Implementation Committee (OLIC), an OL Inspection Committee was constituted under the Chairmanship of Dr. R.D. Rai, Head, Division of Biochemistry. The Committee inspected the progressive use of OL in all the Divisions, Units and other establishments of the Institute. The Committee also visited some of the Regional Stations, namely, Katrain, Shimla, Bihar and Pune, and inspected the progressive use of OL. The committee gave valuable suggestions for making the desired progress of OL implementation in the concerned Division/Section/Centre, etc. and submitted inspection reports.

17.2 AWARDS AND HONOURS

- The Institute was awarded the Second Prize for doing maximum writing work in Hindi for the year 2013-14 under the ICAR ‘Rajarshi Tandon Rajbhasa Puraskar Yojna’.
- The Institute was also awarded the Second Prize for Institute’s Annual Rajbhasa Patrika ‘Pusa Surbhi’ under ‘Ganesh Shankar Vidhyarathi Hindi Krishi Patrika Puraskar Yojna’ of ICAR for the year 2013-14.

17.3 HINDI WORKSHOPS

In order to motivate the staff members in different categories to do maximum work in Hindi, three Hindi workshops were organized by the Institute during the year 2014-15.

- Two-day workshop was organized on May 26-27, 2014 for Administrative Officers of the Institute on “Rajbhasha Niti, Niyan Evam Karyanwyan Tatha Tanaav Prabandhan” (Sixty administrative officials participated).
- Two-day workshop was organized on August 20-21, 2014 for Technical Officers of the Institute on “Takniki Lekhan Mai Computer Ki Bhoomika Evam Hindi Ke Uplabdh softwairon Ki Jankari” (Sixty technical officers participated).
A workshop on Power Point Presentation on “Tikau Krishi” (Sustainable Agriculture) was held on December 5, 2014 for IARI scientists at CESCRA Auditorium. Dr. R.P. Singh, Executive Secretary, Indian Agricultural Universities Association, New Delhi discussed the concept and basics of the Tikau Krishi. Shri A.K. Dubey, former Editor (Hindi), IARI elaborated the difficulties in power point presentation in Hindi (Thirty five scientists participated).

17.4 AWARD SCHEMES/COMPETITIONS

During the year 2014-15, many competitions/award schemes were organized to motivate the employees of the Institute to do their maximum work in Hindi. A large number of officers and employees of different categories of staff participated in these activities. The following activities were organized.

17.4.1 Award Scheme for Carrying out Maximum Official Work in Hindi

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India was implemented as per the directives of the Department and 10 employees of the Institute were given cash awards for doing their maximum official work in Hindi during the reported period.

17.4.2 Hindi Vyavahar Pratiyogita

Hindi Vyavahar Pratiyogita was organized amongst the different Divisions, Regional Stations & Centres; and Sections of Directorate separately and winners awarded mobile shields for doing maximum work in Hindi during the whole year. In the period under report, the CPCT & Regional Station Pusa (Bihar) amongst the divisions & regional stations and personal-II amongst the sections were given mobile shields.

17.4.3 Rajbhasha Patra Vyavahar Pratiyogita

Rajbhasha Patra Vyavahar Pratiyogita was organized for promoting maximum correspondence in Hindi. The CPCT & Division of Nematology got first and second prizes, respectively. The prizes carry mobile shields.

17.4.4 Awards for Science Writing in Different Magazines/Papers

A competition for Popular Science Writing was organized for scientists/technical officers of the Institute and winners were awarded first (₹ 7000/-), second (₹ 5000/-) and third (₹ 3000/-) prizes for their published articles in different journals.

17.4.5 Pusa Vishisht Hindi Pravakta Puraskar

Pusa Vishisht Hindi Pravakta Puraskar was given to Dr. Dinesh Kumar, Division of Agronomy. Evaluation was done on the basis of recommendations of course coordinator and feedback of the trainees. The Puraskar carries a cash prize of ₹ 10,000/- and a certificate.

17.4.6 Power Point Presentation Competition in Hindi

The Institute organized a Power Point Presentation Competition on “Tikau Krishi (Sustainable Agriculture)” in Hindi for the scientists and technical officers on December 5, 2014 at CESCRA Auditorium. Dr. K.V. Prabhu, Joint Director (Research) inaugurated the programme. Ten scientists/technical officers participated in Power Point Presentation. The winners were awarded cash prizes of ₹ 5,000, ₹ 3,000 and ₹ 2,000 to the first, second and third positions, respectively and a citation was given to all the participants.

17.5 HINDI CHETNA MAAS

The Institute celebrated Hindi Chetna Maas from September 1 to 30, 2014. Dr. K.V. Prabhu, Joint Director (Research) inaugurated Hindi Chetna Maas on September 2, 2014. During Hindi Chetna Maas, various other Hindi competitions like poetry recitation, essay writing, noting & drafting, debate, and quiz, etc. were organized for all categories of the staff members. A large number of scientific, technical and administrative officials participated in the competitions.
This year many divisions/ regional stations/ establishment of the Institute organized Hindi Pakhwada/ Hindi Week/ Hindi Divas in their respective divisions/regional stations/ establishment during this period. Many competitions were organized to promote the use of Hindi and participants given prizes.

17.5.1 Hindi Annual Prize Distribution Function

The Institute celebrated its Annual Hindi Prize distribution Function on October 18, 2014 at Dr. B.P. Pal Auditorium. Dr. Ravinder Kaur, Director (Acting), IARI presided over the function, Dr. K.V. Prabhu, Joint Director (Research) and Chairman, Institute Official Language Implementation Committee gave the welcome address. Mrs. Seema Chopra, Deputy Director (OL) presented the Institute Official Language Progress Report. Shri Laxmi Shankar Vajpai, Deputy Director General, All India Radio who was the Chief Guest released Rajbhasha Patrika, Pusa Surbhi and gave away the prizes to the winners of different competitions organized during the year and Hindi Chetna Maas. A Hasya Kavi Sammelan was also organized on this occasion which brought cheers and smiles to the audience.
18. TRAINING AND CAPACITY BUILDING

18.1 TRAINING PROGRAMMES

The Institute organizes several national and international short-term training courses (regular, adhoc and individual) and refresher courses in specialized areas for the scientists of NAREES under the programmes of “Centres of Excellence” and “Centres of Advanced Studies”. In addition, some special training courses were also organized for the benefit of professionals, farmers and extension workers.

Important Training programmes organized

<table>
<thead>
<tr>
<th>Name of the training programme</th>
<th>Dates/Month</th>
<th>No. of trainees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agricultural Chemicals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training on “Pesticide/Formulation Testing and Quality Assessment” for Mongolian trainees</td>
<td>June 16-26, 2014</td>
<td>2</td>
</tr>
<tr>
<td><strong>Agricultural Engineering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Winding for Entrepreneurs</td>
<td>November 17-26, 2014</td>
<td>10</td>
</tr>
<tr>
<td>National training on “Project Formulation, Risk Assessment, Scientific Report Writing and Presentation”</td>
<td>February 17-21, 2015</td>
<td>20</td>
</tr>
<tr>
<td>National training on “Project Formulation, Risk Assessment, Scientific Report Writing and Presentation”</td>
<td>February 24-28, 2015</td>
<td>20</td>
</tr>
<tr>
<td><strong>Agricultural Extension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training in EDP for Farm Women and Farmers in Four Villages of Hapur District</td>
<td>April 3-5, 2014</td>
<td>28</td>
</tr>
<tr>
<td>Farmers’ Workshop on Direct Seeded Rice (DSR)</td>
<td>June, 2014</td>
<td>90</td>
</tr>
<tr>
<td>Farm Entrepreneur and Stakeholders Meet for Developing Agri-entrepreneurship at Naveen Mandi, Hapur</td>
<td>June, 2014</td>
<td>500</td>
</tr>
<tr>
<td><em>Krishak Gosthi</em> on Weed Management in Direct Seeded Rice (DSR)</td>
<td>July, 2014</td>
<td>60</td>
</tr>
<tr>
<td>Field Visit to DSR Demonstration Plots</td>
<td>July, 2014</td>
<td>60</td>
</tr>
<tr>
<td><em>Krishak Gosthi</em></td>
<td>September, 2014</td>
<td>80</td>
</tr>
<tr>
<td>Futuristic Agricultural Extension Approaches and Tools</td>
<td>September 3-23, 2014</td>
<td>25</td>
</tr>
<tr>
<td>Training of IARI Students on Life Skills and Leadership Development</td>
<td>September 16-20 2014</td>
<td>24</td>
</tr>
<tr>
<td>Training of Technical Officer on Enhancing Motivation for High Job</td>
<td>September 22-24, 2014</td>
<td>20</td>
</tr>
<tr>
<td>Training of Technical Officer on Enhancing Motivation for High Job</td>
<td>September 25-27, 2014</td>
<td>26</td>
</tr>
<tr>
<td>Field Visit</td>
<td>September, 2014</td>
<td>105</td>
</tr>
<tr>
<td>Extension Strategies for Up-scaling of Farmer-led Innovations for Extension Professionals</td>
<td>October 9-16, 2014</td>
<td>20</td>
</tr>
<tr>
<td>Training on Weed Control for Zero-tillage System and Farmers- Scientists Meet on Nutrient Resource Management (NRM) Technologies</td>
<td>November, 2014</td>
<td>220</td>
</tr>
<tr>
<td>Empowering Farmers for Agricultural Entrepreneurial Ventures : Building Trainers’ Skills</td>
<td>November 25 - December 15, 2014</td>
<td>19</td>
</tr>
<tr>
<td>Training on Weed Management in Zero-tillage System in Wheat and <em>Krishak Gosthi</em> in NICRA villages</td>
<td>December, 2014</td>
<td>100</td>
</tr>
<tr>
<td>Name of the training programme</td>
<td>Dates/Month</td>
<td>No. of trainees</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Training on m-krishi</td>
<td>January 21, 2015</td>
<td>18</td>
</tr>
<tr>
<td>Training on Conservation Agriculture</td>
<td>January 21, 2015</td>
<td>18</td>
</tr>
<tr>
<td>Trainings on Pest Management in Wheat at Mumtaipur, Lokra and Turkapur villages</td>
<td>January 17, 2015</td>
<td>100</td>
</tr>
<tr>
<td>Trained on Improved Mustard and Wheat Production Technologies for Farmers and Post Masters at KVK, Sheopur</td>
<td>February 24, 2015</td>
<td>100</td>
</tr>
<tr>
<td>Training on Protected Cultivation of Tomato</td>
<td>February, 2015</td>
<td>15</td>
</tr>
<tr>
<td>Training on Improved Wheat Production Technologies for Farmers and Post-Office Staff</td>
<td>March, 2015</td>
<td>50</td>
</tr>
<tr>
<td>Field Day on Zero Tillage in Wheat in NICRA villages</td>
<td>March, 2015</td>
<td>50</td>
</tr>
<tr>
<td>Training on IPM in Vegetable in NICRA villages</td>
<td>March, 2015</td>
<td>30</td>
</tr>
<tr>
<td>Training on Zero Tillage</td>
<td>March, 2015</td>
<td>50</td>
</tr>
</tbody>
</table>

**Agricultural Physics**


**Centre for Environment Science and Climate Resilient Agriculture**

| Training Workshop on “Development of Greenhouse Gas Emission Inventory for Agriculture”       | May 6-7, 2014       | 40             |
| Training Workshop on “Eddy Covariance Flux Measurement”                                      | December 4-5, 2014  | 20             |

**Entomology**

| Model Training Course (MTC) on “Mass Production Technologies of Natural Enemies of Crop Pests” | November 24 - December 1, 2014 | 19             |

**Floriculture and Landscaping**

| Model Training Course on “Avenues in Floriculture for Livelihood”                            | December 10-17, 2014 | 22             |

**Food Science & Post Harvest Technology**

| Valorization of Horticultural and Arable Crops                                               | December 4-11, 2014  | 18             |
| Postharvest Management and Processing of Horticultural Produce                                | March 17-21, 2015    | 18             |

**Fruits and Horticultural Technology**

| Model Training Course (MTC) on “Management of Production Problems of Horticultural Crops for Enhancing Productivity and Quality” | January 27 - February 3, 2015 | 18             |

**Microbiology**

| Training Program on Biofertilizers (VAM production, Compost production, Azotobacter liquid formulation) for Licencees | 2014-15 | 13             |
| Indo-German Collaborative Workshop on “Microbial Ecology and Application of Inoculants in Bio-control” | April 7-10, 2014 | 32             |

**Plant Pathology**

<p>| Genomics of Plant Virus for Diagnosis and Utilisation as Gene Expression Tool                 | October 15- November 6, 2014 | 18             |
| Genetic and Pathogenic Characterization towards Managing Nationally Important Plant Pathogens Causing Wilt and Blight | January 13- February 2, 2015 | 22             |</p>
<table>
<thead>
<tr>
<th>Name of the training programme</th>
<th>Dates/Month</th>
<th>No. of trainees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Physiology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICAR short course on “Non-destructive Phenotyping and Phenomics for Dissection of Abiotic Stress Tolerance, Gene Discovery and Crop Improvement”</td>
<td>July 14-23, 2014</td>
<td>25</td>
</tr>
<tr>
<td><strong>Soil Science and Agricultural Chemistry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11th Advanced Level Training on Soil Testing, Plant Analysis and Water Quality Assessment</td>
<td>September 4-24, 2014</td>
<td>19</td>
</tr>
<tr>
<td><strong>Seed Science &amp; Technology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training on “Maintenance Breeding: Training-cum-Exposure Visit”</td>
<td>September 26-27, 2014</td>
<td>23</td>
</tr>
<tr>
<td>Training on “Identification of Rice Varieties” for Senior Scientists, Exporters and Progressive Farmers.</td>
<td>September 30, 2014</td>
<td>65</td>
</tr>
<tr>
<td>An Orientation Programme on “Identification of Basmati Varieties for Surveyors”</td>
<td>October 14, 2014</td>
<td>40</td>
</tr>
<tr>
<td>Training on “Pranaksh Prakshetra Faslon Mein Beej Upadhan Prodyogiki”</td>
<td>January 21-23, 2015.</td>
<td>25</td>
</tr>
<tr>
<td>Training on “Maintenance Breeding: Training-cum-Exposure Visit”</td>
<td>March 3-4, 2015</td>
<td>25</td>
</tr>
<tr>
<td>Thirteen Trainings Organized for Farmers under Seed Village Scheme during Kharif and Rabi seasons on Different Aspects of Quality Seed Production.</td>
<td>Kharif 2014, Rabi 2014-15</td>
<td>96, 164</td>
</tr>
<tr>
<td><strong>Vegetable Science</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable Field Day</td>
<td>January 29, 2015</td>
<td></td>
</tr>
<tr>
<td><strong>Water Technology Centre</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two One-day Training Programmes for Grass Root Level Workers of Delhi Jal Board on “Water Conservation and Management”</td>
<td>September 2-4, 2014</td>
<td>55</td>
</tr>
<tr>
<td>Two One-day Capacity Building Programs for 33 farmers of Anand, Gujarat and 46 farmers of Balod, Chhattisgarh on “Micro Irrigation Technologies for Improving Water Productivity and Yield”</td>
<td>September 16-29, 2014</td>
<td>79</td>
</tr>
<tr>
<td>Training Programme on “Micro Irrigation Technologies for Increasing the Water Use Efficiencies” for the Farmers from Alwar district, Rajasthan</td>
<td>September 29 - October 1, 2014</td>
<td>26</td>
</tr>
<tr>
<td>Three One-day Training Programmes on Precision Farming Technologies (i.e., Micro Sprinkler, Drip Irrigation &amp; Fertigation, Polyhouse, Insect Proof Net house, etc) for farmers from Chhattisgarh and Karnataka state</td>
<td>November 10, 14 &amp; 27, 2014</td>
<td>153</td>
</tr>
<tr>
<td>Training on Precision Farming Technologies, (i.e., Micro Sprinkler, Drip Irrigation &amp; Fertigation, Polyhouse, Insect Proof Net House, etc.) for farmers from Alwar</td>
<td>November 24-26, 2014</td>
<td>26</td>
</tr>
<tr>
<td>Two Field Day Training Programmes at Muzaffarnagar, Uttar Pradesh.</td>
<td>November 29-30, 2014</td>
<td></td>
</tr>
<tr>
<td>Training Program on “Micro Irrigation Technologies for Increasing the Water Use Efficiencies” for farmers from Alwar</td>
<td>February 4-5, 2015</td>
<td>25</td>
</tr>
<tr>
<td><strong>Centre for Agricultural Technology Assessment and Transfer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill Development Training &amp; Exposure Visit of Farmers, Entrepreneurs and Officials</td>
<td>April 2-11, 2014</td>
<td>19</td>
</tr>
<tr>
<td>Skill Development Training &amp; Exposure Visit of Farmers, Entrepreneurs and Officials</td>
<td>August 4-13, 2014</td>
<td>25</td>
</tr>
<tr>
<td>Skill Development Training &amp; Exposure Visit of Farmers, Entrepreneurs and Officials</td>
<td>September 1-10, 2014</td>
<td>20</td>
</tr>
<tr>
<td>Improved Horticultural Technologies for Horticultural Officers of Himachal Pradesh</td>
<td>October 27-31, 2014</td>
<td>18</td>
</tr>
<tr>
<td>Seed Production and Improved Crop Production Technology for Farmers</td>
<td>March 17-23, 2015</td>
<td>16</td>
</tr>
<tr>
<td>Training on Seed Production Technology</td>
<td>March 24-27, 2015</td>
<td>20</td>
</tr>
<tr>
<td>International Training on “Bio-fertilizers and Bio-pesticides in Agriculture” for Scientists from Iraq</td>
<td>June 6 -20, 2014</td>
<td>4</td>
</tr>
<tr>
<td>Name of the training programme</td>
<td>Dates/Month</td>
<td>No. of trainees</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>International Training on “Bio-organic fertilization” for Scientists from Iraq</td>
<td>June 6 - 20, 2014</td>
<td>4</td>
</tr>
<tr>
<td>Zonal Technology Management and Business Planning &amp; Development Unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mustard Day</td>
<td>March 4, 2015</td>
<td>37</td>
</tr>
<tr>
<td>Agribiz Idol Camp cum Incubation Workshop</td>
<td>May 9, 2014</td>
<td>175</td>
</tr>
<tr>
<td>Regional Station, Pusa (Bihar)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Seed: An important Input in Green Revolution</td>
<td>March 17-26, 2015</td>
<td>50</td>
</tr>
<tr>
<td>Regional Station, Indore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPV &amp; FR Act Awareness Training Programme</td>
<td>January 24, 2015</td>
<td>200</td>
</tr>
<tr>
<td>Regional Station, Katrain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sabji Fasal Uski Beejotpadon Takneekiyon</td>
<td>June 20-21, 2014</td>
<td>25</td>
</tr>
<tr>
<td>Madhya Parsatiye Kshetron Me Sabji Fasal Uski Beejotpadon Takneekiyon</td>
<td>October 30-31, 2014</td>
<td>25</td>
</tr>
<tr>
<td>Regional Station, Shimla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training programme on “Nursery Production of Temperate Fruits” organized at Horticultural Research Farm, Dhanda under IARI, R.S. Shimla</td>
<td>November 21, 2014</td>
<td>80</td>
</tr>
<tr>
<td>Training Programme on “Production and Nursery Management of Temperate Fruits” at Ghumarvin, Bilaspur</td>
<td>February 21, 2015</td>
<td>75</td>
</tr>
</tbody>
</table>

18.1.1 Trainings for Different Target Groups at Institute’s KVK, Shikohpur, Gurgaon

Trainings were organized for different target groups at Institute’s KVK, Shikohpur, Gurgaon to generate the opportunities for income and employment, to provide technical know how to the practicing farmers and farm women, and to update the knowledge of in-service personnel.

Training organized in different target groups

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of training with target groups</th>
<th>No.</th>
<th>No. of beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>Vocational trainings for rural youth and girls:</td>
<td>21</td>
<td>341</td>
</tr>
<tr>
<td>2.</td>
<td>Day long On/Off campus trainings for practicing farmers and farm women (a) On Campus (b) Off campus</td>
<td>29</td>
<td>505</td>
</tr>
<tr>
<td></td>
<td></td>
<td>54</td>
<td>516</td>
</tr>
<tr>
<td>3.</td>
<td>In-Service (refresher course) trainings for field extension functionaries</td>
<td>07</td>
<td>110</td>
</tr>
<tr>
<td>4.</td>
<td>Collaborative /sponsored trainings</td>
<td>01</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td>1518</td>
</tr>
</tbody>
</table>

18.2 CAPACITY BUILDING OF SHGs FOR GENDER EMPOWERMENT

Three women self help groups (SHGs) from the different villages were formed during the year 2013-14. The groups were sensitized and motivated to start their own enterprises in three different areas. In 2014-15, the groups have expanded their reach and selling their products in and outside Gurgaon (Haryana) enabling them to enhance their income levels and living standards.

Achievements of women SHGs formed by KVK, Shikohpur, Gurgaon

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of SHG</th>
<th>Entrepreneurial activity adopted</th>
<th>Duration</th>
<th>Income generation (₹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kshitiz</td>
<td>Soy nut</td>
<td>18 months</td>
<td>2,00,000/-</td>
</tr>
<tr>
<td>2.</td>
<td>Arzoo</td>
<td>Spices &amp; Aonla</td>
<td>15 months</td>
<td>7,50,000/-</td>
</tr>
<tr>
<td>3.</td>
<td>Prayas</td>
<td>Preserved products of seasonal fruits and vegetables</td>
<td>15 months</td>
<td>50,000/-</td>
</tr>
</tbody>
</table>
19. MISCELLANY

I. On-going Projects at IARI as on 31-03-2015
(A) In-house Research Projects 48
   School of Crop Improvement 15
   School of Horticultural Science 09
   School of Crop Protection 08
   School of Natural Resource Management 07
   School of Basic Sciences 02
   School of Social Sciences 07
(B) Outreach Programmes 10
(C) Challenge Programmes 05
(D) Flagship Programmes 04

II. Scientific Meetings Organized
   a) Workshops 24
   b) Seminars 09
   c) Summer institutes/Winter school 03
   d) Farmers’ day(s) 49
   e) Others 41
   Total 126

III. Participation of Personnel in Scientific Meetings
   India
   a) Seminars 278
   b) Scientific meetings 216
   c) Workshops 132
   d) Symposia 125
   e) Others 110
   Total 861
   Abroad
   a) Seminars 24
   b) Scientific meetings 17
   c) Workshops 06
   d) Symposia 05
   e) Others 06
   Total 58

IV. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel

Board of Management
- Replacement of equipment approved under EFC by the various divisions of IARI.

Academic Council
- Grant of IARI scholarship for six month to ICAR-SRFs student beyond three years.
- Medical insurance facility for the students.
- Extension of the duration of split Ph.D programme upto 8 years from 6 years.

Research Advisory Committee
1. School of Crop Improvement
   - Breeding wheat varieties for terminal heat tolerance and yellow rust resistance be given priority by utilizing the diverse wheat germplasm already registered at NBPRG.
   - Work on basmati rice be strengthened further by integrating all the concerned disciplines of the Institute. Efforts should also be made to breed rice hybrids for the benefit of the end users and improved productivity.
   - More emphasis needs to be given to the development of specialty maize. A facility for double haploidy production be established at Dharwad centre.
A reliable and well equipped screening system for evaluating resistance to soil borne diseases (*Sclerotonia* rot and *Fusarium* wilt) in pulses be developed in collaboration with Plant pathology Division.

The genetic base of soybean needs to be broadened further for carrying out more of basic and applied studies. In this regard, the possibility of importing soybean germplasm from USDA be explored.

### 2. School of Horticultural Science
- Mango malformation which continues to be a problem in some parts of India needs to be given due importance and a validated technology developed by integrating physiology, biochemistry and pathology research elements in the programme.
- Papaya breeding needs to be properly strengthened involving the regional stations at Pune and Pusa to breed varieties similar or better than Red Lady, with tolerance to PRSV.
- Major emphasis needs to be give to develop low volume and high value vegetable crops which can fetch more income to the farmers.
- Development of vegetable varieties / hybrids having improved nutritive value to be given high priority.
- Development of varieties suitable for protected cultivation in capsicum, cucumber, tomato, chrysanthemum, rose, tuberose with a special emphasis on parthenocarpic cucumber be made more economical for the benefit of the small as well large farmers.
- With the upgradation of PHT with Food Science having been effected, the School needs to reorient its research for food products/processing needs and the Division needs to incorporate into its research agenda all currently in demand for urban/peri urban requirements of processed foods from horticultural products.

### 3. School of Crop Protection
- Management strategies for controlling major viral and fungal diseases of national importance in mandated crops need to addressed. More concerted efforts are required for the management of BPH in rice and spot blotch and yellow rust in wheat in collaboration with plant breeders.
- Technologies with respect to *Trichoderma* based formulations should be demonstrated in one or two adopted villages on a large scale for the benefit of end user.
- Work on genomics should be undertaken in collaboration with NRCPB.
- Strong research linkages with other Centres located in the campus (NBPG & NCIPM) be made. For this a joint work plan and possibly a common RAC with the Centres will be mutually rewarding.

### 4. School of Natural Resource Management
#### a) Water Management, Precision farming & Mechanization
- The school should develop excellence in the area of wastewater management by undertaking more systematic and long term studies.
- Focussed work on farming system research in partnership with rural farmers needed.
- Research studies on precision farming be given high priority. Appropriate sensors for input management need to be developed for groups of crops and production conditions under precision farming system.
- Validated decision support systems have to be made routine for timely decisions on farm activities which need to be developed by associating with statistics experts from within WTC and IASRI.
- There is an urgent need to develop a strategy for drip/sprinkler system supported rice-wheat, cotton-wheat, soybean-wheat, pigeonpea-wheat systems, etc., with the sole aim of optimum water use and improved WUE.
- Research programmes on vertical farming be given due emphasis with reference to maximum utilization of available natural resources in small and marginal farm lands.
A forecasting model for predicting wheat productivity be developed in different production systems and extended to larger areas.

The orchards on IARI farm should be put under drip irrigation at the earliest.

b) Integrated Nutrient Management & Production Technology

- Alternatives to existing rice-wheat system for higher productivity, better WUE and economic returns need to be worked out.
- Major thrust be given to the research on biodegradation of rice and wheat straw for bio-fuel generation.
- Research studies employing the use of liquid nitrogen and granulated neem coated urea for increasing NUE of crops be given more emphasis. An applicator for granulated neem-coated urea be developed.
- Research studies pertaining to use of Azolla as animal feed be pursued and strengthened.

c) Climate Research, Weather forecasting & Information Management

- Major thrust needs to be given to the region/system-specific adaptation and mitigation strategies to climate change.
- Strategies to reduce methane emissions in rice fields be worked out.
- Climatic prediction studies in relation to crop insurance be taken up.

5. School of Social Sciences

a) Agricultural Economics

- Research programmes on the economic impact assessment of IARI technologies should be given high priority.
- There is an urgent need for making the economic analysis of agricultural technologies (including impact analyses) and policy directives relevant to India as the first priority rather than international developmental aspects which should follow as logical extension to the former.

b) Extension and TOT

- Research studies on impact assessment of the technologies developed by IARI be undertaken in collaboration with Agricultural Economics discipline.
- A comparative study with respect to the efficiency of various extension models in technology dissemination be undertaken for arriving at logical conclusions.
- IARI extension programmes should have more integration with ATMA and KVKs for effective transfer of technologies to the farmers.

c) IARI Mewat Project

- Impact assessment of the model with respect to improved socio-economic status, livelihood and household security of the farmers needs to be done and publicised, specially in SAUs.
- Spread effect of the model needs to be known by replicating it in other troubled villages of the Mewat district and by employing additional technological interventions (horticultural and tree crops / livestock / hydrogel).
6. School of Basic Sciences

- School should focus on priority areas of research targeting few crops / traits / genes. A brainstorming session involving scientists of Basic Science School, NRCPB and experts having wide research experience in specialized areas be organized for reorienting the research agendas of the school for future research programmes.

- Research programmes aimed at improving the abiotic stress (drought / high temperature) tolerance be given high priority involving interdisciplinary approach.

- Research studies pertaining to quality improvement in soybean specially reduction of beany flavour be given due emphasis.

Administrative and Financial Activities

- Filling of the scientific posts in various disciplines be taken up on priority in view of the large vacancies already notified to the council.

- Provision of utilizing the HRD funds for post-doctoral fellowship and international visits/ training programmes of the scientists in specialized areas of research be made. The total budget allocation for HRD be increased and suitably reflected in the EFC document.

Post Graduate School Activities

- Intake of Ph. D. students be increased as compared to M. Sc. students. Due emphasis also need to be laid on Post Doctoral programmes in specialized fields.

- Academic collaboration with universities and International centres needs to be strengthened. In this context, more sandwich programmes for higher education be developed in collaboration with CGIAR international centres / institutions and advanced research institutes (ARIs) abroad.

- More emphasis be given to improve the infrastructure of the hostel buildings as well as IARI library services. Efforts should be made to get master plan cleared for construction of a new international student's hostel for attracting more foreign students.

V. Resource Generation

1) Consultancy & other services

Consultancy services : ₹ 33,80,103
Contract research : ₹ 14,29,348
Contract service : ₹ 24,38,388
Training : ₹ 29,84,213

Total (A) : ₹ 1,02,32,052

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed : ₹ 1,73,19,865
(b) Commercialization : ₹ 15,81,560
(c) Prototype manufacturing : ₹ 9,16,085

Total (B) : ₹ 1,98,17,510

3) Post Graduate School receipt

Training Programme

(a) Foreigners & Indians : -

M.Sc./Ph.D. Programme

(b) Institutional economic fee from foreign scholars under Work Plan : ₹ 50,67,669

(c) Receipt from Registrar (A) Account No. 5432 (9029.201.4314) all fees except institutional economic fee, including sale of information bulletin through D.D. : ₹ 82,14,496

(d) Receipt deposited in Director’s Account No. C-49 (9029.305.17) for theses evaluation, PDC & Misc. (does not include refund of IARI scholarship by students): ₹ 4,41,829

Total (C) : ₹ 1,37,23,994

Grand Total (A+B+C) : ₹ 1,02,32,052 + ₹ 1,98,17,510 + ₹ 1,37,23,994 = ₹ 4,37,73,556

VI. Infrastructural Development

- Renovation of crop improvement laboratory at Regional Station, Katrain, Kullu (HP)

- At the Division of Vegetable Science, biochemical, molecular and tissue culture laboratories renovated.
Three old laboratories, one digestion room and lysimeter got renovated at the Division of Soil Science and Agricultural Chemistry.

Establishment of agricultural machinery testing centre (MOA) and new AICRP centre on Ergonomics and Safety in Agriculture and procured two tractors at the Agricultural Engineering Division.

At the Farm Operation and Service Unit, T.M.O. Seed drill (2), Submersible Pumps (25 Hp and 15 Hp) and Chain Saw were procured to enhance the capacity of FOSU.

At the Agricultural Physics Division the special infrastructure /facilities developed are: (1) A ready to use software platform (http://ideal.egranth.ac.in) for Agricultural Libraries of Indian National Agricultural Research & Education System (NARES), (2) A well-structured Data Center and up-gradation of IARI Campus Network to Gigabit network, and (3) Involved in development of greenhouse of Phenomics Facility and procurement of eight imaging platforms, hardware and software for Phenomics Facility of 1200 plants.

VII. All India Coordinated Research Projects in Operation during the year April 1, 2014 to March 31, 2015

Project Headquarters
1. All India Coordinated Project on Plant Parasitic Nematodes with Integrated Approach for their Control
2. All India Network Project on Pesticide Residues
3. All India Coordinated Research Project on Honey Bees and Pollinators

National Centres Functioning at IARI under All India Coordinated Research Projects
1. All India Network Project on Soil Biodiversity - Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)
2. All India Coordinated Project on Long-Term Fertilizer Experiments
3. All India Coordinated Research Project on Soil Test Crop Response Correlations
4. All India Coordinated Research Project on Floriculture Improvement
5. All India Network Project on Pesticide Residues
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
7. All India Coordinated Research Project on Biological Control of Crop Pests and Weeds
8. All India Coordinated Research Project on Soybean
9. All India Coordinated Research Project on Sub-Tropical Fruits
10. All India Coordinated Research Project on N.S.P. (Crops)
11. All India Coordinated Research Project on Mustard
12. All India Coordinated Research Project on Wheat
13. All India Coordinated Research Project on Rice
14. All India Coordinated Research Project on Pulses
15. All India Coordinated Research Project on Vegetable
16. All India Coordinated Research Project on Pearl millet
17. AINP on White grubs and other Soil Arthropods (AINPWOSA)
18. All India Coordinated Wheat & Barley Improvement Project (AICW&BIP)
### VIII. Foreign visitors during April 1, 2014 to March 31, 2015

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Visitor(s)</th>
<th>Date of visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dr. Stephen Turner, Founder and CTO, Pacific Bioscience of California Inc.</td>
<td>25.06.2014</td>
</tr>
<tr>
<td>2.</td>
<td>A delegation led by Mr. Ir. Ferial Lubis MM, Head of Evaluation and Reporting, Department of Processing and Marketing of Agricultural Product, Ministry of Agricultural, Indonesia</td>
<td>26.06.2014</td>
</tr>
<tr>
<td>3.</td>
<td>An 8-member delegation from the Ministry of Agricultural, Food Security and Cooperative, Tanzania.</td>
<td>8.7.2014</td>
</tr>
<tr>
<td>4.</td>
<td>A Five-member delegation from Surinam led by Mr. Rene B.L. Lievelt, Director, Ministry of Agricultural, Animal husbandry and Fisheries (MAAHF)</td>
<td>1.8.2014</td>
</tr>
<tr>
<td>5.</td>
<td>Dr. Narendra N. Das, Research Scientist, Jet Propulsion Lab (NASA), California, USA</td>
<td>13.8.2014</td>
</tr>
<tr>
<td>7.</td>
<td>Dr. Dath Mita, Senior Crop Analyst, International Production Assessment Division, USDA and Mr. John Slette and Mr. S.K. Singh, US Embassy, New Delhi</td>
<td>2.9.2014</td>
</tr>
<tr>
<td>8.</td>
<td>Dr. Ronnie Green, Vice-chancellor, University of Nebraska-Lincoln Institute of Agricultural and Natural Resources, USA</td>
<td>12.9.2014</td>
</tr>
<tr>
<td>9.</td>
<td>Dr. Aliazam Khosravi, Research Counsellor of Embassy of Islamic Republic of Iran</td>
<td>22.9.2014</td>
</tr>
<tr>
<td>10.</td>
<td>A 10- member delegation from Japan</td>
<td>25.9.2014</td>
</tr>
<tr>
<td>11.</td>
<td>An 11- member delegation from Afghanistan, Afghan National Agricultural Sciences and Technology University, Kandhar, Afghanistan</td>
<td>25.9.2014</td>
</tr>
<tr>
<td>12.</td>
<td>Dr. Masa from Japan</td>
<td>29.9.2014</td>
</tr>
<tr>
<td>13.</td>
<td>A 5- member delegation led by Mr. Raul Urteaga Trani, Coordinator General for International Affairs, Mexico</td>
<td>21.10.2014</td>
</tr>
<tr>
<td>15.</td>
<td>A study visit by Indian-German Bilateral Cooperation meeting</td>
<td>16.12.2014</td>
</tr>
<tr>
<td>16.</td>
<td>A 13- member delegation from Wyoming Leadership Education and Development Programme, USA</td>
<td>9.1.2015</td>
</tr>
<tr>
<td>17.</td>
<td>A 33- member delegation from the University of Nebraska Lincoln, Nebraska, USA</td>
<td>12.1.2015</td>
</tr>
<tr>
<td>18.</td>
<td>A 6- member delegation from French Ministry of Agriculture, France</td>
<td>14.1.2015</td>
</tr>
<tr>
<td>19.</td>
<td>A delegation led by HE I. Batikoto Seruiratu, Minister of Agriculture and Maritime Development and National Disaster Management, Fiji</td>
<td>27.1.2015</td>
</tr>
<tr>
<td>20.</td>
<td>A 3- member delegation from CIMMYT</td>
<td>4.2.2015</td>
</tr>
<tr>
<td>21.</td>
<td>A 20- member delegation led by H.E. Mr. Akram Chehayeb, Minister of Agriculture, Lebanon</td>
<td>06.2.2015</td>
</tr>
<tr>
<td>22.</td>
<td>A 6- member delegation from Morocco</td>
<td>09.2.2015</td>
</tr>
<tr>
<td>23.</td>
<td>Dr. Rezazadeh, Pro Vice-chancellor and Dr. Nikzad, International Relation Officer, Orumieh University, Iran</td>
<td>20.3.2015</td>
</tr>
<tr>
<td>24.</td>
<td>A 6- member delegation from Nepal</td>
<td>25.3.2015</td>
</tr>
</tbody>
</table>

A delegation of Wyoming Leadership Education & Development Programme, USA with IARI team
Appendix 1
Results-Framework Document (RFD) for IARI (2013-14)
Section-1: Vision, Mission, Objectives and Functions

**Vision**

Generation and extension of innovative technologies to achieve food, nutrition and livelihood security with sustainable agriculture, and economic prosperity along with quality human resource development under dynamic constrained physical and economic environment in the country.

**Mission**

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

**Objectives**

1. Germplasm enhancement and development of improved cultivars

2. Development and identification of appropriate crop production, protection and value addition technologies

3. Technology dissemination, capacity building and policy research

4. Excellence in human resources development

**Functions**

To function on the premise that research is the engine of science-led agricultural growth.

To follow the path of scientific research, technology development and extension and human resource development leading to the realization of new paradigms for achieving the congruence among enhanced productivity, sustainability, ecological and environmental security and socio-economic equity.
## Section-2: Inter se Priorities among Key Objectives, Success Indicators and Targets

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Objectives</th>
<th>Weight (%)</th>
<th>Actions</th>
<th>Success Indicators</th>
<th>Unit</th>
<th>Weight (%)</th>
<th>Target/Criteria value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>1</td>
<td>Germplasm enhancement and development of improved cultivars</td>
<td>35</td>
<td>Evaluation of genetic material</td>
<td>Breeding lines and germplasm evaluated</td>
<td>Number</td>
<td>6</td>
<td>18700</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lines identified for unique traits</td>
<td>Number</td>
<td>4</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Development of improved cultivars</td>
<td>Number</td>
<td>8</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Varieties identified for release</td>
<td>Number</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Seed production programme</td>
<td>Breeder seed produced</td>
<td>Weight MT</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Truthfully labeled seed produced</td>
<td>Weight MT</td>
<td>3</td>
<td>1440</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Quality planting material produced</td>
<td>Number</td>
<td>2</td>
<td>33300</td>
</tr>
<tr>
<td>2</td>
<td>Development and identification of appropriate crop production, protection and value addition technologies</td>
<td>25</td>
<td>Development of technologies for enhancing resource use efficiency</td>
<td>Technologies developed and validated</td>
<td>Number</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Development of strategies for biotic/abiotic stress management</td>
<td>Number</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Development of technologies for value addition</td>
<td>Number</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Recommendation of technologies</td>
<td>Number</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Technology dissemination, capacity building and policy research</td>
<td>19</td>
<td>Field demonstrations and agro-advisories</td>
<td>Field demonstrations conducted and agro-advisories issued</td>
<td>Number</td>
<td>8</td>
<td>6100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trainings organized</td>
<td>Number</td>
<td>8</td>
<td>90</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Policy analysis</td>
<td>Number</td>
<td>3</td>
<td>3</td>
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<tr>
<td>4</td>
<td>Excellence in human resources development</td>
<td>10</td>
<td>Post Graduate Teaching and AHRD Trainings</td>
<td>Application: Admission ratio (Ph.D.)</td>
<td>Ratio</td>
<td>2</td>
<td>14:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Degrees awarded</td>
<td>Number</td>
<td>4</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of trainings conducted</td>
<td>Number</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td><em>Efficient Functioning of the RFD System</em></td>
<td>3</td>
<td>Timely submission of Draft RFD (2013-14) for approval</td>
<td>On-time submission</td>
<td>Date</td>
<td>15/05/2013</td>
<td>16/05/2013</td>
<td>17/05/2013</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---</td>
<td>--------------------------------------------------</td>
<td>-------------------</td>
<td>-----</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Timely submission of Results for RFD (2012-13)</td>
<td>On-time submission</td>
<td>Date</td>
<td>01/05/2013</td>
<td>02/05/2013</td>
<td>05/05/2013</td>
</tr>
<tr>
<td><em>Administrative reforms</em></td>
<td>4</td>
<td>Implement ISO 9001 as per the approved action plan</td>
<td>% Implementation</td>
<td>%</td>
<td>100</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prepare an action plan for Innovation</td>
<td>On-time submission</td>
<td>Date</td>
<td>30/07/2013</td>
<td>10/08/2013</td>
<td>20/08/2013</td>
</tr>
<tr>
<td><em>Improving internal efficiency /responsiveness service delivery of Ministry / Department</em></td>
<td>4</td>
<td>Implementation of Sevottam</td>
<td>Independent Audit of Implementation of citizen's charter</td>
<td>%</td>
<td>100</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Independent Audit of public grievances redressal system</td>
<td>% Implementation</td>
<td>%</td>
<td>100</td>
<td>95</td>
<td>90</td>
</tr>
</tbody>
</table>
## Section-3: Trend Values of the Success Indicators

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Objectives</th>
<th>Actions</th>
<th>Success Indicators</th>
<th>Unit</th>
<th>Actual Value for FY 11/12</th>
<th>Actual Value for FY 12/13</th>
<th>Targeted Value for FY 13/14</th>
<th>Projected Value for FY14/15</th>
<th>Projected Value for FY 15/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germplasm enhancement and development of improved cultivars</td>
<td>Evaluation of genetic material</td>
<td>Breeding lines and germplasm evaluated</td>
<td>Number</td>
<td>16215</td>
<td>15000</td>
<td>16850</td>
<td>18800</td>
<td>20700</td>
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<tr>
<td></td>
<td></td>
<td>Lines identified for unique traits</td>
<td>Number</td>
<td>100</td>
<td>120</td>
<td>140</td>
<td>200</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of improved cultivars</td>
<td>Entries contributed to AICRP multi-location trial</td>
<td>Number</td>
<td>112</td>
<td>180</td>
<td>110</td>
<td>112</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Varieties identified for release</td>
<td>Number</td>
<td>18</td>
<td>20</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seed production programme</td>
<td>Breeder seed produced</td>
<td>Weight MT</td>
<td>320</td>
<td>450</td>
<td>750</td>
<td>860</td>
<td>990</td>
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<td>Truthfully labeled seed produced</td>
<td>Weight MT</td>
<td>960</td>
<td>1013</td>
<td>1300</td>
<td>1500</td>
<td>1700</td>
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<td>Quality planting material produced</td>
<td>Number</td>
<td>45,000</td>
<td>65000</td>
<td>30,000</td>
<td>50,000</td>
<td>75,000</td>
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<tr>
<td>2</td>
<td>Development and identification of appropriate crop production, protection and value addition technologies</td>
<td>Development of technologies for enhancing resource use efficiency</td>
<td>Technologies developed and validated</td>
<td>Number</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of strategies for biotic/abiotic stress management</td>
<td>Novel molecules, genes and biological formulations developed and or tested</td>
<td>Number</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>22</td>
<td>25</td>
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<tr>
<td></td>
<td></td>
<td>Development of technologies for value addition</td>
<td>Novel processes/technologies/ products developed</td>
<td>Number</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recommendation of technologies</td>
<td>Technologies recommended</td>
<td>Number</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Technology dissemination, capacity building and policy research</td>
<td>Field demonstrations and agro-advisories</td>
<td>Field demonstrations conducted and agro-advisories issued</td>
<td>Number</td>
<td>3742</td>
<td>5000</td>
<td>5500</td>
<td>6000</td>
<td>6500</td>
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<tr>
<td></td>
<td></td>
<td>Training of farmers/ Extension officials</td>
<td>Trainings organized</td>
<td>Number</td>
<td>70</td>
<td>70</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Policy analysis</td>
<td>Policy briefs/papers prepared</td>
<td>Number</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Excellence in human resources development</td>
<td>Post Graduate Teaching and AHRD Trainings</td>
<td>Applications: Admission ratio (Ph.D.)</td>
<td>Ratio</td>
<td>20:1</td>
<td>17:1</td>
<td>12.5:1</td>
<td>13:1</td>
<td>13.5:1</td>
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<td>208</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of trainings conducted</td>
<td>Number</td>
<td>17</td>
<td>22</td>
<td>25</td>
<td>27</td>
<td>30</td>
</tr>
</tbody>
</table>

### Notes

- **Efficient Functioning of the RFD System**
  - Timely submission of Draft RFD (2013-14) for approval
  - Timely submission of Results for RFD 2012-13

- **Administrative reforms**
  - Implement ISO 9001 as per the approved action plan
  - Prepare an action plan for Innovation

- **Improving internal efficiency / responsiveness service delivery of Ministry /Department**
  - Implementation of Sevottam
  - Independent Audit of Implementation of citizen's charter
  - Independent Audit of Implementation of public grievances redressal system
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Success indicator</th>
<th>Description</th>
<th>Definition</th>
<th>Measurement</th>
<th>General Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Breeding lines and germplasm evaluated</td>
<td>Source material for the improved varieties to be evaluated</td>
<td>Material generated from the basic germplasm</td>
<td>Number of breeding lines evaluated</td>
<td>It depends on the leadership of scientists associated and collaboration</td>
</tr>
<tr>
<td>2</td>
<td>Lines identified for unique traits</td>
<td>Identification of breeding lines for special characteristics</td>
<td>Unique traits are the extraordinary traits in the plants that can be exploited for development of improved crop varieties</td>
<td>Number of such lines identified</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Entries contributed to AICRP multi-location trial</td>
<td>Breeding lines of field and horticultural crops tested at AICRP multilocalional trials against popular cultivated varieties in that region for identification of new varieties for release</td>
<td>Best performing entries are identified as new variety for release</td>
<td>Number of such varieties identified</td>
<td>Number may vary depending upon the material available from the evaluated lines</td>
</tr>
<tr>
<td>4</td>
<td>Varieties identified for release</td>
<td>Breeding lines of field and horticultural crops tested at AICRP multilocalional trials and identified as new varieties for release during Annual workshop</td>
<td>Breeding lines identified for release for superior traits by AICRP Workshop</td>
<td>Number of varieties identified</td>
<td>Number may vary depending upon timely evaluation and fair assessment</td>
</tr>
<tr>
<td>5</td>
<td>Breeder seed produced</td>
<td>Produce from nucleus and breederseed is the starting point in seedchain of producing quality seeds for farmers</td>
<td>Breeder seed is the starting point in seed chain which is multiplied/converted into foundation /certified seed</td>
<td>Quantity produced (MT)</td>
<td>Quantity may vary as per indent received, availability of land and other resources/ facilities</td>
</tr>
<tr>
<td>6</td>
<td>Truthfully labeled seed produced</td>
<td>Truthfully labeled seed are those seeds that are sold to the farmers by showing quality parameter without certification</td>
<td>The seeds which are sold by farmers or companies by showing quality parameter through their label without certification are known as truthful seeds. These seeds don't need permission from government, but seed law regulates the quality parameters mentioned in the label</td>
<td>Quantity produced (MT)</td>
<td>Quantity may vary as per indent received, availability of land and other resources/ facilities</td>
</tr>
<tr>
<td>7</td>
<td>Quality planting material produced</td>
<td>Production of quality planting material of fruit crops</td>
<td>Saplings of fruit plants</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Technologies developed and validated</td>
<td>Development of technologies that enable crops to use resources efficiently for increasing production</td>
<td>Natural resources are chemical fertilizers, water, and pesticides etc. that are essential for crops to grow</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Novel molecules, genes and biological formulations developed and/or tested</td>
<td>Development and testing of novel molecules, biological formulations and isolation &amp; incorporation of genes for biotic/abiotic stress management</td>
<td>Chemical/biochemical compounds that control insect pests and diseases and increase production. Genes are parts of chromosomes that confer resistance for biotic and abiotic stresses in crop plants</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Novel processes/technologies/products developed</td>
<td>Technologies that add value to agricultural produce</td>
<td>Process by which low cost produce can be converted in high value product</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------</td>
<td>---------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Technologies recommended</td>
<td>Recommendation of technologies/GAPs to the farmers for increasing crop yield</td>
<td>Transfer of knowledge by subject matter specialists to the farming community for good farming practices</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Field demonstrations conducted and agro-advisories issued</td>
<td>Trials and demonstrations conducted for technology testing and proving the technology potential production and advisories given to the farmers through direct communication/ DD/Radio/newspapers/SMSs</td>
<td>On-farm trials aims at testing new technologies under farmers condition and management, by using farmers own practice as control. Frontline demonstration is the field demonstration conducted on farmer’s field under the close supervision of scientists. Agro-advisories are issued by various means of communication to the farmers for good agricultural practices, advance forewarnings of weather conditions</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Trainings organized</td>
<td>Capacity building activities related to knowledge and skill improvement/development programmes conducted for farmers, rural youth and extension personnel</td>
<td>Training is a process of acquisition of new skills, attitude and knowledge in the context of preparing for entry into a vocation or improving productivity in an organization or enterprise</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Policy briefs/papers prepared</td>
<td>Policy briefs and policy papers prepared on various economic aspects</td>
<td>The purpose of policy briefs is to help the stakeholders, policy makers and planners for bringing out overall changes in agricultural system</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Application: Admission ratio (Ph.D.)</td>
<td>Ratio of number of students applied for and selected for admission in Ph.D. course at IARI</td>
<td>The ratio may vary depending upon number of applicants in a particular year</td>
<td>Ratio</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Degrees awarded</td>
<td>M.Sc. and Ph.D. degrees awarded to the students</td>
<td>Master and Doctorate degrees</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>No. of trainings conducted</td>
<td>Advanced AHRD trainings provided to the scientist/researcher of ICAR Institutes/SAUs</td>
<td>A process of acquiring new knowledge for improvement in research, teaching and extension</td>
<td>Number</td>
<td></td>
</tr>
</tbody>
</table>
## Section-5: Specific Performance Requirements from other Departments

<table>
<thead>
<tr>
<th>Location Type</th>
<th>State</th>
<th>Organisation Type</th>
<th>Organisation Name</th>
<th>Relevant Success Indicator</th>
<th>What is your requirement from this organisation</th>
<th>Justification for this requirement</th>
<th>Please quantify your requirement from this Organisation</th>
<th>What happens if your requirement is not met.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Government</td>
<td>Departments</td>
<td></td>
<td>Department of Agriculture &amp; Cooperation</td>
<td>Breeder seed produced</td>
<td>Indent for quantity of breeder seed</td>
<td>Variety-wise indent for breeder seed</td>
<td>Quantity of breeder seed produced as per indent</td>
<td>Production of less or more quantity of breeder seed</td>
</tr>
</tbody>
</table>

## Section-6: Outcome / Impact of activities of organization

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Outcome of organization</th>
<th>Jointly responsible for influencing this outcome / impact with the following department (s)/ministry(ies)</th>
<th>Success Indicators</th>
<th>Unit</th>
<th>2011-2012</th>
<th>2012-2013</th>
<th>2013-2014</th>
<th>2014-2015</th>
<th>2015-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Impact on adoption of IARI crop varieties at national and international level</td>
<td>DAC, Planning Commission, Ministry of Environment &amp; Forests, CGIAR Institutes, APEDA, Ministry of Commerce, Basmati exporting companies</td>
<td>a) Wheat*</td>
<td>%</td>
<td>22.5</td>
<td>27.5</td>
<td>23</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Rice (Basmati belt)</td>
<td>%</td>
<td>70</td>
<td>75</td>
<td>76</td>
<td>77</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c) Share of IARI Basmati rice varieties in export</td>
<td>%</td>
<td>74</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>d) Mustard*</td>
<td>%</td>
<td>30</td>
<td>31</td>
<td>35</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>e) Pulses*</td>
<td>%</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Impact on farmers income/ resources/ employment due to IARI technologies</td>
<td>DAC, Ministry of Panchayati Raj, Ministry of Rural Development and State Governments, SAUs, Volunteer organizations</td>
<td>Increase in farmers income</td>
<td>%</td>
<td>15</td>
<td>20</td>
<td>22</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improved rural livelihood and buildup of social capital</td>
<td>Number</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Conservation of resources and environmental quality</td>
<td>%</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Achievement of students and faculty at National/ International level</td>
<td>SAUs, CGIAR Institutes, Foreign Universities, UPSC</td>
<td>a) Employments to IARI graduates</td>
<td>%</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Awards &amp; recognitions</td>
<td>Number</td>
<td>65</td>
<td>86</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

* Percent area estimated based on breeders seed indent
Appendix 2

Members of Board of Management of IARI
(As on 31.3.2015)

Chairperson
Dr. Ravinder Kaur
Director (Acting), IARI

Members
Dr. K.V. Prabhu
Joint Director (Research), IARI

Dr. R.K. Jain
Dean & Joint Director (Education), IARI

Dr. J.P. Sharma
Joint Director (Extension), IARI

Dr. Ravinder Kaur
Project Director, WTC

Dr. D.V.K. Samuel
Head, Division of Agricultural Engineering

Dr. A.N. Mishra
Head, Regional Station, Indore

Dr. Jagdish Kumar
Head, Regional Station, Shimla

Dr. B.S. Dwivedi
Head, Division of Soil Science & Agricultural Chemistry

Dr. C. Viswanathan
Head, Division of Plant Physiology

Dr. Pritam Kalia
Head, Division of Vegetable Science

Dr. Mruthyunjaya
Ex-National Director, NAIP (ICAR)

Dr. Chanda Nimbkar
Director,
Animal Husbandry Division,
Nimbkar Agricultural Research Institute, P.O. Box No. 23, Phaltan, Maharashtra

Dr. K.E. Lawnde
Vice Chancellor

Dr. S. K. Malhotra
Agriculture Commissioner

Dr. R.K. Singh
Director, IVRI, Izatnagar, Bareilly

Sh. Devendra Kumar
Director (Finance) ICAR, Krishi Bhawan, New Delhi

Dr. J.S. Chauhan
ADG (FFC), ICAR, Krishi Bhawan, New Delhi

Development Commissioner
Delhi Administration, Govt. of NCT of Delhi

Dr. S. K. Malhotra
Agriculture Commissioner

Deprt. of Agril. and Cooperation,
Ministry of Agriculture, Krishi Bhawan, New Delhi

Member - Secretary
Smt. Shashi Prabha Razdan
Registrar & Joint Director (Adm.), IARI
Appendix 3
Members of Research Advisory Committee of IARI
(Up to 24.06.2014)*

Chairman
Dr. R.S. Paroda
Former DG, ICAR &
Chairman, Trust for Advancement of
Agricultural Sciences, New Delhi

Members
Prof. S.L. Mehta
Former Vice Chancellor (MPUAT),
Udaipur

Prof. A.N. Mukhopadhyay
Former Vice Chancellor,
Assam Agricultural University, Jorhat

Dr. M. Velayutham,
Former DDG (NRM), ICAR

Dr. G.L. Kaul,
Former Vice Chancellor,
Assam Agricultural University, Jorhat

Dr. Mruthyunjaya
Former National Director, NAIP
A-701, Vasundhara Apartments
Sector 6, Plot No. 16,
Dwarka, New Delhi-110075

Dr. Swapan Kumar Datta,
Deputy Director General (Crop
Science)
ICAR, Krishi Bhavan, New Delhi

Dr. H.S. Gupta,
Director, IARI, New Delhi

Member - Secretary
Dr. K.V. Prabhu
Joint Director (Research), IARI

* New RAC not yet constituted
Appendix 4

Members of Technical Advisory Committee (TAC) for Challenge Programmes
(As on 31.03.2015)

Chairperson
Dr. Ravinder Kaur
Director (Acting), IARI

Co-Chairman
Dr. K.V. Prabhu
Joint Director (Research), IARI

Members
Dr. I.P. Abrol
Ex-DDG (NRM) and
Director, Centre for Advancement of Sustainable Agriculture, NASC Complex, DPS Marg, New Delhi-110012

Prof. S.L. Mehta
Former Vice Chancellor, (MPUAT)
71, Gokul Nagar
Near Bohra Ganeshji Temple
Udaipur-313001, Rajasthan

Dr. Gautam Kalloo
Ex-DDG (Crop Science) and Former Vice Chancellor, JNKV, Jabalpur (M.P.)

Dr. P.K. Aggarwal
Former National Professor, ICAR and Regional Facilitator, Challenge Program on Climate Change, Agriculture & Food Security
IWMI India Office, NASC Complex, DPS Marg, New Delhi-110012

Prof. R. Banerjee
Head
P.R. Sinha Centre for Bioenergy
IIT, Kharagpur-721301 (W.B.)
Appendix 5
Members of Academic Council of IARI
(As on 31.3.2015)

Chairperson
Dr. Ravinder Kaur
Director (Acting), IARI

Vice-chairman
Dr. R.K. Jain
Dean & Joint Director (Education), IARI

Members
Dr. Arvind Kumar
DDG (Education)
ICAR, Krishi Bhawan
New Delhi

Dr. K.C. Bansal
Director, NBPG

Dr. U.C. Sud
Director, IASRI

Dr. T.R. Sharma
Director, NRC on Plant Biotechnology

Dr. K.V. Prabhu
Joint Director (Research)

Dr. J.P. Sharma
Joint Director (Extension)

Dr. S.M. Virmani
Advisor, INRIMT
House No. 811 A, Road No. 41,
Jubilee Hills, Hyderabad-500033 (AP)

Dr. Mruthyunjaya
Former National Director, NAIP

A-701, Vasundhara Apartments,
Sector-6, Plot No.16, Dwarka,
New Delhi-110075

Dr. V.L. Chopra
Former Member
Planning Commi-ssion
New Delhi-110058

Dr. Ajit Varma
Director General
Amity Institute of Microbial Technology
Amity University, Noida

Dr. Ravinder Kaur
Project Director, WTC

Dr. O.P. Yadav
Project Director, DMR, New Delhi

Dr. T. Manjunath Rao
Director (Acting), IIHR, Bengaluru

Dr. K.K. Singh
Director, CIAE, Bhopal

Dr. P.K. Mishra
Director, CSWCRTI, Dehradun

Dr. Irani Mukherjee
Professor, Agricultural Chemicals

Dr. Alka Singh
Professor, Agricultural Economics

Dr. Indra Mani
Professor, Agricultural Engineering

Dr. Premlata Singh
Professor, Agricultural Extension

Dr. Seema Jaggi
Professor, Agricultural Statistics

Dr. K.S. Rana
Professor, Agronomy

Dr. Pramila Aggarwal
Professor, Agricultural Physics

Dr. Archna Sachdev
Professor, Biochemistry

Dr. Anil Rai
Professor, Bio-Informatics

Dr. Seema Jaggi
Professor, Computer Application

Dr. Subhash Chander
Professor, Entomology

Dr. H. Pathak
Professor, Environmental Sciences

Dr. K.V. Prasad
Professor, Floriculture and Landscaping

Dr. A.D. Munshi
Professor, Vegetable Science

Dr. Charanjit Kaur
Professor, Food Science & Postharvest Technology

Dr. S.K. Singh
Professor, Fruits and Horticultural Technology

Dr. Dolly Wattal Dhar
Professor, Microbiology
Dr. Srinivasan
Professor, Molecular Biology and Biotechnology

Dr. Anil Sirohi
Professor, Nematology

Dr. I.S. Bisht
Professor, Plant Genetic Resources

Dr. Pratibha Sharma
Professor, Plant Pathology

Dr. V.P. Singh
Professor, Plant Physiology

Dr. S.K. Jain
Professor, Seed Science and Technology

Dr. R.D. Singh
Professor, Soil Science and Agricultural Chemistry

Dr. Man Singh
Professor, Water Science and Technology

Dr. Vinod
Professor, Genetics

Dr. Anil Sirohi
MOHR

Ms. Usha Khemchandi
Incharge, Central Library

Dr. B.S. Tomar
Principal Scientist, Division of Seed Science and Technology

Dr. S.K. Yadav
Principal Scientist, Division of Seed Science and Technology

Mr. Sakthi Pratibhan R.
President, PGSSU

Mr. Debasis Golui
Student's Rep. to the AC

Sh. Sanchal Bilgrami
Comptroller

Dr. K.M. Manjaiah
Officer Incharge, AIM Cell

**Member- Secretary**

Smt. Shashi Prabha Razdan
Registrar & Joint Director (Adm.)
Appendix 6

Members of Extension Council of IARI
(As on 10.6.2014)

Chairman
Dr. H.S. Gupta
Director, IARI,
New Delhi

Members
Dr. K. Vijayaragavan
Joint Director (Extension), IARI,
New Delhi

Dr. K.V. Prabhu
Joint Director (Research), IARI,
New Delhi

Sh. B.N. Rao
Joint Director (Admn.), IARI,
New Delhi

Dr. A.K. Singh
School Coordinator- Crop
Improvement & Professor,
Genetics, IARI, New Delhi

Dr. Pritam Kalia
Head, Vegetable Science, IARI,
New Delhi

Dr. G.T. Gujral
Head, Entomology, IARI,
New Delhi

Dr. Suresh Pal
Head, Agricultural Economics,
IARI, New Delhi

Dr. S.K. Jain
Professor, SST, IARI, New Delhi

Dr. D.V.K. Samuel
Head, Agricultural Engineering,
IARI, New Delhi

Dr. B.S. Dwivedi
Head, SSAC, IARI, New Delhi

Dr. Pratibha Sharma
Head (Acting), Plant Pathology,
IARI, New Delhi

Dr. Sanjay Kumar
I/c Seed Production Unit, IARI,
New Delhi

Dr. Ravinder Kaur
Project Director, WTC, IARI,
New Delhi

Dr. S.S. Atwal
Head, IARI Regional Station,
Karnal-132001

Dr. J.S. Sandhu
Agril. Commissioner, DOAC,
MOA, Krishi Bhavan, New Delhi

Sh. Kaushal Kishore
Joint Director (Agriculture), Govt.
of NCT Delhi, MSO Building,
11th Floor, IP estate, New Delhi

Sh. V.P. Rao
Director (Ag. Marketing), Delhi
Dev. Deptt. 49, Shamnath Marg,
Old Secretariat, Delhi

Dr. K. Ponnumasy
Head, Extension Division, NDRI,
Karnal (Haryana)

Dr. O.P. Dahiya
Director (FI), Directorate of
Extension, DAC, Krishi Vistar
Sadan, Behind Agronomy
Division, IARI Campus,
New Delhi

DDG (Extension), ICAR, KAB-I,
New Delhi

Member-Secretary
Dr. J.P. Sharma
Head, Agricultural Extension
Appendix 7

Members of Executive Council of IARI
(As on 31.03.2015)

Chairperson
Dr. Ravinder Kaur
Director (Acting), IARI

Members
Dr. K.V. Prabhu
Joint Director (Research), IARI
Dr. R.K. Jain
Dean & Joint Director (Education), IARI
Dr. J.P. Sharma
Joint Director (Extension), IARI
Dr. Ravinder Kaur
PD, WTC

Dr. A.K. Saxena
Head, Microbiology

Dr. A.K. Singh
Head, Genetics

Dr. Pritam Kalia
Head, Vegetable Sciences

Dr. G.T. Gujar
Head, Entomology

Dr. Raj Deo Rai
Head, Bio-Chemistry

Dr. D.V.K. Samuel
Head, Division of Agril. Engineering

Dr. Archana Uday Singh
Project Coordinator (Acting), Nematology

Dr. S.S. Atwal
Head, Regional Station, Karnal

DDG (Crop Science)
ICAR, Krishi Bhawan

Member- Secretary
Smt. Shashi Prabha Razdan
Registrar & Joint Director (Admn.)

Appendix 8

Members of Institute Research Council (IRC)
(As on 31.3.2015)

Chairperson
Director, IARI

Co-Chairperson
Joint Director (Research), IARI

Members
Deputy Director-General (Crop Science), ICAR
All Project Directors/Project Coordinators of IARI
All Heads of Divisions/Regional Stations of IARI
All Principal Investigators of IARI

Member- Secretary
In-charge, PME Cell, IARI
Appendix 9
Members of Institute Joint Staff Council (IJSC)
(As on 31.3.2015)

Chairman
Dr. Ravinder Kaur
Director(Acting)

Members (Official Side)
Dr. K.V. Prabhu
Joint Director (Research)
Dr. S.S. Atwal
Head, IARI Regional Station
Karnal
Dr. A.K. Singh
Principal Scientist
Division of Nematology
Dr. A.N. Mishra
Incharge, IARI Regional Station
Indore
Shri Sanchal Bilgrami
Comptroller

Secretary (Official Side)
Smt. Shashi Prabha Razdan
Registrar & Joint Director (Adm.)

Members of the Staff Side
(Elected)
Ms. Santosh Gautam
Assistant, Audit, Directorate, IARI
Shri Radhey Krishn Thakur
UDC, Audit, Directorate, IARI
Shri Yogesh Kumar
Assistant
Division of Plant Pathology, IARI
Shri Ganesh Rai
Senior Technician,
Division of Entomology
Shri Veer Pal Singh
Senior Technical Assistant, CPCT

Secretary (Staff Side)
Shri Bhagat Singh
Technical Assistant, FOSU
Shri Atiq Ahmed
Technical Assistant,
Division of Agricultural Physics
Shri Umesh Thakur
SSS, Audit, Directorate
Shri Desh Pal
SSS, Directorate
Shri Bijender Singh
SSS, CATAT
Shri Dharm Singh
SSS, Division of SS & AC
Shri Satyendra Kumar
AAO, P-V Section
Directorate
Appendix 10
Members of Grievance Committee of IARI
(As on 31.3.2015)

Chairman
Dr. J.P. Sharma
Joint Director (Extension)

Members (Official Side)
Dr. V.T. Gajbhiye
Head, Agricultural Chemicals
Smt. Piyush Malyan Nimbran
Sr. Admn. Officer, Directorate
Ms. V.B. Jhade
CF&AO, Directorate, IARI

Members of the Staff Side (Elected)
Dr. Jai Prakash
Senior Scientist, Fruits and Horticultural Technology
Shri Brahm Dutt
Assistant Chief Technical Officer, Division of Microbiology
Shri Pankaj
Lower Division Clerk
Audit, Directorate

Shri Mohan
Skilled Support Staff
Audit, Directorate

Member-Secretary
Shri Dev Raj
AAO (P-I), Directorate
# Appendix 11

## Personnel

(As on 31.03.2015)

<table>
<thead>
<tr>
<th>Directorate</th>
<th>Agricultural Engineering</th>
<th>Floriculture and Landscaping</th>
</tr>
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<tbody>
<tr>
<td><strong>Director (Acting)</strong></td>
<td>Head (Acting)</td>
<td>Head</td>
</tr>
<tr>
<td>Dr. Ravinder Kaur</td>
<td>Dr. D.V.K. Samuel</td>
<td>Dr. S.S. Sindhu</td>
</tr>
<tr>
<td><strong>Professor</strong></td>
<td>Dr. Indra Mani</td>
<td><strong>Professor</strong></td>
</tr>
<tr>
<td>Dr. K.V. Prabhu</td>
<td>Dr. Prem Lata Singh</td>
<td>Dr. K.V. Prasad</td>
</tr>
<tr>
<td><strong>Joint Director (Research)</strong></td>
<td><strong>Head (Acting)</strong></td>
<td><strong>Head (Acting)</strong></td>
</tr>
<tr>
<td>Dr. K.V. Prabhu</td>
<td>Dr. Prem Lata Singh</td>
<td>Dr. K. Usha</td>
</tr>
<tr>
<td><strong>Professor</strong></td>
<td>Dr. Prem Lata Singh</td>
<td><strong>Professor</strong></td>
</tr>
<tr>
<td>Dr. J.P. Sharma</td>
<td>Dr. Prem Lata Singh</td>
<td>Dr. S.K. Singh</td>
</tr>
<tr>
<td><strong>Dean &amp; Joint Director (Education)</strong></td>
<td><strong>Head (Acting)</strong></td>
<td><strong>Genetics</strong></td>
</tr>
<tr>
<td>Dr. R.K. Jain</td>
<td>Dr. Prem Lata Singh</td>
<td><strong>Head</strong></td>
</tr>
<tr>
<td><strong>Joint Director (Extension)</strong></td>
<td><strong>Professor</strong></td>
<td>Dr. A.K. Singh</td>
</tr>
<tr>
<td>Dr. J.P. Sharma</td>
<td>Dr. Prem Lata Singh</td>
<td><strong>Professor</strong></td>
</tr>
<tr>
<td><strong>Joint Director (Admin.) &amp; Registrar</strong></td>
<td><strong>Professor</strong></td>
<td>Dr. Vinod</td>
</tr>
<tr>
<td>Mrs. Shashi Prabha Razdan</td>
<td>Dr. Prem Lata Singh</td>
<td></td>
</tr>
<tr>
<td><strong>Principal Scientist (PME)</strong></td>
<td><strong>Agent (Acting)</strong></td>
<td><strong>Microbiology &amp; CCUBGA</strong></td>
</tr>
<tr>
<td>Dr. I. Sekar</td>
<td><strong>Head (Acting)</strong></td>
<td><strong>Head</strong></td>
</tr>
<tr>
<td><strong>Incharge, Publication Unit (Eng.)</strong></td>
<td>Dr. S.S. Sindhu</td>
<td>Dr. Annapurna K.</td>
</tr>
<tr>
<td>Dr. S.S. Sindhu</td>
<td><strong>Professor</strong></td>
<td><strong>Professor</strong></td>
</tr>
<tr>
<td><strong>Comptroller</strong></td>
<td>Dr. S.S. Sindhu</td>
<td>Dr. Dolly Wattal Dhar</td>
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<tr>
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<td>Dr. Rashmi Aggarwal</td>
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Agricultural Technology Information Centre (ATIC)
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Dr. N.V. Kumbhare

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Incharge
Dr. B.S. Patil

IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon
Incharge
Dr. Anjani Kumar

*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.
Addendum
(See as a part of page 36 in continuation of Vegetable Crops)
IARI Regional Station, Katrain, Kullu, HP

**Cabbage.** Using CMS system, three promising cabbage hybrid combinations (9A x C-121, 6A x 9B and 6A x CH-4) were identified. Twelve self-incompatibility system based F₁ hybrids were developed by utilizing 5 SI lines and evaluated against 2 checks (Pusa Cabbage 1 & Vellore). Hybrid combination of S-681 x S-208 was found promising (68.6 t/ha) followed by S-208 x GA-122 (64.5 t/ha). In red cabbage, 7 CMS based experimental hybrids were evaluated against check Rajat. Hybrid 24A x ZH was superior (64.3 t/ha) followed by 23A x ZH (60.5 t/ha).

**Cauliflower.** Ogura male sterile cytoplasm was introgressed into 30 new snowball cauliflower lines after refinement for various floral and seed yield related traits. These lines are now available for use in hybrid development. Doubled haploid plants have been successfully regenerated through microspore culture in snowball cauliflower.

**Kale.** KTK 64, an open-pollinated variety of kale developed by IARI, Regional Station, Katrain was identified for release during the XXXII Group Meeting of the AICRP (VC) held at IGKV, Raipur for zone-I. This is the first ever variety of vegetable kale identified for release in India. It has highly serrated, purplish green leaves measuring around 40-50 cm in length and 15-25 cm in width, plant height is 50-60 cm. Leaves are available throughout the winter season (October-November to March-April in the hills) in multiple harvestings, which can be consumed as cooked green vegetable or mixed with other leafy vegetables. Average leaf yield over locations is 35.0 t/ha. It has higher contents of nutraceuticals like phenols, anthocyanin, ascorbic acid, lycopene and total carotenoids compared to other Brassica vegetables. It has high tolerance to cold and frost conditions.

**Capsicum.** Thirty five station hybrids developed by using 5 lines and 7 testers were evaluated for fruit yield and its contributing traits under open and polyhouse conditions at Katrain. The hybrid KTCH 133 (46.80 t/ha) gave the highest marketable fruit yield followed by KTCH 151 (45.60 t/ha) and KTCH 141 (42.60 t/ha) under polyhouse conditions. Whereas, the hybrids KTCH 141 (38.10 t/ha), KTCH 135 (35.70 t/ha) and KTCH 151 (35.40 t/ha) had performed better for yield parameters under open conditions. These hybrids also had high antioxidant activity (CUPRAC, FRAP, vitamins, carotenoids and phenols).

**Carrot.** In temperate carrot, 45 germplasm lines were evaluated for root yield and its contributing traits. Genotypes Musha Shia (30.15 t/ha), KS 5 (29.55 t/ha) and KS 8 (27.45 t/ha) had high root yield. Eighty one CMS based experimental hybrids were evaluated at Katrain for root yield and nutritional traits. The hybrids, KTCH 720 (36.0 t/ha), KTCH-10K (32.70 t/ha) and KTCH 759 (30.75 t/ha) were found promising. Hybrid KTCH 820 had high antioxidant activity for CUPRAC (4.31 µmol trolox/g) and FRAP (1.47 31µmol trolox/g); KTCH 859 for lycopene (4.45mg/100g); KTCH 8059 for β-carotene (µg/100g) and KTCH 1013 for ascorbic acid content (mg/100g), respectively.

**Pea.** Fifteen advance garden pea breeding lines were evaluated for yield and antioxidant capacity. Lines KTP 102, KTP 101 and KTP 105 had consistently performed well for the last two years over the standard variety Lincoln.
Annual Report
2014-15

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