ISSN 0972-6136

Annual Report
2016-17

ICAR–Indian Agricultural Research Institute
New Delhi-110 012

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ICAR–Indian Agricultural Research Institute
(Deemed University)
New Delhi - 110 012

Printed : July, 2017

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Correct citation : IARI. Annual Report 2016-17, Indian Agricultural Research Institute, New Delhi - 110 012, India.

Copies printed : 1500

ISSN 0972-6136

IARI website : www.iari.res.in

Published by the Director, Indian Agricultural Research Institute, New Delhi - 110 012, India, and printed at Venus Printers and Publishers, B-62/8, Naraina Indl. Area, Phase-II, New Delhi, Ph.: 45576780, 9810089097, E-mail: pawannanda@gmail.com

PREFACE

The Indian Agricultural Research Institute (IARI) has maintained its excellence in research, education and extension research. The Institute was ranked as number one among agricultural universities and 15th among the all the universities in India by National Institutional Ranking Framework, Ministry of Human Resource Development, Government of India. With a history of taking science to the fields of farmers, recently released IARI varieties of wheat, *Basmati* rice and mustard were cultivated in large areas during this year and contributed to the Nation's granary and brought prosperity to the farmers.

Genomics-aided analytical breeding programmes of the Institute accelerated the pace of crop breeding and led to the release of varieties/hybrids with improved yield, quality and climate resilience in field and horticultural crops during 2016-17. In wheat, HD 3171, HS 562 and HW 5207 were released for commercial cultivation in North Eastern Plains Zone (NEPZ), Northern Hills Zone (NHZ) and Tamil Nadu, respectively. A high yielding wheat variety HI 1605 with high protein and micro-nutrients (iron & zinc) was released for Peninsular Zone. *Durum* wheat varieties HI 8759 and HD 4728 with an average yield of >5.4 t/ha were released for timely sown irrigated conditions of Central Zone (CZ). Using marker assisted selection breeding, IARI has released two *Basmati* rice varieties, namely, Pusa Basmati 1637 and Pusa Basmati 1728 with blast and bacterial blight resistance, respectively, for commercial cultivation in *Basmati* growing regions of Punjab, Haryana, Delhi, Jammu & Kashmir, Uttarakhand and western Uttar Pradesh. A dual purpose pearl millet variety Pusa composite 701 with average grain yield of 2.3 t/ha was released. In pulses, *desi* chickpea variety BG 3043, lentil variety L 4717 and mung bean variety Pusa 137 were released for NEPZ, CA and NHZ, respectively.

In horticultural crops, 23 hybrids/varieties of vegetables and 2 varieties in flower crops were identified /released. The Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops released IARI varieties viz., Pusa Santushti (bottle gourd), Pusa Shree (garden pea), Pusa Sabzipetha (ash gourd), Pusa Kaushal (brinjal) and Pusa Ashwini (cauliflower) for cultivation in different zones of the country. Besides, 14 varieties in different vegetables were also notified by CVRC for cultivation in NCT of Delhi. In ornamental crops, Chrysanthemum variety Pusa Guldasta, suitable for spray and pot culture purposes, and gladiolus variety Pusa Sinduri suitable for cut flower, bouquet preparation, vase and floral arrangement were released.

The School of Natural Resource Management standardized and validated technologies for efficient input use, soil health and enhanced productivity and profitability. Precision nutrient management with Nutrient Expert® is recommended for high grain yield and savings of 12 to 25 kg N/ha and 16-29 kg P_2O_5/ha over the state recommendation in maize. Pusa STFR meter has been improved, which is now capable of analyzing fourteen parameters viz., pH, EC, OC, 9 different available nutrients [(derived N), P, K, S, Zn, B, Fe, Mn and Cu], and gypsum and lime requirement. Towards achieving *more crop per drop*, different agronomic practices were evaluated and mungbean residue+ zero tilled direct seeded rice – residue + ZT mustard - mustard residue+ summer mungbean was found to be the best system for water saving. Automated drip irrigation was recommended to save 39.6-48.7% water over manually controlled check basin irrigation in vegetable crops. An Integrated Farming System model with one ha was developed to get ₹3,40,787 as net returns. Farm machinery like gladiolus planter, system of wheat intensification planter, liquid fertilizer applicator, battery assisted four-wheel weeder, solar powered fruit and vegetable grader and other low cost storage structures were developed. Microbiological technologies were developed for enhancing microbe mediated nutrient cycling, stress alleviation, bio-control and biomass degradation *in situ* and *ex-situ*.

The crop protection research led to the development of molecular diagnostic protocols and management technologies for various pathogens. The genome of *T. indica*, *Puccinia striiformis tritici*, *Fusarium fujikuroi*, *Magnaporthe oryzae* and *Meloidogyne graminicola* were sequenced. Utility of host delivered RNAi of two

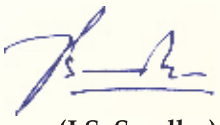
esophageal gland genes, *msp18* and *msp20* was demonstrated for the first time to interfere with nematode penetration in brinjal plants. Resistant sources to different insect-pests were identified in various crops and efficacy of different chemicals / biopesticides was tested against various pests in different crops. Chemo and bioprospecting for agrochemicals through design, discovery and development of novel processes has been undertaken during the period. Antifungal chemical N-heptyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine and N-hexadecyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine were identified as highly effective against *Rhizoctonia solani* and *Sclerotium rolfsii*, respectively. Previously synthesized azomethine derivatives were nano sized employing poly (ethylene glycol).

The basic and strategic research programmes of the Institute have mapped genes/QTLs for yield, quality and stress tolerance have been mapped in different crops which will be useful for marker assisted breeding. A leaf rust resistance gene *LrSel.G12* from *T. timopheevii* Zhuk. QTLs for grain iron and zinc were mapped in wheat and pearl millet. In rice, imazethapyr herbicide tolerance gene was mapped. QTLs for yield and quality related traits were mapped in soybean and bitter gourd. The gynoecious trait (F locus) in Cucumber was mapped. The Institute has also initiated work frontiers areas of next generation breeding. A state-of-art automated high throughput plant phenomics facility for non-destructive phenotyping was established at IARI. CRISPR-Cas9 genome editing constructs were developed for functional validation of stress responsive genes of rice and nutritional quality genes of soybean.

Three day *Krishi Unnati Mela* 2017 was organised from March 15-17 at ICAR-IARI, New Delhi in collaboration with ICAR, Ministry of Agriculture & Farmers Welfare. The mega event, that celebrated the great contribution of Indian farmers to agriculture, witnessed the participation of 342 public and private exhibitors and a large number of farmers from across the states of India. A one day Farm Innovators Meet was organized at IARI. Two farmers' led innovations were documented and screened for scalability. The Agricultural Technology Information Centre (ATIC) continued to provide products, advisory services, technologies and information to the farmers and other stakeholders through a single window delivery system.

In the 55th Convocation of the Post Graduate School of the IARI held on February 9, 2017, 231 candidates were awarded M.Sc. (112), M.Tech. (8) and Ph.D. (111) degrees including 13 international students. During 2016-17, 34 innovative technologies of the IARI were transferred to 19 industry partners. During this year 5 patents and one Trade Mark application were granted to the IARI. The Institute's achievements are expected to significantly improve farm profit, environmental sustainability and food security of the nation.

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



July 14, 2017
New Delhi

(J.S. Sandhu)
Director (Add. Charge)

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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.

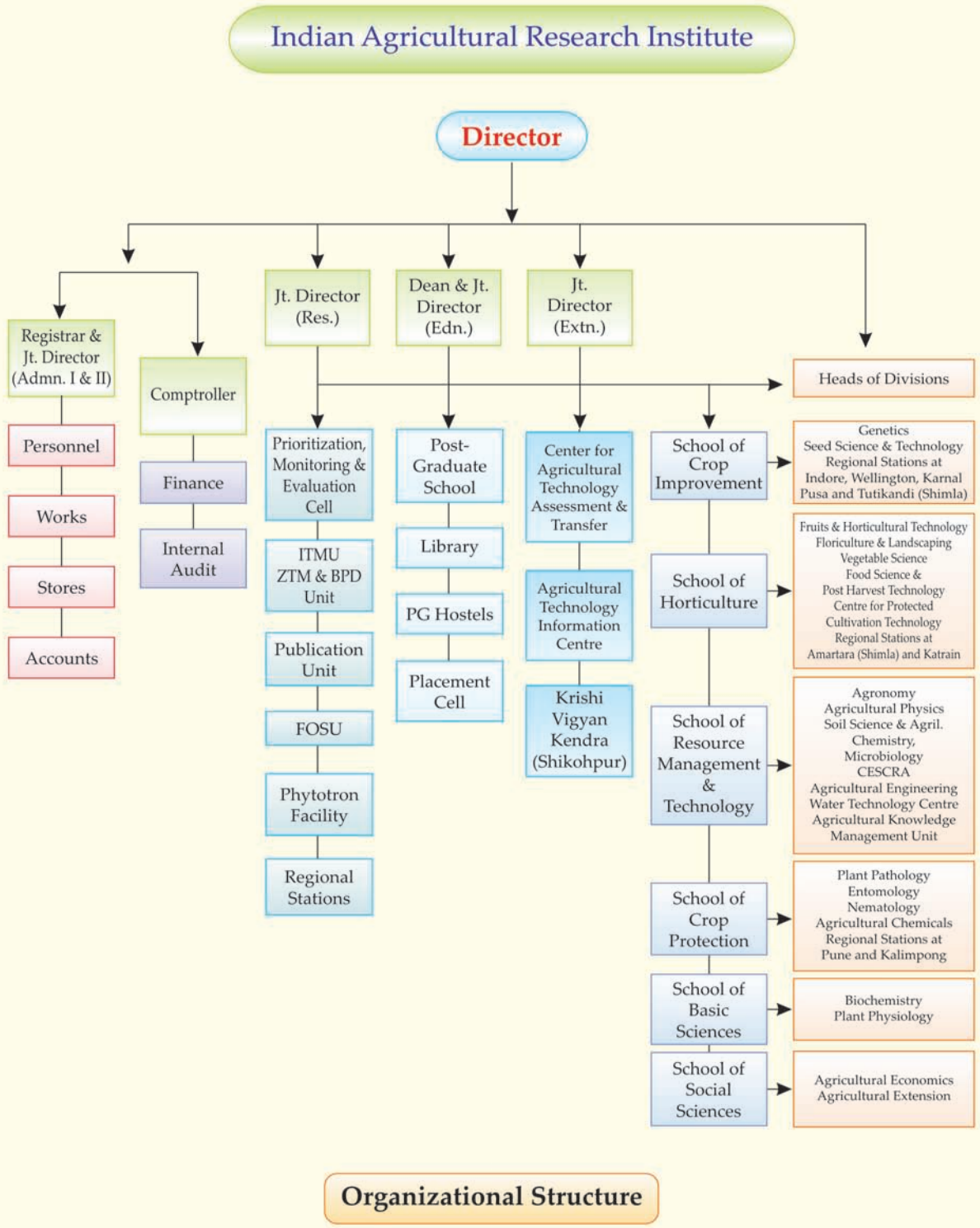
The growth of India's agriculture during the past more than 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout 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-temperate 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 21 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3007 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹41,018 lakh (Plan & Non-Plan) for the year 2016-17.



Organizational Structure

EXECUTIVE SUMMARY

The Indian Agricultural Research Institute (IARI) maintained its leadership role in basic, strategic and applied agricultural research, education and extension. The Institute has employed cutting edge science methods and tools to develop several new varieties/hybrids, crop protection and management technologies, agricultural machineries and post-harvest technologies for food and nutritional security, enhanced resource use efficiency and farm productivity, and environmental sustainability. The salient achievements of IARI in research, extension and education during 2016-17 are summarized below:

Genomics-aided analytical breeding programmes of the Institute resulted in the release of varieties/ hybrids with improved yield, quality and adaptability to climate change in field and horticultural crops suitable for different agro-ecological zones of the country during 2016-17. In wheat, HD 3171, a high yielding variety with an average yield of 2.81 t/ha was released for commercial cultivation under rainfed conditions of North Eastern Plains Zone (NEPZ). Another wheat variety HI 1605 with an average yield of >3.0 t/ha was released for timely sown, restricted irrigation conditions of Peninsular Zone. It has excellent *chapatti* making quality, high protein (~13%) and high amount of micro-nutrients viz., iron (43 ppm) and zinc (35 ppm). Wheat variety, HS562 with an average grain yield of 3.6 t/ha under rainfed and 5.2 t/ha under irrigated conditions of Northern Hills Zone, was also released. In *durum* wheat, HI 8759 and HD 4728 varieties with an average yield of >5.7 and 5.42 t/ha, respectively, were released for timely sown irrigated conditions of Central Zone. HW 5207, a high yielding and disease resistant wheat variety was released for cultivation in Tamil Nadu state. Maintaining its leadership role in *Basmati* rice breeding, the Institute has released Pusa Basmati 1637, a MAS derived near isogenic line of Pusa Basmati 1 with *Pi9* gene for blast resistance, for commercial cultivation in the Basmati growing regions of the western Uttar Pradesh, National Capital Region of Delhi, Uttarakhand, Haryana and Punjab. It produces an average yield of 4.2 t/ha in 130 days. Pusa Basmati 1728, a MAS derived near isogenic line of Pusa Basmati 6, with inbuilt resistance to bacterial blight conferred by *xa13* and *Xa21* genes was released for Basmati growing region of Punjab, Haryana, Delhi, Jammu & Kashmir, Uttarakhand and western Uttar Pradesh.

Pusa composite 701, a dual purpose pearl millet variety with average grain yield of 2.3 t/ha, was released for Zone A regions of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh and Delhi. An early maturing *desi* chickpea variety, BG 3043 was identified for release under timely sown conditions of NEPZ comprising eastern Uttar Pradesh, Bihar, West Bengal, Jharkhand, and Assam. It has a 100-seeds weight of 21-22 g and an average yield of 1.6 t/ ha with a potential yield of 2.5 t/ha. An early maturing lentil variety L 4717 with average yield of 1.2-1.3 t/ ha, was released for Central Zone comprising of Madhya Pradesh, parts of Uttar Pradesh and Rajasthan, and Chhattisgarh. Pusa-137, a mung bean variety with average yield of 0.90 t/ha, was released for Northern Hills Zone consisting of Tripura, Manipur, Jammu & Kashmir and Himachal Pradesh.

The focused research of the School of Horticulture on improvement of disease resistance, quality and yield led to the release/identification of 23 hybrids/ varieties in different vegetables and 2 varieties in flower crops. The Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops released IARI varieties viz., Pusa Santushti (bottle gourd), Pusa Shree (garden pea), Pusa Sabzipetha (ash gourd), Pusa Kaushal (brinjal)

and Pusa Ashwini (cauliflower) for cultivation in different zones of the country. Besides, 14 varieties in different vegetables viz., Onion (Pusa Riddhi & Pusa Soumya - a bunching onion variety), broad bean (Pusa Udit), summer squash (Pusa Pasand), cucumber (Pusa Barkha), ridge gourd (Pusa Nutan), cauliflower (Pusa Kartiki), carrot (Pusa Rudhira & Pusa Asita), radish (Pusa Shweta, Pusa Jamuni & Pusa Gulabi), bitter gourd (Pusa Rasdar & Pusa Purvi) and a carrot hybrid (Pusa Vasuda) were also notified by CVRC for cultivation in NCT of Delhi. Four varieties, namely, Pusa Bhindi 5 in okra, Pusa Green in *Chenopodium* (Bathua), Pusa Prabal in garden pea and a sponge gourd hybrid Pusa Shrestha were identified by IARI Variety Identification Committee for cultivation in NCT of Delhi.

For protected cultivation, promising genotypes of musk melon DHM 162 (with 4.90 t/1000 m^2 yield and 13.5 °Brix TSS) and DHM 159 (4.60 t/1000 m^2 yield and 13.8 °Brix TSS) were identified. Six tomato lines with *Ty-2* and *Ty-3* genes in the background of elite varieties viz. Pusa Ruby, Pusa Rohini, Pusa 120, Pusa Gaurav and Punjab Barkha Bahar-2 developed with resistance to ToLCV (PDI<10%) and a fruit weight of 100-150 g. CMS based carrot hybrids viz., DcatEH 798, DcatEH 713 and DcatEH 298 with about 20 t/ha yield and heat tolerance were developed. Okra hybrid DOH-1 with 23t/ha yield and high levels of resistance to YVMV disease.

In mango, hybrids H 11-2, H 1-5, H 8-4 and H 3-5 with high fruit weight and pulp percentage were developed. New SSRs markers were designed from whole genome sequencing and transcriptome data and were validated among a set of 24 mango genotypes, and 85.27% primer pairs and 83.8% bands were found to be polymorphic. Sweet orange lines MS 3, MS 7, MS 9, MS 10, MS 20 and MS 21 were found promising with regard to fruit weight, juice content and quality parameters. In acid lime, clone ALC 107 had significantly highest fruit weight (95.48 g), while juice acidity was measured highest in ALC 1 (7.46%). Amongst lemon collections, genotype LS 5 excelled over others in respect of highest fruit weight (77.08 g), juice (53.25%) and acid (6.97%) contents. Six hybrids of grape, namely, ER-R_2P_{36}, 'ER-R_2P_{19}, ER-R_2P_{16}, 16/2A-R_3P_{18}, 16/2A-R_2P_{16}, 16/2A-$R_1P_9$and 16/2A-R_1P_{14} were developed for early maturity (second fortnight of May). Three grape hybrids viz., 16/2A-R_1P_9, 16/2A-R_1P_{14}, and 76-1 have been found promising in terms of loose bunch, bold berry (4-6 g), early maturity (1st week of June), bunch size (325.46 g to 450.25 g), desirable total solids content (18.57 to 21.15 °Brix) and moderate titratable acidity (0.41-0.71%).

Root stock studies lead to the identification of suitable rootstocks for different fruit crops. Performance analysis of mango varieties, Pusa Arunima, Pusa Surya and Amrapali on five polyembryonic rootstocks, i.e., K-5, K-3, K-2, Kurakkan and Olour showed that the maximum fruit weight (298.68 g) and pulp:stone ratio (6.09:1) can be obtained with Pusa Surya on K 2 rootstock. In Kinnow mandarin, fruit weight, fruit length and width were recorded maximum on *Jatti khatti* followed by sour orange rootstock. Lemon cv. Kagzi Kalan on RLC-4 rootstock yielded the highest fruit weight (73.10 g), while juice recovery was highest on *Billikichli* (41.12%). In Grapefruit, Marsh Seedless proved to be the most vigorous on sour orange, while for Red blush on rough lemon rootstock.

In ornamental crops, Chrysanthemum variety Pusa Guldasta, suitable for spray and pot culture purposes, and gladiolus variety Pusa Sinduri suitable for cut flower, bouquet preparation, vase and floral arrangement were released. One promising rose line suitable for loose flower purpose was isolated from Rose Sherbet. *In-vitro* protocol for mass multiplication of promising open pollinated seedling of cv. Rose Sherbet of *Rosa* × *hybrida* L was standardized. Interspecific crosses of lilium viz., KILH-13×Prato and KILH-13× Brunello showed significantly early flowering and took 322.0 days and 349.3 days, respectively, from seed sowing to flowering. The number of flowering stems in Eustoma was significantly increased whereas the flowering was delayed and plant height and stem length were significantly reduced by pinching. The treatment of Eustoma cuttings with 250 ppm Indole-3-butyric acid (IBA) for 10 minutes induced maximum rooting.

The Institute has a vibrant programme for collection, maintenance, pre-breeding and utilization of plant genetic resources including land races, wild relatives of crops, exotic and indigenous genotypes and introgression lines. In wheat, cytologically stabilized introgression lines from *Aegilops markgraffi*, *Aegilops speltoides* and *Triticum militinae* were evaluated against diverse races of leaf rust pathogen and found to provide broad spectrum resistance. In rice, a set of 144 F_6 families derived from two wide crosses with *O. rufipogon* and *O. nivara* were evaluated for various agro-morphological traits during *kharif*-2016. A set of 210 tropical *japonica* rice (TPJ) lines were analyzed using gene based/ linked markers for fertility restorer genes, *Rf3* and *Rf4*, and potential restorers and maintainers were identified. In maize, promising germplasm, genotypes and inbreds with various combinations of genes such as *crtRB1*, *lcyE* (for provitamin-A), *opaque2*, *opaque16* (for lysine and tryptophan), *VTE4* (for vitamin E), *sh2, su1, sh2/su1* (for sweetness), *wx1* (for waxy texture), *lpa1*, *lpa2* (for low phytate), and CMS-system (for male sterility) were maintained. In soybean, seeds of about 100 inter-specific (*Glycine soja* x *G max*) recombinant inbred lines (RIL) along with the parental lines were tested for seed coat permeability and germinability after 3 years of ambient storage.

Various disciplines of the School of Natural Resource Management (NRM) focused their research on standardization and validation of efficient input use through resource conservation, precision nutrient management and maintaining soil health by residue recycling and biofertilizers use. Studies conducted under maize-wheat system under precision nutrient management indicated that nutrients application as per Nutrient Expert® gave highest maize grain yield along with savings of 12 to 25 kg N/ha and 16-29 kg P_2O_5/ha over the state recommendation. The real time N scheduling at 25 and 42 DAS through GreenSeeker along with Nutrient Expert® recommendation for 7 t/ha grain yield curtailed 25 kg N/ha over state recommendation with highest agronomic N use efficiency (31.6 kg grain/kg N). In wheat, zero till (ZT)+5 t/ha maize residue+ 75% N + the rest N based on GreenSeeker resulted in relatively 17.1% lower CO_2 emission over conventional till without residue +100% N treatment. The total soil organic carbon concentrations at ZT-DSR followed by ZT wheat with residue retention in both 0-15 and 15-30 cm soil layers were (20 and 40%) higher than conventional tilled rice and wheat (CTR-CTW) plots, respectively. Pusa STFR meter has been improved, which is now capable of analyzing fourteen parameters viz., pH, EC, OC, 9 different available nutrients [(derived N), P, K, S, Zn, B, Fe, Mn and Cu], and gypsum and lime requirement. Provision of making fertilizer recommendation was made for 100 crops including field crops, horticultural crops and spices.

Different resource management technologies were focused towards enhancing household income and ensuring nutritional security of small and marginal farm holders. Under rainfed situations of Trans-Gangetic Plains, maximum productivity, net returns, B:C ratio, income and land use efficiency can be realized with babycorn followed by bottle gourd and vegetable cowpea. From one ha area of Integrated Farming System model, gross and net returns of ₹ 8,12,984 and ₹ 3,40,787, respectively can be obtained with labour requirement of 675 man days.

For enhancing water use efficiency, different agronomic practices were evaluated and mungbean residue+ZT-DSR-rice residue+ ZT mustard-mustard residue+ summer mungbean was found to be the best system for water saving than TPR. The irrigation water use efficiency and field water use efficiency was higher in system of rice intensification method with SDI drip. Water savings of 39.6-48.7% can be achieved using automated drip irrigation over manually controlled check basin irrigation for vegetable crops.

The farm machinery like gladiolus planter, system of wheat intensification planter, integral power equipment for small farm mechanization, liquid fertilizer applicator, battery assisted four - wheel weeder, walking type battery operated boom sprayer, solar powered fruit and vegetable grader and other low cost storage structures were developed and demonstrated. Evaluation of various food processing

and value addition interventions like enhancing shelf life of apple through filming, bagging in guava, dehydration in pine-apple, establishing anti-diabetic potential of ragi, enhancing cooking and nutritional quality of rice and developing new food products is the major research focus.

The significant progress has been made through microbiological interventions in blue green algae based composite liquid inoculants, encapsulated microbial inoculants for phosphorus nutrition, enhancing microbe mediated nutrient cycling under aerobic and anaerobic conditions, water stress alleviation and bio-control, developing efficient low-cost technologies for utilization of biomass, *in situ* and *ex-situ* biomass degradation.

The crop protection programme made significant advancement in pathogen diversity analysis, diagnostics and development of integrated management technologies for agricultural pests and pathogens of national importance. A multiplex PCR assay was developed to detect and quantify foliar pathogens of wheat, namely, *Puccinia triticina, P. Graminis tritici, P. Striiformis* and *Bipolaris sorokiniana*. A quick and reliable LAMP protocol was developed for speedy detection of wheat leaf rust pathogen *P. triticina*. Complete genome of Indian peanut clump virus was characterized. New Phytoplasma were identified on vegetable and legume crops. A highly simplified isothermal polymerase amplification based assay for diagnosis of *Banana bunchy top virus* was developed. A duplex RT-PCR assay was developed for simultaneous detection of two orchid viruses: CymMV and ORSV.

The monoteliosporic culture of *T. indica* isolate (RAKB_UP_1), *Puccinia striiformis tritici* (pathotype 38S102), *Fusarium fujikuroi* isolate F250 and Isolate RMg-Dl of *Magnaporthe oryzae* were sequenced and deposited in DDBJ/ENA/GenBank. The full-length genome clone (BP4) of *Cucumber green mottle mosaic virus* (CGMMV) successfully caused infection after agro inoculation to different cucurbits which was confirmed by electron microscopy, ELISA and RT-PCR. Resistance sources have been identified against various fungal, bacterial and viral diseases. Integrated management for bakanae disease of rice and papaya diseases were developed.

Resistant sources to different insect-pests were identified in various crops and efficacy of different chemicals / biopesticides tested against various pests in different crops. Monitoring of chickpea pod borer, *Helicoverpa armigera* and *Spodoptera exigua* moths using pheromone traps revealed that the first trap catch of male moth of *H. armigera* during 51st standard week in normal sown crop, while in early and late sown the trap catches were initiated during 1st and 4th standard week, respectively. Functional response of adult males and females of *Nephus regularis* (Sicard) against the different densities of cotton mealybug *Phenococcus solenopsis* (Tinsley) was worked out. Effect of storage temperature on the shelf-life extension of different stages of *Chrysoperla carnea* was studied. Among the different diets tested, larval rearing of *Bactrocera cucurbitae* on liquid diet (LD-I) was found most suitable.

Utility of host delivered RNAi of two esophageal gland genes, *msp18* and *msp20* was demonstrated for the first time to interfere with nematode penetration due to their oscillating effect on cell wall modifying enzymes using C^{14} labelling of brinjal plants, which established that nematode genes could be silenced even before they start feeding through the feeding cells. Starvation of 4th instar, *Galleria mellonella* larvae for 72 h prior to infecting them with *H. indica* resulted in suppressing the co-infection of *Bacillus bombysepticus* by 98.6% compared to 76.5% when starved for 48 h. Rapid virulence annotation (RVA) assay was undertaken to identify the potential virulence loci in the toxin genes of *Photorhabdus luminescens*. Insect mortality was achieved within 72 h of injection with six toxin genes such as Txp40, TcaA, TcaB, PirB, TccA and TccC. The genome of *M. graminicola* was sequenced along with the transcriptome of two populations of the species.

Chemo and bioprospecting for agrochemicals through design, discovery and development of novel processes has been undertaken during the period.

Antifungal assay suggested that N-heptyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine was the most active against *Rhizoctonia solani* (ED_{50} 24.59 mg/L) and N-hexadecyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine (ED_{50} 20.03 mg/L) against *Sclerotium rolfsii*. Previously synthesized azomethine derivatives were nano sized employing poly (ethylene glycol). Studies on biogel based EPN formulations were undertaken. Biogel (KG) performed best in close proximity with Pusa Nemagel (KCH gel). Methods for detection and quantification of contaminants in raw agricultural commodities, processed food and environmental samples were standardized and validated.

The basic and strategic research programmes at IARI focused on deciphering the molecular basis of stress tolerance of crops, characterization of genetic resources, mapping of QTLs/genes for economically important traits, the physiological basis of crop yield, mitigation studies on climate change, development of remote sensing and GIS techniques for assessment and management of crops and natural resources.

Towards elucidation of epigenetic basis of heat tolerance in wheat, whole genome bisulfite sequencing was carried-out in thermotolerant cv. Raj 3765 and thermosensitive cv. HD 2329 at anthesis stage. Analysis of methylome sequencing data for differentially methylated regions (DMR) between control and heat stress treated samples revealed that Raj 3765 had 25% more DMRs than HD 2329. Backcross-derived populations were screened for validation of previously identified QTLs and identification of new QTLs linked to drought and heat tolerance in wheat. Expression of introgressed QTLs were found to be higher in few selected lines compared to the recurrent parent. Work was initiated to develop Multi-parent Advanced Generation Intercrosses (MAGIC) population for drought and heat tolerance. A total of 70 double crosses were attempted from 28 single crosses. The reduction in photosynthesis at high temperature stress in wheat is due to inactivation of Rubisco activase (RCA) which activates Rubisco. Towards engineering a thermostable RCA, 6 potential hot spots were identified as candidate amino acid residues for thermostability and these sites were engineered with site directed mutagenesis.

Several important QTLs for various traits have been mapped in different crops which will be useful for marker assisted breeding. A leaf rust resistant stock "Selection G12" was developed from the cross between bread wheat line CM 108-31 x *T. timopheevii* Zhuk (2n= 28, A^tA^tGG). Molecular mapping and linkage analysis was used to map the leaf rust resistance *LrSel.G12* gene on long arm of 3B chromosome. QTL mapping for grain iron, zinc and protein in a biparental mapping population with 176 RILs led to the identification of 11 QTLs for grain iron, zinc and protein. Using F_2 progenies of Pusa1656 x Herbicide Tolerant Mutant of Nagina 22, Imazethapyr herbicide tolerance gene was mapped on Chromosome 2 at a genetic distance of 1.2 cM from the SSR marker RM6844 in rice. Genome-wide association studies for high grain iron and zinc contents in pearl millet led to the identification of linked markers for these traits. In soybean, 48 QTLs were mapped for 12 yield and domestication-related traits, of which 12 were novel and 7 were consistent QTL. Breeding values of 240 maize subtropical lines phenotyped for drought at different environments using 29,619 cured SNPs were tested using seven genomic selection models. From Bayes B, a set of the top 1053 significant SNPs with higher marker effects was selected across and out of these SNPs, 77 SNPs associated with ten drought-responsive transcription factors for different physiological functions. These SNPs will be useful for the selection of superior genotypes and candidate genes for breeding drought-tolerant maize hybrids.

In cauliflower, marker assisted pyramiding of black rot resistance gene *Xca1bo* and downy mildew resistance gene *Ppa3* genes in the recurrent parent of Pusa Meghna and Pusa Sharad was achieved. By employing genotyping by sequencing (GBS) approach, in bittergourd QTLs for gynoecious (*gy-1*), ridgeness (*cr*), fruit tubercles (*Tb*), first pistillate flower appearance, sex ratio (♂:♀), fruit characters and yield were mapped. Similarly, using 213 F_2 plants of the cross Pusa Uday × Pant Parthenocarpic Cucumber 2,

the gynoecious trait (F locus) in Cucumber (*F* locus) was mapped which will be useful for selection of stable gynoecious lines with high efficiency using marker assisted breeding.

To elucidate the microRNA biogenesis in rice under abiotic stresses, yeast-two-hybrid (Y2H) screen was carried out with Dicer-Like 1 (DCL1), an enzyme involved in microRNA biogenesis, as bait. Prey library was constructed in pGADT7 vector using RNA samples from abiotic stress treated tissues sample of drought and heat tolerant rice cv. Nagina 22. Several putative DCL1 partners were identified using Y2H genetic screen.

Phenomics, the next generation phenotyping (NGP), is emerging as a tool to bridge phenotype-genotype gap. A state-of-art automated high throughput plant phenomics facility for non-destructive and accurate characterization of a large number of germplasm and recombinant inbred lines under defined environmental treatment conditions was established at IARI, New Delhi. To identify donors for low nocturnal transpiration, an experiment was conducted with sixty rice genotypes at automated Plant Phenomics Facility, IARI and significant genotypic variation in nocturnal transpiration were identified which will be useful for improving water use efficiency (WUE) of rice. Phenomics analysis of rice transgenics overexpressing the *ABA receptor 6* (*ABAR6*) gene showed that the PSII yield decreased drastically in WT and *ABAR6-RNAi* lines, while *ABAR6* overexpressing lines maintained PSII yield under drought stress. This result suggests that enhanced stability of PSII is an important component of drought tolerance conferred by *ABAR6* gene.

Soybean seed is rich in health-promoting bioactive compound isoflavones. To understand the regulation of isoflavonoid biosynthesis in seeds of soybean, 31 new miRNAs along with their 245 putative target genes were identified from soybean seed-specific ESTs. Five miRNAs viz., GmamiRNA12, Gma-miRNA24, Gma-miRNA26, Gma-miRNA28, and Gma-miRNA29) may regulate isoflavone metabolic pathway.

Genome editing is emerging as an important tool for functional genomics and crop improvement. IARI has initiated work on genome editing for functional validation of genes for ABA-dependent and –independent pathway of drought tolerance in rice and enhancing nutritional quality of soybean. CRISPR-Cas9 genome editing constructs were developed for stress responsive genes of rice and nutritional quality genes of soybean and transformation is in progress.

The capacity of rice to store sucrose in the stem and its mobilization to grains are promising traits to buffer yield in environments with limited water availability. A study was conducted for non-invasive high throughput estimation of sucrose in rice stem using hyperspectral reflectance data collected in the spectral range of 350 to 2500nm for different rice genotypes grown under soil moisture deficit stress levels. Two spectral indices like ratio sucrose index (RSI) and Normalized Difference Sucrose Index (NDSI) in NIR range were proposed with reliable accuracy of sucrose estimation.

A web-based application of the crop simulation model 'Web InfoCrop - Wheat' was designed and developed by the Institute using Visual Studio Express, SQL Server, NET framework 4.0 and hosted at http://InfoCrop.iari.res.in. The 'Web InfoCrop – Wheat' crop model provides an efficient approach to be used as a decision support tool in the agricultural production system.

About 105 agro-met advisory bulletins were prepared in Hindi as well as in English on every Tuesday and Friday, and were uploaded on the Institute website (www.iari.res.in), IMD website (www.imdagrimet.gov.in) and farmer portal (http://farmer.gov.in). The bulletins were also sent to ATIC, KVK Shikohpur, KVK Ujawa, IKSL, NGO, e-choupal, Krishi Darsan, DD Kisan, and local Hindi newspaper through E-mail for wider dissemination among farmers. It helped in reducing cost of cultivation, saving of input resources and increases in net profit.

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. The experiments conducted on payment basis from non-ICAR institutes led to the earning of ₹11,31,559/= as users fee. During this period, the NPF was visited by a number of domestic and foreign visitors.

The School of Social Sciences and Technology Transfer analyzed the progress of agriculture and rural economy and development of innovative agricultural extension models and approaches including agri-entrepreneurship, and assessment and transfer of agricultural technologies. Economic impact analysis of 'Pusa Rudhira' variety of carrot released by IARI indicated that the total returns on R&D investment was ₹1.65 crore at 2015-16 prices.

Governmental programmes such as *Rashtriya Krishi Vikas Yojana* (RKVY) have played a crucial role in narrowing rural-urban poverty by expanding its public services in rural India. Various social-economic factors majorly impacted decision of the farmer to invest in the farm business. Studies on credits to rural households revealed that the non-institutional and institutional agencies had advanced credit to 19 and 17% per cent of rural household, respectively. An analysis of crop diversification at all India level indicated a trend in diversification towards fruits and vegetables. Introduction of e-mandis has revolutionized the agricultural marketing system and prices in India. All stakeholders expressed increased transparency and reduced delay in payment in e-mandis. Andhra Pradesh, Tamil Nadu and Maharashtra were the top 3 states which had highest number of Food Processing Industries.

In order to boost agricultural business, entrepreneurship skills were inculcated to the farmers. Most of them were found to be confident of taking up value addition enterprises. A whatsapp group involving farm innovators and scientists was created to extend advisories and exchange information. Studies on the food production and consumption diversity across 28 states suggested that dietary diversity significantly increases with production diversity and per-capita income and is significantly higher in other states as compared with north-eastern states. Assessing the nutritional level (BMI) primary data studies across the states revealed that under nourishment of women comparatively more than that of men. Under agri-nutri smart village model, interventions were conducted to increase the awareness level on nutrition and to sensitize the farmers about the importance of nutritional security and gender empowerment.

Rural women and youth were trained to become entrepreneurs along with the extension initiatives like information and farm advisory services, on- farm testing, trainings, field days, exhibitions, feedback mechanism, publications of farm magazines and extension literature. Assessment of adaptability of improved varieties of wheat, paddy and vegetables of the Institute indicated that IARI varieties were given generally higher preference by the farmers over the local varieties. In most of these cases, these improved varieties resulted in a better yield.

The three day *Krishi Unnati Mela* 2017 was organised from March 15-17 at ICAR-IARI, New Delhi in collaboration with ICAR, Ministry of Agriculture & Farmers Welfare. During *mela* time, Portals developed by IARI, New Delhi and NIAIM, Mau, were launched, for an easy access to quality knowledge by the farmers. The mega event, that celebrated the great contribution of Indian farmers to agriculture, witnessed the participation of 342 public and private exhibitors. A one-day Farm Innovators Meet was organized at IARI. Two farmers' led innovations were documented and screened for scalability.

Mera Gaon Mera Gaurav, a national initiative, is implemented in 120 clusters comprising of 600 villages by 480 scientists of the Institute along with IASRI and NBPGR. The scientists regularly interact with the farmers of their allotted clusters to improve their productivity by adopting latest scientific interventions. In Agricultural Technology Information Center (ATIC), a 'single window' delivery system for the technology, services and products of the Institute,

live demonstrations of paddy, maize, *moong*, wheat, mustard, vegetables, flowers, medicinal garden, nutri-garden, fruit orchard, drip irrigation system, crop *cafeteria*, high density fruit trees and a herbal block were laid out for the benefit of the visitors and for the awareness of farmers. The Institute's *Krishi Vigyan Kendra* at Shikohpur, Gurugram, is playing a catalytic role for technological empowerment by increasing farmer's awareness and farm productivity through TOT programmes. Around 2250 agricultural extension activities were organized for the speedy dissemination of technologies. During the period, 398 demonstrations, covering an area of 166.8 /ha, on oilseeds, pulses, cereals and vegetable crops under different schemes were organized.

As rural women play significant role in agricultural development, empowering them through capacity building in farm and non-farm alternative occupations holds a key towards realizing their full potential and to achieve the intended goals of sustainable food, nutritional and livelihood security. A number of interventions were implemented to address the women empowerment and gender issues by involving them in income generating activities, seed production and developing entrepreneurial skills, etc. The KVK, Shikohpur is playing a vital role in empowering rural women by organizing various need based self-employment and income generating activities. It has organized a number of programmes and activities for rural women. The Self Help Groups (SHGs) formed two years back started their own enterprises in soy nuts, pearl-millet based products, preserved products of seasonal fruits and vegetables and have increased their income. Under Seed Village Programme, farm women were given training on various aspects of quality seed production of paddy varieties Pusa Basmati 1121 and Pusa Basmati 1509. The adoption of entrepreneurial activity by the women, on one hand helped them in gaining self-confidence through financial independence, and on the other hand it has also enhanced their recognition in the society.

The Institute ranks number one among agricultural universities, 15th among the all the universities and 23rd among all the Institutions in India in National Institutional Ranking Framework, Ministry of Human Resource Development, Government of India. The 55th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 9, 2017 with Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh as the Chief Guest. Dr. T. Mohapatra, Secretary, DARE & Director General, ICAR, former Director Generals of ICAR and former Directors and Deans of IARI graced the function. During this Convocation, 231 candidates (112 M.Sc., 8 M.Tech. and 111 Ph.D.) were awarded degrees including 13 (7 M.Sc., 1 M.Tech. and 5 Ph.D.) international students.

The Institute brought out 601 quality research publications in scientific peer reviewed research journals with international impact factor. In addition, several 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. During 2016-17, 34 innovative technologies of the IARI were transferred to 19 industry partners which earned the institute a revenue of ₹62,00,000. Three new patent applications filed with 4 renewals of existing patents has been done, along with 7 responses to First Examination Report (FER), 2 hearings, During this year 5 patents and one Trade Mark application were granted to the IARI. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions and brought laurels to the Institute.

1. CROP IMPROVEMENT

The crop improvement programme of the institute is primarily aimed at enhancing the productivity and nutritional quality of various field crops through judicious use of both conventional and modern precision breeding tools. A number of improved varieties with higher yield, superior nutritional quality and tolerance to biotic and abiotic stresses suited to different agro-ecological conditions have been developed during the reporting period. Besides, a large number of promising genotypes in several crops are under various stages of evaluation in All India Coordinated trials. The crop improvement programme was supported by quality seed production and research in other relevant areas of seed science.

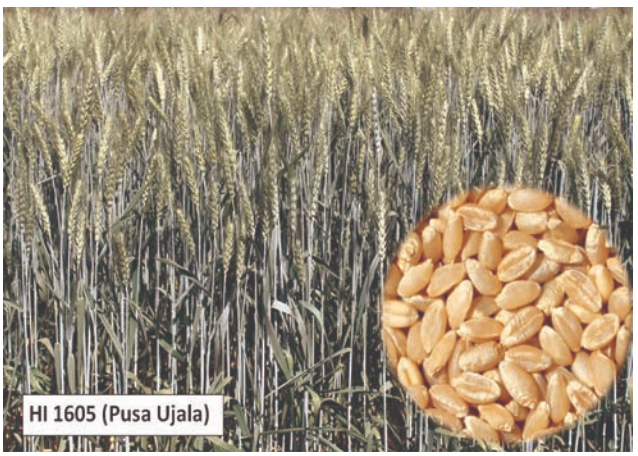
1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

HD 3171. A high yielding wheat variety with an average yield of 2.81 t/ha, was released for commercial cultivation under rainfed conditions of North Eastern Plains Zone by Central Sub-Committee on Crop Standard, Notification and Release of Varieties for Agricultural Crops. It showed resistance to yellow, brown and black rusts both under natural and artificial epiphytotic conditions during three years of testing. The resistance base in HD 3171 for yellow rust is postulated on the basis of unknown resistance gene, and for brown rust it is based on slow rusting gene, *Lr* 13 along with *Lr* 10.

HI 1605 (Pusa Ujala). A high yielding bread wheat variety, HI 1605 with an average yield of >3.0 t/ha and potential yield up of 4.4 t/ha under timely sown, restricted irrigation conditions of Peninsular Zone, was released by Central Sub-Committee



on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety is medium statured, lodging tolerant and matures in 105 to 110 days. It is resistant to black and brown rusts and also has good level of resistance to flag smut, Karnal bunt, leaf blight and foot rot diseases of wheat. It has excellent *chapatti* making quality, good sedimentation value (~55 ml), high protein (~13%) and high amount of micro-nutrients like iron (43 ppm) and zinc (35 ppm).

HI 8759 (Pusa Tejas). A high yielding *durum* wheat variety HI 8759, with an average yield of >5.7 t/ha and potential yield of 7.6 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 for Agricultural Crops. It is dual purpose variety suitable for making *chapatti*, pasta and other traditional food products along with high protein content (12%), β-carotene (5.7 ppm), less gruel solid loss, high overall acceptability (7.5) and essential micronutrients like iron (42.1 ppm) and zinc (42.8 ppm). It has a high level of rust resistance.

HS 562. A high yielding wheat variety, HS 562 with an average grain yield of 3.6 t/ha under rainfed and 5.2 t/ha under irrigated conditions of Northern Hills Zone, was released and notified by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety has good *chapatti* score (7.6) and bread making qualities. The variety possesses good amount of micronutrients like iron (38.4ppm) and zinc (34.5ppm). It has combination of rust resistance genes (*Yr* A+, *Lr*23, *Sr*8a+*Sr*8b) to combat rust pathogens.

HD 4728 (Pusa Malwi). A *durum* wheat variety, HD 4728 was released and notified for timely sown irrigated condition of Central Zone comprising Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh. The variety gave an average yield of 5.42 t/ha with maximum genetic potential of 6.8 t/ha. This is a semi dwarf variety (90 cm) having high tillering capacity, 120 days maturity duration with high degree of resistance to leaf and stem rusts. The variety possesses amber colored, lustrous bold grains (48.3g/1000 - kernels) and superior quality traits for end-use in semolina-based industries.

HW 5207 (COW3). A high yielding and disease resistant wheat variety, HW 5207 was released for Tamil Nadu state. The variety gave an average yield of 4.08 t/ha suited for short winter conditions of Tamil Nadu and carry *Lr24+Sr24, Sr2 and Yr15* gene complexes conferring high degree of resistance to leaf, stem and yellow rusts.

1.1.1.2. Elite lines under All India Coordinated Wheat Improvement Programme

A total of eighty-nine genotypes were tested in all India coordinated trials under various production conditions in all the six wheat growing zones of the country. Two genotypes viz., HI 1612 (bread wheat) and HI 8777 (*durum*) are in final stage of testing. Ten entries viz, HD 3226, HI 1617, HD 3237, HI 1619, HS 611, HI 1620 (NWPZ), HD 3219, HI1620, HS 611(NEPZ) and HI 8791(CZ) were tested in Advanced Varietal Trial(AVT) -1. In addition, there were 50 new entries in different national initial varietal trials in plains, and 27 in northern and southern hills zones.

1.1.2 Barley

1.1.2.1 Elite lines under All India Coordinated Barley Improvement Trials

One line was promoted to AVT (Dual purpose) and four lines each in Initial Varietal Trial (IVT)/AVT Grain and IVT/AVT dual purpose were nominated in Northern Hills Zone under All India Coordinated Trials during *rabi* 2016-17.

1.1.3 Rice

1.1.3.1 Variety released and notified

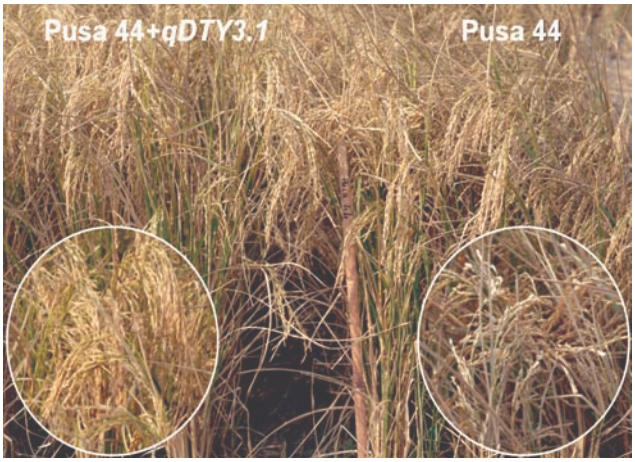
Pusa Basmati 1637. Pusa Basmati 1637 (IET 24570) is a Molecular Marker Assisted Selection (MAS) derived near isogenic line of Pusa Basmati 1 possessing *Pi9* gene for blast resistance. It has been

released for commercial cultivation in the *Basmati* growing regions of the western Uttar Pradesh, National Capital Region of Delhi, Uttarakhand, Haryana and Punjab. It produces an average yield of 4.2 t/ha in 130 days. It is semi-dwarf, non-lodging, high yielding and possesses superior grain and cooking quality traits, and most importantly it has resistance to leaf blast.

Pusa Basmati 1728. Pusa Basmati 1728 (IET 24573) is a MAS derived near isogenic line (NIL) of Pusa Basmati 6 with inbuilt resistance to bacterial blight (BB) governed by two genes for BB resistance, viz., *xa13* and *Xa21.* It has been released for the *Basmati* growing regions of India, namely, Punjab, Haryana, Delhi, Jammu & Kashmir, Uttarakhand and western Uttar Pradesh. It has a seed to seed maturity of 140 to 145 days and average yield of 4.18 t/ha. It has shown highly resistant reaction to BB disease as compared to the severe susceptibility shown by parent Pusa Basmati 6. Pusa Basmati 1728 possesses extra-long slender grains with very occasional grain chalkiness, good kernel length after cooking, and strong aroma.

1.1.3.2 Elite lines in All India Coordinated Rice Improvement Programme

A total of 23 genotypes were nominated in different stages of testing in the All India Coordinated Rice Improvement Programme (AICRIP) trials during *kharif*-2016. It includes one near NIL, Pusa 1850-27 (IET25480) with three genes for blast resistance, namely, *Pi54*, *Pi1* and *Pita* in the genetic background of BPT5204 which were tested in AVT2-NILs (Blast) and one entry in AVT1-E TP (IET 25574). Besides these, there were 21 new entries nominated in Initial varietal trials of AICRP including 5 entries (Pusa 1551-05-2-8-129-125, Pusa 1557-06-8-176-162-56, Pusa 1682-10-17-1-5-1, Pusa1692-10-20-1-1-2 and one Basmati hybrid, Pusa RH49) in IVT-BT, 3 entries (Pusa 2019-15-10, Pusa 2014-252-57 and Pusa 2014-252-77) in IVT-IME, 4 entries (Pusa 2035-15-19, Pusa 2005-14-13, Pusa 5159-13-1-4-2-2-6 and Pusa 5159-13-1-4-2-2-24) in IVT-IM, 2 entries (Pusa 1638-07-130-2-67-1-1 and Pusa 1638-07-171-1-81-1-2) in IVT-ASG, 1 entry (Pusa 2048-15-3) in IVT-L and six hybrids including 2 entries (Pusa RH 48 and Pusa RH 50) in IHRT-E, 2 entries (Pusa RH 44 and Pusa RH 46) in IHRT-IM and 2 entries (Pusa RH 43 and Pusa RH 45) in IHRT-IME were tested in the AICRIP trials during *kharif*-2016.



1.1.3.3 Incorporation of drought tolerance quantitative trait loci (QTLs) in *Basmati* and non-*Basmati* rice varieties

Marker assisted backcross breeding was adopted to incorporate the QTLs governing drought tolerance such as *qDTY1.1* from N 22 and *qDTY3.1* from IR81896-B-B-142 into genetic background of Pusa Basmati 1 and Pusa 44, respectively. A set of 108 single plant selections with *qDTY3.1* in the genetic background of Pusa 44, developed through marker assisted backcross breeding were evaluated under drought stress as well as irrigated conditions during *kharif*-2016 to identify desirable progenies for further evaluation in multi-locational trials. In Pusa Basmati 1 background, 3 desirable progenies were identified by marker assisted foreground selection using linked marker to the QTL governing drought tolerance, *qDTY1.1*. A total of 50 single plants from these families were selected for further generation advancement in the off season 2016-17.

1.1.3.4 Development of multiple biotic stress resistance in rice varieties

Advance generation backcross derived lines homozygous for two genes for BB resistance, namely, *xa13* and *Xa21* as well as three genes for blast resistance, *Pi54*, *Pi1* and *Pita* in the background of BPT5204 have been developed and multi-location evaluation was conducted. In another introgression programme, advance generation backcross derived lines homozygous for three genes for BB resistance, namely, *xa13*, *Xa21* and *Xa38* as well as two genes for blast resistance, *Pi54* and *Pi2* in the background of PB 1121 have also been generated.

1.1.4 Maize

1.1.4.1 Maize hybrids in All India Coordinated Maize Improvement Programme

AQH 4, AQH 8 and AQH 9, MAS-derived quality protein maize (QPM)version of HM 4, HM 8 and HM 9, respectively, were tested under the AICRP-quality trials during *kharif*-2016. APQH 9, MAS-derived pro-vitamin-A rich version of Vivek QPM 9 was also evaluated under the AICRP-quality trial. Grains of these entries evaluated at IARI-New Delhi, IIMR-Ludhiana and VPKAS-Almora, were tested for lysine, tryptophan and pro-vitamin-A at the maize quality lab of Division of Genetics, IARI. Based on the data, identification proposal of these four essentially derived varieties (EDVs) were submitted to variety identification committee. Two sweet corn entries viz., ASKH 1 and ASKH 2 have been promoted to AVT-II. Further, baby corn hybrids, AH 5021 and AH 7043 have been promoted to AVI-II and AVT-I, respectively.

1.1.4.2 Characterization of provitamin-A enriched elite QPM inbreds

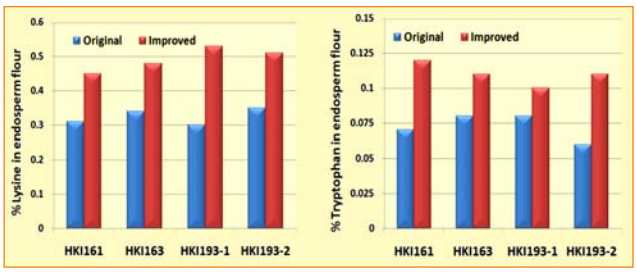
Elite QPM inbreds, HKI 161, HKI 163, HKI 193-1 and HKI 193-2 that are the parents of QPM hybrids: HQPM 1, HQPM 4, HQPM 5 and HQPM 7, have been

Phenotypic similarity of improved progenies with original parental inbreds

improved using marker-assisted stacking of *opaque2*, *lcyE* and *crtRB1* genes. The newly derived introgressed progenies possess high mean pro-vitamin-A (~13-21 µg/g) compared to original inbreds (~2.5 µg/g). These improved inbreds were characterized for various plant-, ear- and grain- characteristics, including the flowering time. Improved progenies resembled with their respective original inbreds for majority of the agronomic characters, yield, and contributing traits.

1.1.4.3 Pyramiding of *opaque2* and *opaque16* for enhancement of lysine and tryptophan

Parental inbreds of HQPM 1, HQPM 4, HQPM 5 and HQPM 7 possessing *opaque2* allele were targeted for introgression of *opaque16* allele from Chinese source germplasm using marker-assisted selection. BC_2F_2-derived progenies of parental inbreds viz., HKI 161, HKI 163, HKI 193-1 and HKI 193-2, possessing *o2o2/o16o16* had higher lysine and tryptophan in endosperm flour than *o2o2* alone. Across selected progenies, increase of lysine was in the tune of 41-77%, while it was 25-83% for tryptophan.



Lysine and tryptophan in original inbreds and their improved progenies

1.1.4.4 Introgression of *VTE4* for enhancement of vitamin E in QPM hybrids

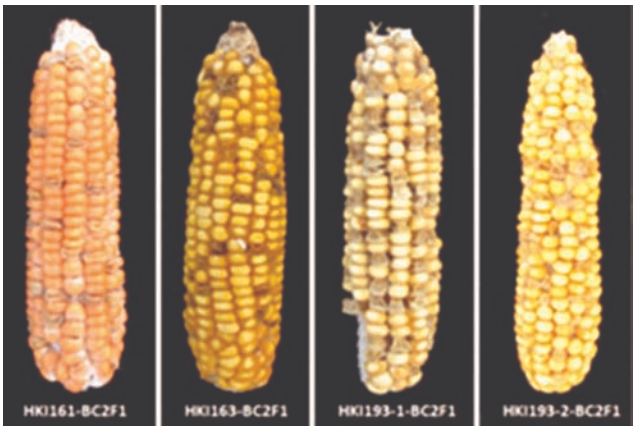
Traditional maize contains low α-tocopherol, which possesses high vitamin E activity as compared to γ-tocopherol that comprises major fraction of the total tocopherol. Screening of diverse inbreds led to the identification of genotypes having favourable allele of *VTE4* gene, capable of enhancing α-tocopherol from 7-10 µg/g to 22-32 µg/g in maize kernel. Provitamin-A rich version of QPM inbreds that are parents of four popular hybrids (HQPM 1, HQPM 4, HQPM 5 and HQPM 7) were targeted for introgression of *VTE4* favourable allele. In BC_2F_1 populations, plants homozygous for *crtRB1, lcyE* and *opaque2*, and heterozygous for *VTE4* gene were selected, and used for generating BC_2F_2 populations. In BC_2F_2, segregants homozygous for *crtRB1, lcyE, opaque2* and *VTE4* have been selected in each of the four genetic backgrounds.

1.1.4.5 Introgression of *lpa1* and *lpa2* mutant into elite inbreds

Bioavailability of Fe in humans is 5%, while it is 25% for Zn. The low bioavailability is mainly attributed to presence of higher concentration of phytic acid (in maize kernel), which chelates positively charged ions like Fe and Zn, and make them unavailable in human gut. Low phytic acid lines increase the bioavailability of Fe and Zn in humans. Elite inbreds such as HKI 161, HKI 163, HKI 193-1, HKI 193-2, HKI 323, HKI 1105 and HKI 1128, were targeted for introgression of *lpa1-1* and *lpa2-1* using marker-assisted selection. Low phytic acid mutants were procured from USA. Phytic acids in elite inbreds were 85-95% of the total phosphorus, while in donor it was 50-60% of the total phosphorus. BC_1F_1 populations were genotyped using associated markers of *lpa1-1* and *lpa2-1*. Foreground positive segregants with high genome recovery were backcrossed to recurrent parents to develop BC_2F_1 populations.

1.1.4.6 Enrichment of sweet corn hybrids with lysine, tryptophan, provitamin-A and vitamin E

Provitamin-A rich parental inbreds (HKI 161, HKI 163, HKI 193-1 and HKI 193-2) of popular QPM hybrids (HQPM 1, HQPM 4, HQPM 5 and HQPM 7) were targeted for introgression of *shrunken2* (*sh2*) allele. In BC_2F_1 populations, plants desirable for *crtRB1, opaque2* and *sh2* were selected for generating BC_2F_2 populations. The BC_2F_2 seeds segregated (on BC_2F_1 ear) for normal and shrunken type, indicating the true introgression of *sh2* allele from sweet corn inbreds. Further, parental inbreds of ASKH 1 and ASKH 2, two promising *sh2sh2*-based sweet corn hybrids were further targeted for enrichment of (i) provitamin-A



Segregation for normal and shrunken seeds on BC_2F_1 cobs

and vitamin E, and (ii) provitamin-A, lysine and tryptophan through introgression of (i) *crtRB1* and *VTE4* and (ii) *crtRB1* and *opaque2* alleles, respectively under two backcross breeding programme. Backcross populations of inbreds viz., SWT 16, SWT 17 and SWT 18 were genotyped, and segregants with favourable combinations of alleles of (i) *sh2*, *crtRB1, VTE4,* and (ii) *sh2*, *crtRB1, o2* were selected. The MAS-derived inbreds will be used for developing nutritionally rich sweet corn hybrids.

1.1.4.7 Development of high amylopectin maize genotypes

A set of 77 high amylopectin-based maize inbreds possessing *waxy1* (*wx1*) allele, were developed from exotic source population and through introgression breeding at IARI. These inbreds included both yellow and white endosperm types. Waxy genotypes possess 95-100% amylopectin as compared to 70-75% in traditional maize. Based on the endosperm colour and flowering synchrony, 77 waxy hybrids developed from the inbreds were evaluated during *kharif*-2016. Two highly promising waxy hybrids viz., Pusa Waxy 1 and Pusa Waxy 2 were identified.

White- and yellow-endosperm based waxy inbreds and their comparison with wild-type white and yellow inbreds

1.1.4.8 Utilization of cytoplasmic male sterility system for baby corn purpose

Manual detasseling in baby corn cultivation is a laborious and time consuming process, which increases the cost of the cultivation. Also, delay in detasseling would promote pollination, and deteriorate the quality of baby corn ears. Cytoplasmic male sterility (CMS) system that promotes male sterility holds significance in baby corn. A set of elite lines viz., HKI 323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1, HKI 193-2, V335-PV, V345-PV, CM150-Q, CM151-Q, SWT 16, SWT 17, SWT 20 and SWT 21 were crossed as male with source germplasm having CMS cytoplasm. Majority of F_1s were completely sterile, and did not produce any pollen. Backcrossing of F_1s has been carried out to convert the elite inbreds into male sterile version.

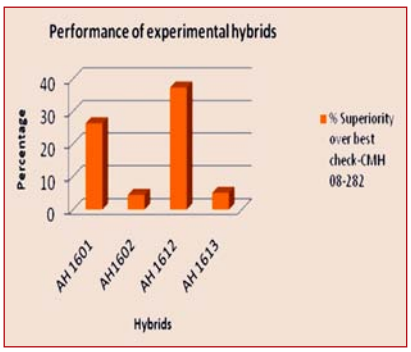
A. Male sterile florets, B. male fertile florets, C. male sterile F_1s

1.1.4.9 Development of pop corn hybrids

Popcorn has emerged as one of the most popular snacks worldwide, demand of which has been steadily increasing for decades. A set of 29 diverse pop corn inbreds has been developed from exotic- and indigenous- sources. Using these diverse inbreds, a set of 140 hybrids have been generated and evaluated with suitable checks. Based on multi-location testing two hybrids viz., Pusa Pop 1 and Pusa Pop 2 were found to be promising. Large scale seed production of these hybrids has been carried out for nomination for testing under AICRP-Maize.

1.1.4.10 Identification of potential maize genotype for grain yield

Development of medium to late maturing hybrid is of prime importance in enhancing maize productivity. A total of 101 PML lines were evaluated in *rabi* season to explore medium to late maturing inbred lines with high *per se* performance for yield, and identified 18 inbreds with *per se* yield more than 3 t/ha. Further, a total of 55 new single cross hybrids were developed and evaluated over multi-locations, covering different maize growing zones of India. Among them 4 hybrids, viz., AH 1601 (UMI 1210 x PML 93), AH 1602 (UMI 1200 x PML 42), AH 1612 (PML 54 x PML 93) and AH 1613 (PML 54 x V 385) have been found superior to best check CMH 08-282.



Grain yield superiority of promising hybrids over check

1.1.4.11 Breeding for biotic stress resistance

Of the 400 single cross hybrids developed and evaluated for yield superiority and biotic stress resistance, AH 8181, AH 8183, AH 8087 in late, AH 8071R, AH 7080, AH 8141R, AH 7242 in medium and AH 8917, AH 8971, AH 8945, AH 8957 in early maturity category were promising with more than 20% heterosis over best check. These hybrids were also highly to moderately resistant against Turcicum Leaf Blight (TLB). Another set of 50 hybrids were also screened against TLB, and 10 hybrids were resistant with AH 1261, AH 7078, AH 8181, AH 8183 and AH 8315 having disease score of <2.

1.1.4.12 Breeding for abiotic stress tolerance

A set of 22 hybrids along with 3 checks were evaluated under drought stress during *rabi* 2015-16. The performance of two experimental hybrids (Hybrid 5 and Hybrid 16) was found superior (11.53% to 21.04%) under drought stress as compared to check hybrids viz., PMH 1, PMH 3 and PMH 5. An experiment with 26 newly developed hybrids along with 4 checks was also conducted under water-logging condition during *kharif*-2016. The superiority of experimental hybrids (AH 1614, AH 1619, and AH 1628) over checks was found to be 13 to 25%.

1.2 PEARL MILLET

1.2.1 Variety Released and Notified

Pusa composite 701. A high yielding dual purpose pearl millet variety, Pusa composite 701 was released and notified (S.O. 2238 E 29.6.16) for Zone A having regions of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Delhi. It is having average grain yield of 2.31 t/ha which was 6.01 to 25.5 % higher than those of four checks, Raj 171 (2.15 t/ha) by 7.49 %,

Pusa composite 383 (2.19 t/ha) by 6.01 %, JBV 2 (2.04 t/ha) by 13.87 % and ICMV 221 (1.84 t/ha) by 25.55 %. It is highly resistant to downy mildew and blast.

1.2.2 Advanced Hybrid and Population Entries of Pearl Millet in Pipe Line

One hybrid, Pusa 1504 and two populations, Pusa Composite 709 and Pusa Composite 710 were tested in advance trial (2nd year) during *kharif*-2016. Three hybrids Pusa 1601, Pusa 1602 and Pusa 1603 in IHT-M, and another three hybrids, Pusa 1604, Pusa 1605 and Pusa 1606 were tested in IHT-E. Three new populations, Pusa Composite 712, Pusa Composite 713 and Pusa Composite 714 were also tested in PT-A/B.

1.2.3 Hybrid Development and Evaluation

A total of 490 hybrid combinations (Sixty hybrids based on A_4 cytoplasm) were developed and 56 hybrids evaluated in different station trials during *kharif*-2016. Four hybrids viz., Pusa 1701 (ICMA 04999 x TPR 8), Pusa 1703 (ICMA 843-22 x IPC 1518), ICMA 99111 x DPR 7 and ICMA 843-22 x 15458 will be nominated for testing in coordinated trial (Initial Hybrid Trial-Medium) to be conducted during *kharif*-2017.

1.2.4 Population Development and Evaluation

Two populations, namely, Pusa Composite 709 and Pusa Composite 710 were tested in advance population trial (2nd year) of All India Coordinated Research Project on Pearl Millet conducted during *kharif*-2016. In addition, four new population viz., Pusa Composite 712, Pusa Composite 713, Pusa Composite 714 and Pusa Composite 715 were also tested in population trials for Zone A and B.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Variety identified

BG 3043. The *desi* chickpea variety, BG 3043 (DG 5016 x FLIP 94-509C) was identified for release under timely sown conditions of NEPZ (comprising of eastern Uttar Pradesh, Bihar, West Bengal, Jharkhand, and Assam). It is an early maturing (130 days) variety and ideal for sustainability of the rice-based cropping systems of eastern Indian states. It has an average yield of 1.6 t/ha and a potential yield of 2.5 t/ha. Its 100-seeds weight is 21-22 g.

Plant and grain type of BG 3043

1.3.1.2 Farmers' field trial of promising chickpea entry

A high yielding chickpea genotype, BGD 111-1 was tested in farmers' field along with the check, JG 11. The entry has already been tested in multi-location trials in Karnataka and will be proposed for identification by SVRC. The entry BGD 111-1 recorded higher grain yield than the check JG 11.

1.3.1.3 Promising chickpea entries in All India Coordinated Programme

Fourteen promising entries (including 2 entries from Dharwad centre) were entered into IVT 2016-17. One *Kabuli* entry BG 3057 was promoted to AVT- 2 (in NWPZ) and four entries, BG 3068, BG 3071, BG 3072 and BG 3073 were promoted to AVT-1 in different zones.

1.3.1.4 Validation of chickpea genotypes for dry root rot resistance

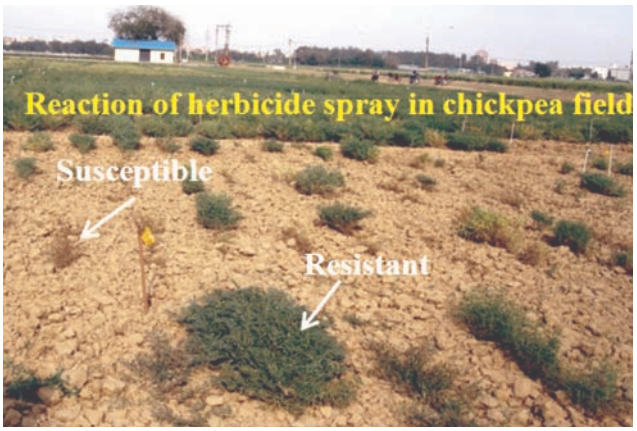
The genotypes identified as tolerant to dry root rot (DRR) during *rabi* 2015-16, were subjected for validation in sick pots. The genotypes, BG 14-14, BG 12-119, H 208 and ICC 14395 were tolerant to DRR (<15% disease incidence).

1.3.1.5 Screening of segregating generations for biotic and abiotic stresses

F_5 (from 116 crosses) and F_6 (from 112 crosses) populations were screened in wilt sick plot. Wilt resistant single plants (>2500) were selected. $F_{3:4}$ lines were screened under salt affected soils at Ugar Khurd (near Dharwad) and ICAR-CSSRI, Karnal. High yielding lines were identified for yield testing. A panel of 232 (DCP 92-3 x ICCV 10) $F_{7:8}$ population was also phenotyped at Ugar Khurd and CSSRI, Karnal (EC 6 dS/m, pH 7.0).

1.3.1.6 Post-emergence herbicide tolerance in chickpea

Nine tolerant to moderately tolerant and three susceptible genotypes were evaluated under control- and sprayed- condition during *rabi* 2015-16. Genotype x environment interactions were observed for days to 50% flowering, NDVI, days to maturity, yield, biomass, harvest index, 100-seed weight and branched chain amino acids (BCAA) (valine, leucine and isoleucine) content. The spraying of herbicide reduced the total biomass production. Analysis of BCAA content in sample revealed non-significant differences for percent valine content in ICCIL 04001, ICCV 00305, ICCV 96003 and ICCL 82104, for isoleucine content in all the genotypes except ICCV 3 and ICCV 96003,



and for leucine content in case of ICCV 03407, ICCIL 04001, ICCV 10, ICCV 96003, ICC 1710, ICCV 00108 and ICCL 82104. The genotypes tolerant to post-emergence herbicide, Imazethapyr identified based on non-significant reduction in the yield attributes and BCAA content in the sample, were ICC 82104, ICCV 10, ICCV 96003, ICCV 00305 and ICC 1710. These genotypes can be used to study the genetics and mapping of gene(s) for herbicide tolerance in chickpea and in breeding programmes for developing lines with tolerance to post-emergence herbicide Imazethapyr.

1.3.2 Pigeon pea

1.3.2.1 Development of compact and erect- plant type lines of short duration

Two early maturing lines (PAE 34-1 and PAE 34-2) with compact and erect plant type, bold seed size (9.5 to 10 g/100 seeds) and 4-5 seeds/pod have been developed from the cross H2001-4 x ICP 7035. These lines are suitable for close planting with row to row spacing of 30 cm, and can be grown in high density planting.

Phenotypic performance of compact and erect plan type of pigeon pea under different row spacing

1.3.3 Lentil

1.3.3.1 Variety released

L 4717. An early maturing lentil variety, L 4717 for Central Zone was released and notified by CVRC for states of Madhya Pradesh, parts of Uttar Pradesh and Rajasthan, and Chhattisgarh. Average yield of this variety is 1.2-1.3 t/ ha. L 4717 is resistant to powdery mildew disease and moderately resistant to *Ascochyta* blight and *Fusarium* wilt. It exhibited earliness, with mean maturity 100 days (over years and locations). Earliness helps in escaping terminal moisture and heat stress in Central Zone.

Plant-and grain characteristics of L 4717

1.3.4 Mungbean

1.3.4.1 Variety released

Pusa 1371. This mungbean variety for Northern Hills Zone was released and notified by CVRC for the states of Tripura, Manipur, Jammu & Kashmir and Himachal Pradesh. Average yield of this variety is 0.90 t to 0.95t/ha (*kharif* season). Pusa 1371 showed multiple resistances to MYMV, root rot, web blight and anthracnose. Seed size is medium bold (100 - seed weight 3.26g).

Plant and grain characteristics of Pusa 1371

1.4 OILSEED CROPS

1.4.1 *Brassica*

1.4.1.1 Elite entries in coordinated trials

Seventeen genotypes were contributed to various AICRP Rapeseed Mustard trials at national level *viz.*, IVT-Early (NPJ 201, NPJ 202); IVT - Timely (NPJ 203, NPJ 204); IVT-Rainfed (NPJ 205, NPJ 206); IVT-Late (NPJ 207, NPJ 208); IVT-Quality [PDZ 7 (00), PDZ 8 (00), LES 54 (0), LES 55 (0)]; AVT-I Quality [PDZ 5 (00), PDZ 6 (0)] and AVT-II Quality [PDZ 1 (00)].

1.4.1.2 MAS for white rust resistance and quality traits

Molecular markers linked to white rust resistance and oil quality traits were screened in thirty backcross populations generated for introgression of white rust resistance, and low erucic acid and glucosinolate traits in different promising Indian mustard varieties/ genotypes viz., Pusa Mustard 22, Pusa Mustard 24, Pusa Mustard 30, Pusa Jagannath, PDZ-4, LES-52 and LES-53. Based on genotyped data for the three traits viz., white rust resistance, erucic acid and glucosinolates, 31 backcrosses were attempted with the respective recipient parents.

1.4.1.3 Hybridization and pre-breeding

A total of 214 trait based crosses were attempted which include white rust resistance in 0/00 genotypes (11 F_1 and 93 backcrosses), creation of genetic diversity and improving agronomic traits using introgressed lines derived from *B. juncea* x *B. carinata* crosses and *Diplotaxis erucoides* (55 crosses), yield improvement of the short duration cultivars (50 crosses) and improvement of high temperature tolerance (15 crosses).

1.4.1.4 CMS lines evaluation and maintenance

Three alloplasmic isonuclear CMS lines, having cytoplasm from *Moricandia arvensis (mori), Diplotaxis erucoides (eru)* and *Diplotaxis berthautii (ber)* were evaluated and maintained by full-sib crossing between pollen tested A-line and respective true to type B- line

plants. Twenty paired crosses were attempted for maintenance of each of these set of lines (A & B lines). Open pollinated seeds of these A and B lines will be used for hybrid seed production.

1.4.1.5 Cytoplasm diversification and CMS line development

To transfer nuclear genome from 24 genetic backgrounds to different sterility inducing cytoplasms *viz.*, *mori*, *eru* and *ber*; 73 backcrosses (BC_3-BC_{10}) were attempted in three pairs each.

1.4.1.6 Restorer development

Backcrosses (BC_2-BC_4) were attempted to transfer the *Rf* gene, which restores fertility in *mori*, *eru* and *ber* sterile cytoplasms, to 45 nuclear backgrounds. Homozygous dominant plants of restorers (in BC_4F_4 and BC_5F_3 generations) developed through MABB for transferring *Rf* gene to five genetic backgrounds, were selfed for their further utilization. Raised 115 progenies developed through limited back crossing followed by pedigree selection. Also, 105 progenies of different restorers were maintained, evaluated and utilized in crossing programme. Thirty one restorers of the hybrids were evaluated and maintained as well.

1.4.1.7 Hybrid evaluation and seed multiplication

A total of 31 hybrids were evaluated in different hybrid station trials viz., early sown (9), timely sown (5), multilocation trials under CRP Hybrid Technology (12) and observational yield trials under early (8) and timely (6) sown situations. In addition to 44 hybrids contributed by collaborators under CRP Hybrid Technology evaluated in the alpha lattice design, 206 hybrids were evaluated in the single row plot. Hand pollinated seed of 19 hybrids was generated and open pollinated seed of eight hybrids multiplied in isolation through (A x R) crosses.

1.4.1.8 Breeding material evaluated and advanced

Total 3454 single plant selections and 74 bulks have been made from early sown (253 single plants and seven bulks), timely sown (329 single plants and 22 bulks), late sown (126 single plants and 17 bulks), low erucic acid (1164 single plants and 22 bulks) and double low (1582 single plants and 6 bulks) breeding material from $F_2 - F_7$ populations/progenies for further evaluation and advancement. Sixty one F_{1s} raised for identification of good combiners have also been evaluated for 11 morphological traits. In addition, 123 single plant selections from 142 multiple crosses were also made.

1.4.1.9 Evaluation of elite purelines

Total 128 entries, bulked during 2015-16 were evaluated in eight replicated station trials under early, timely, rainfed and late sown conditions. These entries also include 22 low erucic acid and double low genotypes of which twelve genotypes were developed through marker assisted backcross breeding in the background of Pusa Mustard 21 and Pusa Karishma. Out of the twenty two genotypes evaluated under early sown condition (September 6, 2016) along with four checks, the genotypes MSTE 16-8, MSTE 16-9, MSTE 16-13, MSTE 16-15 and MSTE 16-19 were found early (110 days or less) maturing and promising.

1.4.2 Soybean

1.4.2.1 Elite entries in coordinated trials

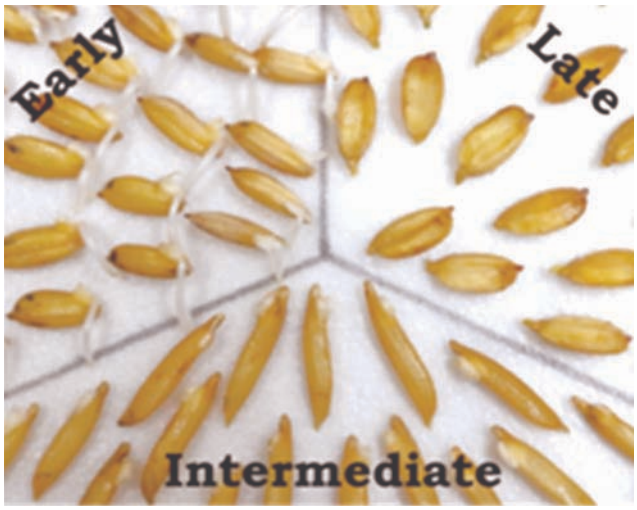
Two lines viz., DS 3105 and DS 3106 were tested in IVT of the AICRP. DS 3105 was advanced to AVT I in NEZ, while DS 3106 advanced to AVT I in NPZ.

1.5. SEED SCIENCE AND TECHNOLOGY

1.5.1 Studies on Seed Quality Traits

1.5.1.1 Seed development and vigour in rice

Sixty-eight genotypes including hybrids and their parental lines belonging to different maturity groups i.e., early, medium and late, were evaluated for induction of germination or dormancy, dry mass accumulation (DM) and moisture loss (MC) during different developmental stages. In general, seed moisture loss and dry mass accumulation were associated inversely, however, their rates varied viz., dry mass accumulation was higher and rapid



Phenotype of contrasting rice genotypes for speed of germination

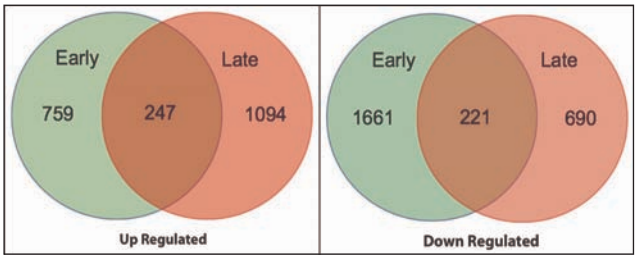
in PRR 78R, Pusa Sugandh 3, Vandana and CRD 305 while gradual in Samba Mahsuri, CRD 143-2-2 and CRD 204. Induction of germination also varied as fresh seed germination at stage I ranged from 0.0 to 10% while desiccated seeds after 15 days of harvest showed germination from 0.0 to 100%, indicating that non-dormant seeds require desiccation before exhibiting full germination. At stage I, fresh seeds in most of the non-dormant genotypes showed low germination but increased gradually at successive stages. Varieties belonging to early maturity group showed no seed dormancy during post harvest storage, while seeds of medium maturity group exhibited some degree of dormancy for a period of about one month. Most of early maturity varieties germinated even at dough stage viz., Rasi and Vandana (>30%) and JD 6, VLDhan 221, Heera and Makom (>20%). A high speed of germination (SOG) was recorded in early maturity group as the radical emergence is quite fast and it ranged from 0 to 24.49 among all the genotypes. In late maturity group (Mangla and Basmati 370) higher degree of seed dormancy was recorded even after one month of storage. Thus, crop duration had a positive trade off in increasing degree of dormancy. In non-dormant genotypes seed germination and vigour enhanced even after three months of storage indicating that it requires some post-harvest maturity period to exhibit full germination potential.

1.5.1.2 Management of paddy bunt (PB) through Mechanical Processing

Post harvest management of bunt in paddy through mechanical processing was undertaken to recover high quality healthy seed. Seeds were processed in Nippon Sharyo (Japan) make processing plant of one tonne per hour capacity. Top and bottom screen of air screen machines was 3.2 mm (round) and 2.1 mm (oblong), respectively. The inclination of deck, feeding and output were adjusted for better separations of low density and diseased seeds from the lot. Seeds of two lots of Pusa 44 variety produced during *kharif* 2014 and one lot produced during *kharif* 2015 were processed. Pre-cleaner and screen grader removed 44.7, 34.8 and 42.2% of total bunt infected seed present in the three seed lots and reduced bunt infection from 1.32 to 0.73, 1.58 to 1.03 and 3.05 to 1.76%, respectively. Eighteen combination treatments comprising of three deck slopes (S_1- 2.5^0, S_2- 2.0^0, S_3- 1.5^0), three feedings (F_1- 9kg, F_2- 12kg, F_3- 15kg per minute) and two output settings (O_1- 30cm deck width, O_2- 40cm deck width) of specific gravity separator were studied with an objective of getting maximum bunt free seed per unit of time. Maximum seed recovery (13.27 and 13.31 and 13.60kg/minute) and bunt infection in final product (0.44, 0.41 and 0.46%) with 89.1, 89.7 and 92.3% recovery effi ciency has been obtained by the treatment $S_3F_3O_2$ (slope of deck 1.5^0, feeding 15 kg/minute, output deck width 40cm) in the three seed lots. Thus, mechanical processing reduced bunt infection by more than 65 per cent, depending on the intensity of infection, as well as increased seed quality i.e., seed germination improved by 7.0% and physical purity by 4.64%.

1.5.1.3 Transcriptome analysis for speed of germination in rice

To understand whether speed of germination in rice relies on specific subsets of long lived mRNA, the transcriptome of long lived mRNA of dry seeds of the contrasting rice genotypes comprising of early germinating (24±2 hours for radicle emergence), intermediate (36±2 hours for radicle emergence) and late germinating (48±3 hours for radicle emergence)



Venn diagram of differentially expressed transcripts in early and late genotypes

genotypes were studied. Micro Array plots representing the distribution of expression ratios of all transcripts showed that major variations were included between $\log_2$ ratio values of -1.5 and +1.5 at $p<0.01$. A Venn diagram shows that 759 transcripts were more abundant in early germinating genotype and that 1094 transcripts were more abundant in seeds of late compared with seeds of intermediate genotype. Similarly, 1661 and 690 transcripts were found to be less abundant in early and late genotypes, respectively. Among these differentially expressed transcripts, machinery-favoring higher ABA/GA ratio in matured seeds (OsNCED1, OsNCED3, OsNCED4, OsNCED5 and OsGA2OX5) were up regulated in late germinating genotype than in early genotype. On the contrary, machinery favoring higher of GA/ABA ratio (OsGA20Ox2, OsCPS2, OsKOL5, OsKSL4, OsKSL7 and OsCYP707A7) were up regulated in early germinating genotype than in late genotype. Besides, GA repressor transcripts (RGL3 and SLR1) were down regulated and GA receptor (OsGID1L2) was up regulated in early phenotype. Thus, in early germinating genotype, germination promoting hormone (GA) related metabolic and signaling pathway machineries were well equipped, which manifests in early germination compared to late germinating genotype.

1.5.1.4 Physiological changes induced in seeds of yellow seeded Indian mustard quality genotypes during ageing

Yellow seeded Indian quality mustard genotypes have low germination potential and vigour compared to conventional varieties. Physiological differences of the yellow seeded conventional and quality genotypes after controlled deterioration were studied for seed longevity. Yellow seeded quality genotypes showed significant deterioration and lower germination (%), vigour indices and higher electrical conductivity as compared to conventional genotypes. The effect was however, more pronounced after controlled deterioration. The conductivity test effectively detected seed deterioration in these genotypes, and membrane permeability correlated with both germination and vigour loss. The activities of various antioxidant enzymes and other biochemical constituents suggest that yellow seed quality genotypes lack some abilities to protect the embryo against adverse environmental conditions and lead to the poor storability.

1.5.1.5. Effect of storage on Ascorbate-Glutathione cycle in parents and various RILs of soybean

Effect of ageing on antioxidant system was studied in three years old ambient-stored seeds of cultivated soybean (*Glycine max* L. Merr.) variety DS 9712, wild type (*G. soja* Sieb. & Zucc.) genotype DC 2008-1 and three RILs developed from inter-crossing of DS 9712 and DC 2008-1. Germination in the seeds of DS 9712 was 13% as against 85% and above in the seeds of DC 2008-1 and RILs. Concentration of the membrane damaging enzymes TBRAS and conjugated diene (CD) in the seeds of DS 9712, DC 2008-1 and the RILs were high, low and intermediate, respectively, which corresponded inversely with their level of germination. Among the RILs, RIL-2 had the least concentration of TBRAS and CDs and the highest level of germination. TBRAS equivalent was found to be negatively correlated with the germination per cent (r= -0.9966). The antioxidant enzymes involved in Ascorbate-Glutathione cycle viz., APX, DHAR, MDHAR, and GR were significantly low in DS 9712, while their concentration was medium to high among the RILs and DC 2008-1. The AsA-GSH system possessed weaker reduced oxidized forms in DS 9712 as compared to DC 2008-1 and the RILs. Efficient Ascorbate-Glutathione cycle in the seeds of DC 2008-1 and the three RILs might have prevented accumulation of ROS saving the membrane from damage leading to increased germination.

1.5.1.6 Improvement of field stand in pigeonpea under stress conditions

Genotypic differences for imbibition pattern were observed in four pigeonpea varieties viz., Pusa 992, Pusa 991, Pusa 2001 and Pusa 2002. It took 30h for pigeonpea seeds to start the radicle protuberance. Imbibition of pigeonpea seeds for 10h at 25^{0}C resulted in significant improvement of seed germination (87.8%), vigour index I (2870.0) and vigour index II (20.1) over untreated control seeds. The germination of variety Pusa 992 was found to be relatively sensitive to higher temperatures than other three varieties viz., Pusa 991, Pusa 2001 and Pusa 2002. On exposure of seeds to 30^{0}C from 1h to 30h, no significant improvement over control in the seed vigour parameters was observed. However, significantly higher germination (96.0), vigour index I (3248.6) and vigour index II (18.7) over control (82.2, 2388.9 and 17.4, respectively) were observed when exposed at 40^{0}C for 6h, however highest value for vigour index–I (3498.2) was observed after 24h exposure at 40^{0}C which was at par with 6h exposure. Therefore, it is recommended that hydropriming of seed for 10h at 25^{0}C could be beneficial under moisture stress and hardening for 6h at 40^{0}C might help in better stand establishment in pigeonpea under high temperature stress conditions.

1.5.1.7 Seed quality evaluation in specialty maize

Seed composition is reported to affect the seed vigour and longevity in maize. QPM, sweet corn, high lysine, high sugar and oil maize genotypes have lower vigour than normal maize genotypes and exhibit poor field emergence, low and uneven plant stand under sub-optimum conditions. An investigation was undertaken to study the kernel composition in different specialty maize genotypes in relation to the seed vigour, physiological and biochemical activities and storage behaviour. The results showed that specialty maize varieties and genetic stocks showed variation in chemical composition with respect to kernel carbohydrates, starch, sugar, protein and oil content. Seed germination and vigour, toughness, membrane integrity and enzymatic activities (hydrolytic, respiratory, anti-oxidant) showed variation in different compositional groups. Sweet corn and QPM types had lowest (45-57%) and waxy and popcorn genotypes had highest (74-82%) field emergence under sub - optimum temperatures. Sweet corn, dent corn and QPM genotypes imbibed more water and waxy corn and pop corn the least during imbibitional studies which influenced their storage behavior due to differences in kinetics of free water in seed. Popcorn genotypes had high germination, vigour, better membrane integrity and toughness among genotypes studied. The grain compactness studies revealed that sweet corns (shrivelled texture and sugary nature) and popcorn (tough endosperm) had the lowest and highest grain toughness, respectively, which had influence on their susceptibility to stored grain pest (*Sitophilus oryzae*). Among maize compositional groups, popcorns stored longest followed by dent and flint corns. Sweet corns and QPM types had poor storability among the specialty corns. The study concluded that seed composition had influence on field emergence under sub optimum conditions, seed physiological and biochemical activities and storage behaviour of specialty maize.

1.5.2 Hybrid Seed Production

1.5.2.1 Synchronization studies in parental lines of rice hybrids

The A and B lines of rice hybrids were studied for their synchronization behavior and maintenance. Some of the A and their corresponding B lines showed variation of three to six days in panicle emergence during two consecutive years possibly due to their sensitivity to climatic conditions. These lines are: COMS 15A, RTN13A, IR 64608A and Pusa 6A. The study indicated that appropriate corrective measures need to be taken for achieving synchronization of flowering between the parental lines for foundation seed production.

1.5.2.2 Hybrid seed purity assessment in rice

The commercial success of hybrid technology depends onto a large extent on the supply of genetically pure hybrid seeds to the farmers at an affordable

price. Hence, testing the genetic purity of hybrid seeds prior to commercial cultivation is necessary. In order to replace GOT with a rapid, unbiased, cost-effective and easy to perform DNA-based assay for hybrid seed purity testing single fertility restorer (Rf) gene linked co-dominant STMS marker RM6100 was used for genetic purity assessment of eight popular rice hybrids commercially grown in India. The genetic purity of hybrid seed lots ranged from 96.00% to 100.00%. Similarly, the purity status of hybrid seed lots assessed by conventional Grow-Out- Test (GOT) in the field on 400 plants revealed that genetic purity varied from 97.00% to 99.50%. The comparative assessment showed that molecular marker was efficient and precise that could detect 0.25-2.50% more off-types with ease and confidence even in smaller seed sample in comparison to GOT. The study suggests that molecular markers linked to Rf gene can be used an alternative to GOT for testing hybrid seed purity in rice.

1.5.2.3 Evaluation of hybrid maize parental lines

Parental lines of nutritionally enriched commercial quality protein maize (QPM), baby corn hybrids and sweet corn hybrids were evaluated for their morphological, flowering traits and synchronization pattern to assess their potential for successful hybrid seed production. The parental lines showed uniformity in all the vegetative and floral characters. The parental lines of all the hybrid combinations synchronized well for flowering and exhibited good pollen shedding and long stigma receptivity period (6-8 days) in male and female parental lines, respectively, resulting in high seed set percentage (65- 82%).

1.5.2.4 Level of hybridity of Indian mustard

Six released Indian mustard hybrids were evaluated for male fertility through selfing of inflorescences. The hybrids showed 66-81% fertile hybrid plants, the remaining failed to set seed under selfing conditions. The results indicated that there is a need to improve the hybrid purity level in the hybrid not only at the time of its yield evaluation but also in the final product after its release for cultivation. Hybrid seeds in Indian mustard (NRCHB 506) produced under insect proof net were also evaluated for its purity using pollen fertility/ sterility and seed set upon selfing of inflorescence. The hybrid showed 100% fertile pollen and complete seed set. The restorer line showed presence of fertility restorer genes using SCAR markers. The resultant hybrids also showed the genetic purity with the presence of band due to SCAR marker. This indicates that maintenance of parental lines needs to be strengthened.

1.5.3. Mitigating Heat Stress

1.5.3.1 Mitigation of the effect of elevated temperatures on seed set, yield and quality in wheat

Heat stress was found to have a significant influence on the seed quality parameters resulting in loss of germination capacity from 95% under normal sown conditions to 84% under heat stress conditions. Two different mitigation strategies were devised to alleviate the adverse effects of heat stress injury viz., first was treatment with different priming agents viz., halo priming with KH_2PO_4 (1%); osmo-priming (PEG-6000) (– 1Mpa) and plant growth regulator GA_3 (@50 ppm); and second strategy was the exogenous application of certain chemicals viz., alpha tocopherol (150ppm), ascorbic acid (10ppm) + citric acid (1.3%), KCl (1%) and salicylic acid (400ppm). Based on the speed of germination, three best priming treatments were identified viz., halo-priming with KH_2PO_4 (1%); osmo-priming (PEG-6000) (–1Mpa), and plant growth regulator GA_3 (@50 ppm). Seed priming with GA_3 was found to be the best treatment as compared to others. Foliar sprays with different chemicals were carried out at booting stage (~65 days after sowing) and seed filling stage (~85 DAS). All the chemicals were found to have a positive effect on various morphological, phenological and seed quality parameters as compared to the control. The estimation of Malondialdehyde (MDA) based on Thiobarbituric acid (TBA) number, revealed higher value of MDA in control plots, thereby, indicating more damage in wheat membrane due to heat stress but lower values in different foliar treatments indicated less

damage by heat stress. Higher value of electrical conductivity (EC) for control plots also indicated low vigour of seed as compared to the treated ones and *vice versa*. Dehydrogenase activity which is a measure of viability of embryo and high vigour was observed to be higher in treated plots as compared to control. Hydrogen peroxide (H_2O_2) activity, which damages the cell membrane, protein and lipid of cell and ultimately causes loss in vigour of seed and germination capacity, was observed to be significantly lower in the treated plots as compared to the control; hence emphasizing the beneficial role of the various chemicals in mitigation of heat stress.

1.6 SEED PRODUCTION OF FIELD CROPS

The Seed Production Unit at IARI, New Delhi and three regional Stations of IARI viz., Karnal, Indore and Pusa (Bihar) produced seed of different varieties of field crops which include nucleus, breeder and truthfully labelled seed. The details are as follows:

Seed production(t)

Crop Group	Nucleus Seed	Breeder Seed	IARI Seed	Total Seed
Seed Production Unit, IARI, New Delhi				
Cereals	3.0	140.58	150.31	**293.89**
Pulses	0.898	3.575	12.552	**17.025**
Oilseeds	-	2.117	8.921	**11.038**
Regional Station, Karnal				
Cereals	2.96	162.01	328.69	**493.66**
Pulses	0.02	2.33	0.80	**3.15**
Forages	0.05	0.51	0.15	**0.71**
Oilseeds	-	1.47	1.04	**2.51**
Others	-	-	0.19	**0.19**
Regional Station, Indore				
Cereals	-	161.6	-	**161.6**
Regional Station, Pusa, Bihar				
Cereals	-	71.215	26.980	**98.195**
Pulses	-	-	5.342	**5.342**
Oilseeds	-	-	2.841	**2.841**
Others	-	-	1.011	**1.011**
Total	**6.928**	**545.407**	**538.827**	**1091.162**

2. HORTICULTURAL SCIENCE

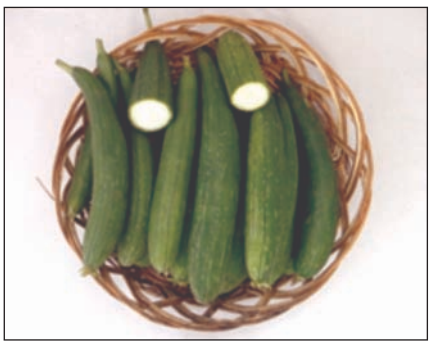
India witnessed the shift in area from food grains towards horticultural crops over last five years. The area under horticultural crops has been increased about 18% but expansion of area under food grains is only 5% during the stipulated period. The production of horticultural crops has outpaced the production of food grains since 2012-13. During 2013-14, the production of horticultural crops was about 283.5 million tonnes from an area of 24.2 million hectares. The School of Horticultural Sciences of IARI has focused its attention to technological innovations in the form of genetic enhancement, efficient production and resource management strategies. Pre-breeding for genetic stocks creation has been targeted by integrating genes from diverse genetic resources for resistance to diseases and insect pests, abiotic stresses and nutrients. Breeding in perennial fruit crops was aimed for achieving better quality and higher productivity, short stature canopy, input effi cient, enhanced biotic and abiotic stress tolerance with better shelf-life using conventional and modern biotechnological tools. Efforts were made to develop genotypes with novel characters in flower crops like rose, chrysanthemum, gladiolus, marigold and tuberose through various approaches. Several varieties and hybrids were notified/identified either through Central Sub-committee on Crop Standards, Notifi cation and Release of Varieties for Horticultural Crops, All India Coordinated Research Projects, Delhi state or Institute's committee during the year. New promising lines/hybrids have also been developed.

2.1 VEGETABLE CROPS

Varieties and hybrids notified. Five varieties were notified for different zones in 24th meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops viz., bottle gourd-Pusa Santushti for Zone IV (Punjab, U.P., Bihar and Jharkhand) & VII (M.P., Chhattisgarh and Maharashtra), garden pea- Pusa Shree for Zone I (J&K, Uttarakhand and Himachal Pradesh), ash gourd- Pusa Sabzipetha for Zone VIII (Karnataka, Tamil Nadu and Kerala), brinjal- Pusa Kaushal (DBL 2) for Zone I, IV and VI (J&K, H.P., Uttarakhand, Punjab, Delhi, U.P., Bihar, Jharkhand, Rajasthan, Gujarat, Dadra & Nagar Haveli and Daman & Diu) and cauliflower-Pusa Ashwini for Zone IV (Punjab, U.P., Bihar and Jharkhand).

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

Varieties and hybrids identified. One okra variety Pusa Bhindi 5 (DOV 66), chenopodium- Pusa Green (Bathua Sel 2), garden pea-Pusa Prabal (GP 473) and sponge gourd hybrid-Pusa Shrestha (DSGH 9) were identified by IARI Variety Identification Committee for cultivation in NCT of Delhi.



A sponge gourd hybrid, Pusa Shrestha (DSGH 9)

2.1.1 Cole Crops

2.1.1.1 Cauliflower

Development of promising lines. A total of 160 F_1 hybrids (121 CMS based, 39 SI based) of early group

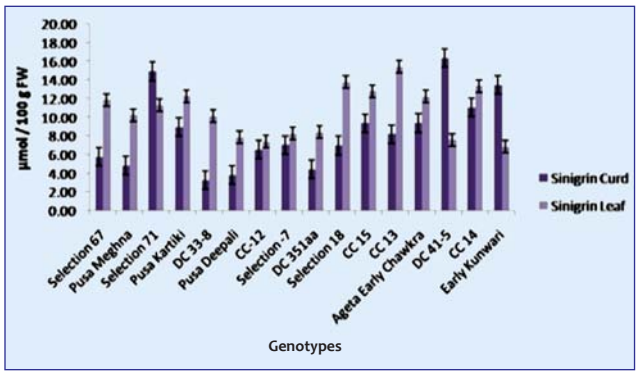
cauliflower were evaluated and among these lines, DCEH 2303 (24.6 t/ha), DCEH 2324 (20.8 t/ha)and DECH 9903 (17.7 t/ha) were found to be promising. Out of 40 CMS based F_1 hybrids evaluated in mid-early maturity group, the promising hybrids were DCMEH 1025 (28.2 t/ha), DCMEH 2213 (27.8 t/ha) and DCMEH 2228 (27.3 t/ha). Among 44 (CMS based 41 and 3 SI based) in mid-late group, the F_1 hybrids DCMLH 4015 (35.0 t/ha), DCMLH 4016 (33.7 t/ha) and DCELH 8476 (33.2 t/ha) were found promising. Besides, 18 CMS lines (12 in early, 4 each in mid-early and mid-late) and 12 self-incompatible lines (8 in early, 4 in mid-group) were maintained. Efforts were continued to convert 30 elite inbred lines into CMS lines through backcross breeding.

Development of hybrids. At IARI Regional Station, Katrain, 100 CMS based hybrids were evaluated in different climatic regions and the hybrid, Ogu-1A × 13-05 was the highest yielder (64.9 t/ha) for the last two years with all desirable traits. Other promising hybrids were Ogu122-5A × Kt-15 (64.1 t/ha), Ogu33A × Kt-178 (61.3 t /ha) and Ogu1A × Kt-25 (59.6 t/ha). One DH based F_1 hybrid, Ogu1A × 53-1 was identified to be promising.

Black rot resistance advanced breeding lines. In cauliflower, 143 RILs population and 110 inbred lines were evaluated for resistance to black rot by inoculating with *Xcc* race 1, 4 and 6. Five new moderately resistant lines DC 328, DC 431, CC 3210, PH 2-1, Lawyana and DC 42 were identified against race 1 and race 4. The resistant individuals in RILs population of Pusa Himjyoti × BR-161 and Pusa Sharad × BR- 207 were advanced to F_7 generation and Pusa Himjyoti × BR-2 to F_9 generation. At IARI Regional Station, Katrain, mapping populations have been developed in *Brassica carinata* for characterization of genes responsible for resistance to *Xanthomonas campestris* pv. *campestris* (Race-4).

Breeding for enhanced β-carotene content in early and mid-early maturity group and advancing of breeding materials. A total of 471 '*Or*' gene carrying lines in six genetic backgrounds, 3 each of early and mid- maturity were evaluated. Among these, 211 were from early maturity group comprising BC_1F_5, BC_2F_2, BC_2F_4, BC_3F_3, BC_4F_2, BC_5F_1, F_6 generations in the background of Pusa Meghna, CC 14 and DC 41-5, whereas 262 were from mid maturity group comprising BC_3F_3, BC_4F_2, BC_5F_1, F_6generations in the backgrounds of DC 309, CC 35 and DC 18-19 were evaluated for their curd quality traits (compactness, orange colour) and maturity. Promising elite plants within generation across the lines in each background were intermated to accumulate alleles of interest.

Promising inbred lines for high bioactive compounds. In early cauliflower, maximum sinigrin was recorded in curd of DC 41-5. Leaf sinigrin was recorded maximum in CC 13, Selection 18 and CC 14 with 15.43, 13.77 and 13.36 µmol /100g FW, respectively. Pusa Deepali, Pusa Kartiki and Selection 67 possessed highest CUPRAC values of 24.36, 24.24 and 24.13 mg GAE/100g. In mid- group, the maximum of 88.53, 65.64 and 58.88 mg L-ascorbic acid /100g FW were found in DC 522, Pusa Sharad and DC 325, respectively. In mid-late groups highest curd sinigrin was recorded in Pant Gobhi 2 (16.45 µmol /100g FW), followed by DPca 2 (15.96 µmol /100g FW) and Selection 18-19 (15.95 µmol /100g FW). High phenolics was recorded in CC 32, DC 431 and DC 402 with 53.22, 48.21 and 44.29 mg GAE /100g FW, respectively.



Sinigrin concentration in curd and leaf of 16 early cauliflower genotypes

2.1.1.2 Broccoli

Promising genotype. Pusa Purple broccoli was found to be promising for cultivation in *rabi* season. It has average head weight of 667 g with average head width and length of 18.2 cm and 15.4 cm, respectively. The marketable yield potential of Pusa Purple broccoli

was estimated to be 20.86 t/ha in 85–95 days after transplanting.

Promising hybrids. At IARI Regional Station, Katrain, 31 hybrids of broccoli developed by using 6 CMS lines were evaluated for yield and quality traits against private sector hybrid Anastya and standard check Pusa Broccoli KTS 1. Hybrid SMDA × VCH recorded the highest head yield (15.21 t/ha) along with lycopene and total carotenoids (9.18 mg/100g and 8.08 mg/100g, respectively), anthocyanin content (5.87 mg/100g), chlorophyll a, chlorophyll b and total chlorophyll (8.10, 10.70 and 9.79 mg/g f.w., respectively) followed by KTSA × 676710 (14.43 t/ha) and SMDA × KTS-1 (14.24 t/ha) than standard checks. Two hybrids KTHB 303 and KTHB 304 are under testing in multi-location trials under AICRP (VC). Hybrid BROHYB 4 has given a yield of 14.04 t/ha.

2.1.1.3 Cabbage

Promising white cabbage hybrids. At IARI Regional Station, Katrain,111 CMS based F_1 hybrids of white cabbage were evaluated for their performance for yield and nutritional quality traits along with 3 standard checks viz., Goodyball 65, Bahar and KTCBH 81. The hybrids 1A × Sel-5-83-6 (58.5 t/ha) and 208A × C-122 (52.85 t/ha) were found superior over the best standard check KTCBH 81. For head maturity, hybrid 1A × Sel-5-10 (71.5 days) was significantly earlier than earliest check KTCBH 81. Fifty six SI based hybrid combinations were also evaluated and among them, S-645 × FM, S-645 × 83-5-83-6-204, S-602 × GE, S-645 × 83-5-83-6 and S-645 × Sel-5-GA-122 were found promising and produced net head weight of 1.68 kg, 1.51 kg, 1.49 kg, 1.46 kg and 1.39 kg, respectively, against the best check Pusa Cabbage 1 (1.01 kg). Cross combination S-208 × GE was observed to be the earliest (68.5 days) for days to 50 per cent head maturity followed by S-681 × Sel-5-83-5 (69.00 days) against the check Saint (Seminis; 75 days) and Pusa Cabbage 1 (76.5 days). Among the 56 hybrids, the highest cupric ion reducing antioxidant capacity (CUPRAC) was found in hybrid S-691 × GE (12.92 µ moltrolox/g) while ferric reducing antioxidant power (FRAP) was highest in hybrid S-208 × C-8-204 (3.95 µ moltrolox/g). Out of 15 test hybrids of cabbage at IARI, New Delhi, KTCBH 822 (43.7 t/ha), KTCBH 881 (40.2 t/ha), KTCBH 705 (36.5 t/ha) outperformed the check Pusa Cabbage Hybrid 1 (34.0 t/ha). One F_1 hybrid of cabbage KTCBH 822 has been evaluated in AVT-I under AICRP trials.

Promising red cabbage hybrids. In red cabbage, hybrids RRMA × C-121 (1.41 kg), KRA × ZH (1.39 kg), KRA × Rajat (1.32 kg) and RCGA × ZH (0.99 kg) exhibited significantly higher net head weight than best standard check Primero (0.75 kg). RRMA × C-121 (68 days) was significantly earlier for days to 50 per cent head maturity than earliest check Primero (107 days).

Genetic diversity analysis of self-incompatible (SI) lines using SSR marker. Characterization and genetic diversity analysis of eight self-incompatible (SI) lines of cabbage was carried out using 13 morphological traits and 49 SSR markers in cabbage at IARI Regional Station, Katrain. Morphological characterization depicted considerable variations for both qualitative and quantitative traits studied. In molecular study, a total of 112 alleles were amplified by 49 simple sequence repeat (SSR) primers, averaging to 2.20 alleles in each locus. Genotypes S 645 and S 681 were found the most divergent based on morphological and molecular studies, respectively.

Development of doubled haploids. The effect of different culture densities on microspore embryo-genesis was studied in four cabbage genotypes at Katrain. All the tested genotypes produced very few embryos with the microspore density of 2×10^4/ ml. The microspore density of 4×10^4/ ml induced the maximum embryos per plate in genotypes, S-208 × Sel-5, S-661×S-621 and S-208×S-645. Twenty doubled haploid lines were evaluated for various horticulture traits, out of which 12 lines found to be promising. These lines are presently being used for hybrid development in cabbage. For diversification of CMS system, the BC_2 and BC_3 generations with *Trachystoma ballii* and *Diplotaxis catholica* male sterile cytoplasms were developed using *in-vitro* embryo rescue technique.

2.1.2 Cucurbitaceous Crops

2.1.2.1 Bitter gourd

Promising genotypes. One long fruited genotype Sel 2 was found to be promising for yield and its related parameters. Its fruits are green, 25-30 cm long, 3.5-4.5 cm diameter with broken ridges, curved at harvesting stage and individual fruit weight (90-95 g). The estimated yield was 22.5 t/ha under open field conditions. Two promising selections DBGS32 1 and DBGS 57 were found promising under polyhouse growing condition and produced fruit yield of 3.84 and 3.77 t/1000 m^2 with individual fruit weight of 108 and 122 g, respectively.

Fruits of Sel 2 **Fruits of DBGS 32-1** **Fruits of DBGS 57**

The highest β- carotene and lycopene content was recorded in S 54 (Pusa Rasdar) in parts at 20 days after pollination (DAP). The higher amount of β-carotene was recorded in fully ripened stage of whole fruit whereas lycopene content was higher in seed aerial of bitter gourd seed. The anti-diabetic compounds like saponin and charantin were recorded higher in early stages (8 DAP) of bitter gourd fruit. The genotype S 32 had highest saponin content in all three stages compared to other lines and 8 days after pollination showed the highest in whole fruit (84.38 µg/g). The genotype S 57 had highest charantin content at 8 and 12 days after pollination compared to other lines and 8 days after pollination showed the highest in whole fruit (50.32 µg/g).

Promising hybrids. Twenty one hybrids were evaluated for yield and related traits. The best performing F_1 hybrids for yield were DBGH 542 (25.2 t/ha), DBGH 5463 (24.8 t/ha) and DBGH 154 (24.5 t/ha) and showed high percentage of heterosis as 43.00, 37.89 and 34.57, respectively. Whereas DBGH 154, DBGH 57 and DBGH 137 were the best early yielding hybrids.

Fruits of DBGH 542

Genetic studies. The segregation ratio of F_2 population of DBGS-54 × DBGS-2 revealed that, discontinuous ridges (*Cr*), tubercles (*Tb*), curved (*Cf*) fruits and black seed coat (*Bs*) colour are controlled by single dominant genes. The fruit flesh thickness in bitter gourd was controlled by more than six genes. Inheritance pattern of gynoecy was investigated in cross DBGy-201 × Pusa Do Mousami, indicated that single recessive gene controlling the gynoecism (*gy-1*) in bitter gourd. Among monoecious F_2 individuals and $F_{2:3}$ families, more tendency of pistillate flower indicating that the gynoecious gene (*gy-1*) might have a semi-dominant effect on the sex ratio or that additional genes around the *gy-1* locus might be responsible for the determination of the sex ratio.

2.1.2.2 Cucumber

Promising genotypes. During spring summer season of 2016, 198 germplasm /advance breeding lines including 21 new collections and 12 gynoecious lines were evaluated and promising lines maintained. Out of thirty selections evaluated under replicated trial, DC 83 and DC 22 showed consistently good performance and yielded 18.9 and 17.5 t/ha showing an increase of 25.1% and 15.9% over national check

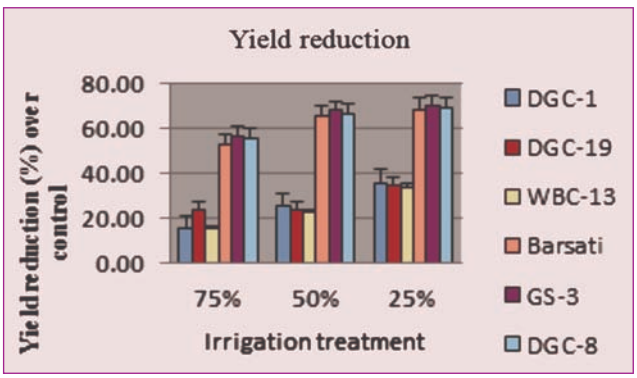
Pant Khira 1 (15.1 t/ha), respectively. These selections were advanced to AVT-II in AICRP (VC) trial.

Out of 59 F_1 hybrids evaluated under replicated trial gynoecious hybrids DGCH 18 and DGCH 15 yielded 27.3 and 25.8 t/ha which were 29.4 and 22.3 per cent higher than the check Pant Sankar Khira 1 (21.1 t/ha), respectively and advanced to AVT-II of AICRP (VC) trial. Two new gynoecious hybrids DGCH 31 and DGCH 40 yielded 27.0 and 28.0 t/ha, respectively, as compared to National check Pant Shankar Khira (20.0 t/ha) and were entered into IET of AICRP (VC) trial. Large scale seed multiplication of promising gynoecious parthenocarpic variety Pusa Seedless Cucumber 6 and parthenocarpic line DPaC 9 was done and promising gherkin lines DG 5, DG 8 and DG 11 and tropical gynoecious lines DGC 102 and DGC 103 were maintained under insect proof net house.

During *kharif* season, 178 lines were screened for downy mildew resistance. Two lines of DC 77 and DC 502 were highly tolerant based on disease reaction to downy mildew under challenge inoculation besides having high yield and other desirable horticultural characters. Out of 17 F_1 hybrids evaluated, DCH 16 (22.3 t/ha) and DCH 19 (21.4 t/ha) were found to be promising with high yield and tolerant to downy mildew disease.

Promising genotypes and hybrids for protected cultivation. During winter season evaluation of 25 gynoecious parthenocarpic lines were carried out under low cost polyhouse. Pusa Seedless Cucumber 6 showed the best performance as it yielded 1380 kg per 100 sq m under polyhouse during winter season (off-season). Out of 12 parthenocarpic gynoecious gherkin lines evaluated, the lines DG 8 and DG 3 were found most promising with an average yields of 8.82 and 7.45 t, respectively, in 100 sq.m polyhouse which was significantly higher than private company check Annaxo (7.18 t). Fifteen gynoecious parthenocarpic F_1 hybrids of cucumber were broken by using silver thiosulphate for induction of male flowers and simultaneously selfing and individual plant selections were carried out on the basis of true gynoecious and parthenocarpic character.

Promising genotypes for abiotic stress resistance. In cucumber, drought stress adversely affects the desirable physiological and biochemical parameters, and the adverse effect increased with the increase in soil moisture deficit. The yield reduction was observed as high as 51.97% under 25% of recommended irrigation. The physiological parameters such as proline, reducing sugars, phenol content on dry weight basis were increased significantly (p=0.05) as the drought stress increased from 100% irrigation to 25 % irrigation level. In contrast, the relative water content (RWC), chlorophyll stability, membrane stability index and fruit yield decreased significantly (p=0.05) with the increase in drought stress in all genotypes. Among the genotypes, DGC 1, DGC 19 and WBC 13 recorded better RWC, membrane stability, and lower yield reduction (%), while DGC 8, GS 3 and Barsati were sensitive to drought under all irrigation levels (75, 50 and 25%). These traits would be used as selection criteria for drought stress breeding and could be identified as the marker parameters for explaining the response mechanism of water deficit in cucumber. The best hybrids with maximum heterosis values were DGC-1 × WBC-13 for fruit weight, DGC-13 × DGC-19 and WBC-13 × DGC-8 for fruit numbers and WBC-13 × GS-3 and DGC-19 × DGC-8 for yield per plant at 25% irrigation, and all these crosses had one of the parents as resistant and another as susceptible.



2.1.2.3 *Luffa*

Promising genotypes. In sponge gourd, a total of 63 germplasm including 3 accessions of wild species *Luffa echinata*, 4 accessions of *Luffa graveolens*

and 22 accessions of *Luffa hermophrodita* (Satputia) were evaluated and maintained. Out of 22 selections evaluated in replicated trial during spring summer 2016, DSG 43 (13.2 t/ha), and DSG 33 (13.8 t/ha) were found to be very promising and apart from superior fruit quality, showed an yield increase of 11.9 and 16.9%, respectively, over check Kalyanpur Hari Chikni (11.8 t/ha). Out of 25 F_1 hybrids evaluated, DSGH 52 (14.9 t/ha) and DSGH 34 (15.1 t/ha) were found to be promising and showed an yield increase of 26.3 and 28.0%, respectively, over check Kalyanpur Hari Chikni. These selections and F_1 hybrids were advanced in AVT-II AICRP (VC) trial.

In ridge gourd, 10 gynoecious lines were evaluated for colour, shape and size. DRGGL 8 line having light green attractive colour, long fruit (20-25 cm) and true gynoecious character was recorded most promising and maintained by spraying sliver thiosulphate. Out of fifteen F_1 hybrids evaluated, monoecious F_1 hybrid DRGH 4 and gynoecious hybrid DGRGH 8 were found promising with an average yield of 17.3 and 19.6 t/ha, respectively, as compared to Pusa Nutan (16.8 t/ha).

2.1.2.4 Pumpkin

Promising genotypes. Seventy genotypes were evaluated for yield related traits and carotenoids content. In small fruited and semi-vigorous vine segment, the genotypes DPU 41 and DPU 43 were found promising for fruit weight, vine length and fruit yield of 2 kg & 2.2 kg, 2.8 m & 3 m, and 20 t/ha & 21.5 t/ha, respectively. Promising high yielding medium fruit size (4.5-4.8 kg) genotypes are DPU 26 and DPU 80. The genotypes DPU 76 and DPU 80 had high flesh carotenoids content of 432.4 µg/g FW and 428.4 µg/g FW, respectively. The total carotenoids in the genotypes ranged from 32.67 to 432.42 µg/g FW.

2.1.2.5 Muskmelon

Promising selections. Twenty one advanced lines/selections of muskmelon were evaluated during summer 2016 and genotypes DM 154 (23.9 t/ha) and DM 159 (22.9 t/ha) were found most promising. Promising genotypes for protected cultivation were identified as DHM 162 (4.90 t/1000 m^2 with TSS 13.5 ^oBrix), DHM 159 (4.60 t/1000 m^2 with TSS 13.8 ^oBrix).

Promising hybrids. Twenty eight hybrids of muskmelon from two horticultural groups *C. melo* var. *inodorous* and *cantaloupensis* were evaluated in two seasons (March-June) and (September to December) in net house/polyhouse and three most promising hybrids for protected cultivation were identified as DMH 12 (5.5 t/1000 m^2), DMH 16 (5.1 t/1000 m^2), and DMH 5 (4.5 t/1000 m^2) with better fruit quality traits and post harvest storability.

2.1.2.6 Watermelon

Source of resistance against watermelon bud necrosis virus. Twenty three watermelon genotypes and three population derived from inter specific crosses of watermelon and wild progenitor *Citrullus colocynthis* were evaluated in open field and net house conditions. The source of resistance against watermelon bud necrosis virus was identified in *Citrullus colocynthis* lines and its hybrid with watermelon cultivar.

Source for drought tolerance. Fifty six watermelon exotic germplasm lines from core collection of USDA germplasm were screened for resistance to drought under hydroponic system in controlled environment of phytotron and 4 lines from *C. lanatus* var. *citroid* and *C. lanatus* var. *lanatus* identified as tolerant against drought.

2.1.3 Solanaceous Crops

2.1.3.1 Brinjal

Promising genotypes. In round fruited brinjal genotypes, DBR 3, DBR 5 and DBR 9 were found promising with an average yield of 41.56, 38.5 and 38.9 t/ha, respectively In long fruited brinjal genotypes, DBL 8 (dark purple), DBGL 17 (green with white blotches at bottom), DBL 60 (shiny purple) were found to be promising selections with an average yield of 38.5, 31.5 and 41.2 t/ha, respectively.

Promising hybrids. Thirteen round fruited hybrid combinations were evaluated for yield. Out of these,

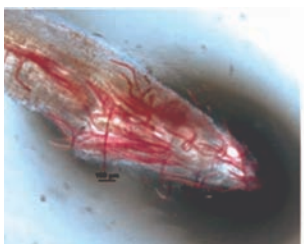
DBHR 190

DBHL 211

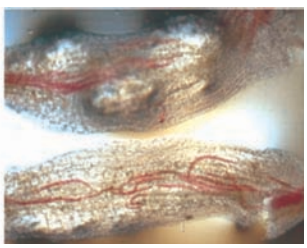
DBHR 4013 (round purple, 65.30 t/ha), DBHR 190 (oval round, 61.5 t/ha) and DBHR 112 (oval round, 58.6 t/ha) were found to be superior over the check Navina (45.30 t/ha). In long fruited hybrid trial, DBHL 211 (long purple, 49.8.1 t/ha), DBHL 215 (long purple, 45.20 t/ha) and DBHL 62 (shiny purple, 52.6 t/ha) were found superior than check. Thirteen hybrids were evaluated for bioactive compounds. The hybrid DBHR 190 was also found to be highest in the antioxidant CUPRAC and FRAP contents, 15.12 µmoltrolox/g and 8.02 µmoltrolox/g, respectively. The maximum phenolic content was observed in DBHR 19013 (335.18 mg/100 g). The hybrid DBHR 4013 was found to be maximum for anthocyanin content (667 mg/100 g).

Promising resistant genotypes. A total of 14 wild accessions were evaluated. Among the wild accessions, *S. torvum* (Ac-1) and *S. sysimbrifolium* (EC-790352) were found to be resistant to *Fusarium* wilt under artificial inoculation in pots. Out of 102 genotypes, DB 9, DBWL 1, Guhalachatua Local and wild accessions *S. sysimbrifolium* (EC 790352), *S. integrifolium* (Ac-1), *S. khasianum* (Ac-1) and *S. torvum* (Ac-1) were found to be resistant under field condition.

Eleven wild accessions of brinjal including *S. melongena* cv. Pusa Purple Long were penetrated by the second stage juveniles of *M. incognita* and a swarm of juveniles was found upon staining with NaoCl-acid fuchsin in the vascular cylinders of the root tip regions. However, in comparison to *Solanum melongena* cv. Pusa Purple Long, the other test accessions appeared relatively less susceptible. Six accessions (*S. indicum*, *S. torvum* (Ac1), *S. khasianum* (Ac1), *S. khasianum* (Ac2), *S. unduatum* and *S. aethiopicum* were also evaluated under pot conditions and all the six accessions displayed no infection after 60 days of inoculation.



S. melongena cv. Pusa Purple Long



S. unduatum

2.1.3.2 Tomato

Promising genotypes and hybrids for protected cultivation. Fourteen pure lines/parental lines and 28 F_1 cross combinations were raised under protected condition in October for yield and quality traits. Sel 60 and Sel 11 were found promising and highly suitable for low cost and climate control polyhouses. Sel 60 was recorded with high TSS (5.6°Brix) and lycopene (4.5 mg/100 g) and average fruit weight of 105 g. However, Sel 11 recorded average fruit weight of 65 g and TSS 6.5. Cherry types were also selected from F_2 generation of F_1 hybrids. More than 7.5°Brix of TSS was recorded in cherry selections, however, number of fruits per cluster varied from 25 to 130. The fruit weight was varied from 6 to 15 g.

Tomato Selection 60 (DTPH 60) under climate control polyhouse

Screening for virus resistance. One accession of *Solanum peruvianum* (PI 126944) was reported to be resistant to tomato leaf curl virus (ToLCV) as well

as pea-bud necrosis virus (PBNV). In addition, 53 breeding lines of tomato carrying genes for resistance to ToLCV, ToMV, late blight, *Fusarium* wilt and heat. In a station trial, 35 F_1 combinations, 44 breeding lines along with local checks were evaluated for ToLCV resistance, yield, fruit characters, and quality attributes. Among these, six hybrid combinations with *Ty-2* and *Ty-3* genes as donors and elite varieties, Pusa Ruby, Pusa Rohini, Pusa 120, Pusa Gaurav and Punjab Verka Bahar 2 were used as recipient parents, were found promising for resistance to ToLCV with PDI (< 10 %) and the fruit weight varied from 100 to 150 g.

Interspecific crosses. Advanced segregating lines of interspecific crosses of (15SB × LA1777) × P-120 and (15SB × LA1777) × Pusa Rohini were found promising for tolerance to ToLCV and late blight, fruit set at high temperature (37°C), fruit weight (>100 g) and high TSS (>7.0°Brix).

2.1.3.3 Chilli and sweet pepper

Screening for resistance to chilli leaf curl disease. Three genotypes of *Capsicum annuum*, namely, Black Bullet and Utkal Yellow and one wild relative *Capsicum flexuosum* have exhibited field resistance to leaf curl disease during the field screening conducted in *kharif*. Black Bullet has 1-1.5 cm round purple fruits which grows upright in clusters on the plant. The plant has dark purple stems, purple/green variegated leaves and produce purple flowers. Utkal Yellow is an Indian variety which is a tall plant and gives yellow color fruits on ripening, while *C. flexousum* belongs to secondary gene pool of *C. annuum.*

Study of genetics for LCV resistance. F_2 population raised from the resistant parent DLS-Sel 10 and susceptible parent Phule Mukta were screened for response to chilli leaf curl disease including parents and F_1 hybrid both naturally and through challenge inoculation using viruliferous whiteflies carrying chilli leaf curl virus. The F_1 hybrids showed susceptibility and the F_2 population segregated in the ratio of 3:1 for susceptible and resistant plants indicating the monogenic and recessive in nature of resistant gene.

Genotypes for high temperature tolerance. Selfed progenies of local collections showing fruit setting at high temperatures were evaluated for the tolerance to high temperature during summer. Good fruit setting under high temperatures (average max. temp of 43°C and minimum of 28°C in the months of May and June) was recorded in HT-Sel 1, HT-Sel 2 and HT-Sel 3 having cluster erect, cluster drooping and solitary drooping fruiting behaviour, respectively. The lines HT-Sel 1, HT-Sel 2 and HT-Sel 3 yielded 572, 650 and 600 g fruit yield per plant, respectively, in two rounds of picking where the heat susceptible varieties showed no fruit setting at all.

Development of CMS and restorer lines in sweet pepper. At IARI Regional Station, Katrain, 3 CMS lines ,namely, KCS-1A, KCS-2A and KCS-3A are developed and being converted into stable indigenous CMS lines by transferring the sterile cytoplasm into sweet pepper (BC4) background having desirable fruits, shape and size along with other horticultural traits. Based on the pollen viability, pollen germination and morphological characteristics of previously developed fifty test crosses; five fertility restorers (*Rf*) of CMS have been identified and maintained for their further use.

Development of sweet pepper hybrids. A total of 100 station hybrids were evaluated for fruit yield and its contributing traits under open field conditions at Katrain. The hybrid KTCH 5 (41.92 t/ha) gave the highest marketable fruit yield per plant followed by KTCH 9 (40.64 t/ha) and KTCH 129 (38.72 t/ha) under field conditions. These hybrids revealed more than 10 per cent increase in marketable yield over standard variety. They also possess desirable fruit shape, size and colour as per the consumer preference.

Fifty station hybrids were evaluated for fruit yield and its contributing traits under polyhouse conditions at Katrain. The hybrid KTCH-13-Y, KTCH 155 and KTCH 17 were found promising with high yield potential of (1125 kg/100 m^2), (855 kg/100 m^2) and (720 kg/100 m^2), respectively, under polyhouse conditions. The hybrids KTCH-13Y and KTCH 155 had performed consistently better over two years under polyhouse.

Evaluation of capsicum hybrids under poly house conditions at IARI Regional Station, Katrain

2.1.4 Root and Bulbous Crops

2.1.4.1 Carrot

Development of promising hybrids. In heat tolerant group, 46 CMS based hybrids were evaluated and promising F_1 hybrids (yield above 20 t/ha) were DcatEH 798, DcatEH 713, DcatEH 298 and DcatEH 7104. In normal season carrot, out of 76 CMS based hybrids evaluated including 46 of red coloured, 20 black/purple and 10 orange coloured. Out of them, the promising F_1 hybrids were DcatH 5316, DcatH 5323, DcatH 1104, DcatH 9816, DcatH 9811 and DcatH 2455 having yield potential higher than 40 t/ha with attractive extrinsic and intrinsic root traits.

Thirty three station hybrids were evaluated for root yield and its related traits in temperate carrot at Katrain. The best performing hybrids were KT 2559 (39.14 t/ha), KT 821 (37.43 t/ha), KT-10K (35.34 t/ha) and KT 759 (34.77 t/ha). These hybrids showed very good marketable root shape, size and colour. The hybrids KT-10K and KT 759 had performed better for root yield continuously for two consecutive years at Katrain.

Evaluation of inbred lines. Thirty inbred lines in early season (August sowing) were evaluated and IPC 13, IPC 96 and IPC 116 were found to be promising (>15.0 t/ha). While in main season (October sowing), out of 63 inbred lines, IPC 4, IPC 06, IPC 36, IPC 92, IPC 104 Red and IPC 54 were promising for root appearance, uniformity and root yield (>30 t/ha).

The genotype KS 22-1 was found to have maximum contents of total carotenoids and beta carotene (2.26 mg/100 g and 4.853 µg/100 g) followed by KS 73-1 (1.684 mg/100 g and 3.61 µg /100 g) and KS 50 (1.67 mg/100 g and 3.57 µg /100 g). The genotypes NK 1 (4.55 mg/100 g), KS 22-1 (4.28 mg/100 g) and KS 21 (3.76 mg/100 g) were recorded with highest contents of lycopene. Among 36 promising lines of carrot evaluated at Katrain, KS 73 (28.9 t/ha) and KS 12 (27.03 t/ha) were recorded best for root yield and other marketable traits.

2.1.4.2 Onion

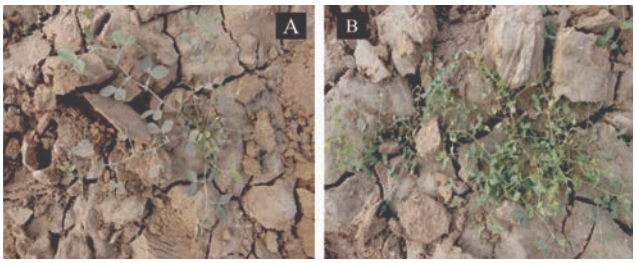
Promising genotypes identified. During *kharif* 2016, 49 accessions of onion were evaluated for their bulbing potential using sets and seedlings. Based on the bulbing capacity under *kharif* conditions, a total of 250 bulbs were selected from 41 genotypes for seed production. In onion, bolting tolerance exhibited that three genotypes had no bolters in November planting.

2.1.5 Leguminous Crops

2.1.5.1 Garden pea

New genetic material developed. Among 12 new bulks/genotypes evaluated with two checks GP 17 and Arkel, the promising genotypes were recorded were GP 1102 (13.82 t/ha), GP 912 (12.65 t/ha) and GP 1101 (12.32 t/ha) against the best check GP 17(10.90 t/ha). Besides, 175 crosses ($55F_1$, $9F_2$, $30F_3$, $70F_4$, $11F_6$) were retained for further selection/evaluation.

Interspecific hybridization. A total of 30 accessions of *Pisum* including *P. sativum* (15), *Pisum elatius* (01), *Pisum sativum* var. *elatius* (10) and *Pisum fulvum* (04)



Wild species of garden pea (A) *Pisum elatius*, (B) *Pisum fulvum* exhibiting long vegetative phase

were grown and characterized for horticultural traits. A wide range was observed for days to 50% flowering (43-130 days). None of the accession of *Pisum fulvum* and *Pisum elatiu* showed flowering at IARI Delhi conditions due to long vegetative phase.

2.1.5.2 Other legumes

Entries of *Dolichos* bean pole type (DB 10 and DB 15) and cowpea bush type (CP 55) were promoted for testing in AICRP (AVT-II) and *Dolichos* bean pole types DB 3 and DB 5 are under evaluation in IET.

2.1.6 Malvaceous Crop

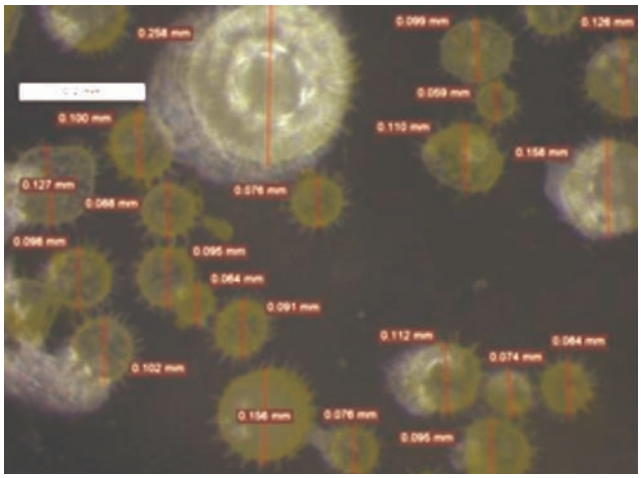
2.1.6.1 Okra

Promising genotypes and hybrids for YVMV resistance. A total of 54 parental lines and 24 advance lines of okra were evaluated for yield, fruit quality and YVMV resistance during *kharif*. DOV 66 and DOV 92 were found resistant to Bhendi yellow vein mosaic virus (YVMV) disease and recorded average yield of 18 and 17.5 t/ha, respectively, with dark green pods. However, Pusa Sawani and Arka Anamika were found susceptible to YVMV disease. However, Pusa A 4 yielded 14.5 t/ha with 35% YVMV incidence. Resistance to YVMV in DOV 66 was controlled by single dominant gene.

Out of 24 F_1 combinations along with 10 private sector hybrids, DOH 1 recorded 23 t/ha yield and found highly resistant to YVMV disease with thin, dark green, smooth and attractive pods.

Promising okra selection Pusa Bhindi 5 (DOV 66) showing resistance to YVMV disease

Inter-specific crosses. Sixteen wild okra (*Abelmoschus* sp.) genotypes from 6 species, 16 wild F_1 crosses with Pusa A 4 and DOV 66, 5 back crosses (BC_1 and BC_2) with one F_2 wild combination were evaluated for resistance to major disease and insects. Eight accessions of three wild species (*A. moschatus, A. caillei* and *A. tetraphyllus*) were found resistance to YVMV. Resistant wild accessions were crossed with Pusa A 4 and DOV 66 for development of new cross combinations. F_1 plants showed no seed setting, however, colchicine treated F_1 plants recorded few seeds. Pollen studies in wild crosses showed huge variability in pollens size (0.076 - 0.258 mm) and germination of F_1 plants.



Pollen size variation in F_1 of wild okra (Pusa A 4 × *A. tetraphyllus*)

2.1.7 Lettuce

Promising genotypes identified. Thirty seven genotypes of lettuce were evaluated for yield and yield attributing traits. Out of these, three genotypes were of Iceberg/heading types, 6 butter head, 18 loose leaf, 7 cos or romaine and 3 stem lettuce. The promising selections identified were EC 687336 (42 t/ha), DL 11 (34 t/ha) and DL 1 (33.5 t/ha). The maximum chlorophyll content was observed in EC 687336 (4.70 mg/100 g) and ascorbic acid in DL 16 (7.4 mg/100 g).

2.2 FRUIT CROPS

2.2.1 Fruit Breeding

2.2.1.1 Mango

Hybridization and promising hybrids. Eleven cross combinations were attempted and a total of 901

panicles having 6,578 flowers were crossed employing Amrapali, Mallika, Pusa Arunima and Kesar as female parents and Sensation, Janardan Pasand, Irwin and Pusa Arunima as male donor parents. From previous year crosses, 52 hybrid stones were obtained and sown in the pots. Out of which, 38 stones germinated and finally 30 hybrid plants were planted in the hybrid evaluation block.

One hundred five mango genotypes were evaluated for 18 physico-chemical traits and hybrids H 1-5, H 3-4, H 3-5, H 8-4, H 8-11 and H 11-2 had more than 200 g fruit weight. The maximum fruit weight was noted in H 11-2 (256 g) followed by H 1-5, H 3-4 and H 3-5. Pulp content was maximum in H 1-5 (70.13%) followed by H 11-2 (69.88%). The fruits of hybrid H 12-5, H 3-2, H 4-2 had intense red colouration on the fruit shoulder. In mango rootstock breeding, total 605 flowers on 146 panicles were crossed using Olour, Kurukkan, Bappakkai and Amrapali as parents.

Validation of SSRs. The SSRs designed from whole genome sequencing and transcriptome data were validated on a set of 24 mango genotypes. Out of 145 SSRs used, 129 primer pairs gave 210 scorable bands. Among 129 informative primers, 110 (85.27%) were found to be polymorphic and 19 (14.73%) were monomorphic, while 16 primer pairs failed to amplify in the present set of germplasm. Analysis based on UPGMA divided the 24 germplasm into three main clusters. The mango varieties from western India like Kesar and Sindhu were grouped together and Amrapali and Mallika having the close ancestry were in the same clade. Tommy Atkins and Maya were also appeared to be in one clade. Similarly, polyembryonic mango rootstocks Kurrakan and Olour appeared in one clade. The genetic distance ranged from 53 to 77%. High polymorphism obtained indicates that mango hypervariable SSRs are effi cient for evaluating genetic diversity in mango germplasm.

SSR polymorphism studies among parental mango genotypes. Another set of 79 SSRs derived from whole genome sequencing data were screened against three parental mango genotypes, namely, Amrapali, Sensation and Tommy Atkins. Among 79 primer pairs, 61 produced 105 alleles, while 18 primer pairs did not amplify at all. Out of 61 primers, 21 (26.58%) primer pairs showed polymorphism between Amrapali and Sensation, while 26 (32.91%) primer pairs detected polymorphism between Amrapali and Tommy Atkins. The number of alleles ranged from 1 to 3. Of the total 105 bands generated, 27 were found to be polymorphic between Amrapali and Sensation and 31 between Amrapali and Tommy Atkins. Primer pairs viz., SSR20, SSR23, SSR51, SSR54 and SSR70 showed the high allelic differences among the mango genotypes and thus can be used for future marker-assisted mango breeding and selection of progenies at the seedling stage.

Fruits of mango hybrid 11-2

2.2.1.2 Citrus

Evaluation of sweet orange clones. Sixteen accessions of sweet orange along with three varieties, viz., Jaffa, Pusa Sharad and Pusa Round. Based on growth, yield and quality performance, six accessions, namely, MS 3, MS 7, MS 9, MS 10, MS 20 and MS 21 were found promising. The heaviest fruits were obtained in MS 20 (294.60 g) followed by MS 21 (269.83 g) and MS 3 (240.15 g), as compared to Jaffa (204.10 g). The highest juice content (53.50%) was measured in MS 9 as against Jaffa (49.8%). TSS was found to be highest in MS-3 (14.33^{0}Brix), which did not differ significantly with the rest of the selections except MS 10 (14.25^{0}Brix) and MS 7 (13.73^{0}Brix). Nonetheless, minimum acidity was recorded in Jaffa (0.39%). TSS/acid ratio was found to be the highest in MS 7 (24.82), which was at par with Pusa Round (23.45). Highest yield was recorded in Pusa Round (38.51 kg/tree), followed by Pusa Sharad (37.44 kg/tree) and MS 9 (22.29 kg/tree). Based on overall performance, Pusa Sharad, Pusa Round, MS 3, MS 7 and MS 21 had consistently better performance than the rest of variants and check studied.

Evaluation of acid lime clones. Clone ALC 107 had significantly highest fruit weight (95.48 g) followed by ALC 2 (75.12 g), ALC 21 (51.86 g), and ALC 73 (44.02 g) and the lowest fruit weight was found in ALC 51 (31.10 g). However, the highest juice recovery (54.26%) was in Pusa Udit, while it was lowest in ALC 107 (33.85%). Acidity was measured highest in ALC 1 (7.46%) which did not differ significantly with Pusa Udit (7.43%), Pusa Abhinav (7.19%) and ALC 73 (7.31%). The number of fruits/ tree was found to be the highest in Pusa Udit (506.67 fruits/tree) followed by Pusa Abhinav (456.67 fruits/tree), ALC 101 (398.00 fruits/tree) and ALC 21 (394.00 fruits/tree).

Evaluation of lemon clones. Seven lemon genotypes were evaluated. Genotype LS 5 excelled over others in respect of highest fruit weight (77.08 g), juice (53.25%) and acid (6.97%) content, although it was similar statistically with LS 1 in respect of juice content. Genotype LS 1 had the thinnest peel (1.00 mm), while LS 4, LS 5 and LS 6 had significantly lower seed numbers per fruit (23.8-27.2). The highest juice and ascorbic acid content were exhibited by LS 4 (52.39 mg /100 ml juice). Although Konkan Seedless was most productive (365.4 fruits/ tree), but had thick peel, high seed number and low juice and acid contents. Selections LS 3 and LS 4 were statistically similar with Kagzi Kalan, i.e., high TSS content (9.54-10.4°B).

Evaluation of Tangerine cultivars. Murcott proved to be 40 and 44 days earlier to harvest than Dancy and Kinnow mandarin, respectively. It was the most productive cultivar (93.42 kg/ tree) with highest fruit weight (247.8 g), juice (60.46%) and TSS (11.30°Brix) contents. Cultivar Dancy had the highest ascorbic acid content (43.20 mg/ 100 ml juice) with lowest acid content (0.42%) and seed numbers (16.00 /fruit).

Evaluation of citrus hybrids against salinity. Of the 33 citrus hybrid (pummelo × Troyer citange) rootstocks evaluated against NaCl (50 mM) induced salinity ($EC_{(1:2)}$5.01 dS/m), six hybrids, namely, Pu ×Tr -7, Pu × Tr-14, Pu × Tr-19, Pu × Tr-23, Pummelo× Tr-26 and Pu × Tr-29 were found resistant, as they maintained their higher photosynthetic rate (5.30 -7.50 µmol m^{-2} s^{-1}) with very low leaf scorching/ injury (0.98- 23.47%) against *Jattikhatti* (1.04 µmol m^{-2} s^{-1} and 75.12%, respectively) and Troyer citrange (1.36 µmol $m^{-2}s^{-1}$ and 76.50%, respectively). In these six hybrids, the number of leaves (7.24 - 414.29%) was higher over initial number, while the severe defoliation was observed in *Jattikhatti* (-51.39%) and Troyer citrange (-51.39%).

Citrus hybridization. The maximum seeds were recovered from cross between PS-1 × Mosambi (332) which gave 162 seedlings. The highest germination was found in PS-2 × Pusa Sharad (79.17%), while minimum in PS-1 × Mosambi (48.80%). During March, 2017, in rootstock improvement, crosses were made between Cleopatra mandarin and Rangpur lime as female parent, and Troyer citrange, Morton, Carrizo and Sacaton as pollen parents using 490 flowers. Among different crosses, maximum fruit set at 15 DAP was recorded in Rangpur lime × Troyer citrange (45.98%) followed by Cleopatra mandarin × Troyer

(44.38%) while the lowest was found in Cleopatra × Morton (33.87%).

Mutagenesis in Kinnow mandarin and sweet orange. Significant variation was recorded in fruit quality parameters with respect to number of seeds/ fruit, juice recovery percentage, period of fruit maturity, etc. in Kinnow mandarin mutants developed through mutagens. Delayed maturity (mid-Feb) was recorded in the mutants M 10-4 and M 25-1. The average fruit weight (224.15 and 221.95 g), length (71.61 and 68.11 mm) and width (80.99 and 79.17 mm) were recorded maximum in the mutants M 15-4 and M 25-7, respectively, while the average number of seeds/ fruit was significantly lower in the mutants M 5-3 (05-07) and M 35-4 (08-10) as compared to normal Kinnow (parent type) (30-35). Significant dwarfism, thus exhibiting 35-40% reduction in plant height over mother plant was recorded in the mutants EMS 9, C 1 and C 2. The selected promising mutants were found free from Indian Citrus Ring spot virus (ICRSV). Mutagenesis was also attempted in sweet orange for seedlessness and other desirable traits using different doses of gamma irradiation (15, 20, 25, 30, 35 and 40 Gray). Doses beyond 35 Gray were found to be lethal for sweet orange as the bud survival was significantly reduced to less than 30% at 40 Gray.

Charaterisation of Kinnow mandarin and sweet orange developed by using colchicine. Based on leaf characteristics and internodal distance, 34 tentative colchiploids of Kinnow mandarin and Mosambi sweet orange were identified and the buds from such branches were grafted on rough lemon rootstock. Budding success was more in sweet orange as compared to Kinnow mandarin. Furthermore, flowering in colchicine treated Kinnow plants were observed from last week of February to third week of March. The maximum flowering was recorded in 0.05% colchicine treatment (64.29%), in comparison with no flowering in 0.20% colchicine. Similarly, in Mosambi sweet orange, maximum flowering was observed in 0.15 and 0.20% treatment (100%) and minimum in 0.10% treatment (60%). It is observed that 0.10% colchicine resulted in low bud take, plant survival and delayed flowering in both Kinnow mandarin and Mosambi sweet orange. In the treated bearing plants, almost 100% flowering was observed in Mosambi sweet orange in all treatments except 0.20%, where it was recorded 66.67%. But in Kinnow mandarin, flowering was not observed except in 0.05% colchicine conc.

2.2.1.3 Grape

Hybrid evaluation. Sixty seven hybrids/ varieties were evaluated for early maturity and fruit quality traits. The hybrids Pusa Aditi and Pusa Trishar yielded highest (13.67 kg/vine and 12.9 kg/vine, respectively) per vine on trellis system. The maximum bunch weight was also recorded in Pusa Aditi (427 g/bunch) and Pusa Trishar (389 g/bunch) as compared Perlette (288 g/bunch). Based on the seedlessness trait, four hybrids were found promising i.e., Pusa Trishar, Pusa Aditi, ER-R_2P_{19} and ER-R_2P_{36}. Three grape hybrids viz., 16/2A-R_1P_9, 16/2A-R_1P_{14}, and 76-1 have been found promising in terms of loose bunch, bold berry (4-6 g), early maturity (1st week of June), bunch size (325.46 g to 450.25 g), desirable total solids content (18.57 to 21.15°Brix) and moderate titratable acidity (0.41-0.71%).

The maximum total monomeric anthocyanins was recorded in Pusa Navrang, followed by 16/2A-R1P18, 16/2A-R_4P_7, Punjab Purple, 16/2A-R_4P_{13} and 16/2A-R_3P_{10} ranged from 554.22-854.56 mg/kg. The maximum total flavonoid content was detected in *V. parviflora* followed by 16/2A-R_3P_{10}, 16/2A-R_4P_7, 16/2A-R_3P_{12}, Syrah, Tempranillo and Punjab Purple.

2.2.1.4 Papaya

Genetic diversity. A significant range of variation was noticed for morphological qualitative traits in dioecious papaya genotypes. Among gynodioecious genotypes, maximum variation was noticed for stem pigmentation in P 9-5, purple pink colour in genotype P 9-15-5, while it varied from greenish light grey to grey among the studied population. Two genotypes, namely, P 15-1 and P 9-15-5 had distinct purple colour pigmentation on the stem of the female and male plants. Leaf petiole colour was primarily light green to

green in most of the genotypes whereas it was noticed green with shades of purple in case of genotype P 9-25, P 14-9 and P 15-2. Petiole sinus shapes also varied from slightly open to strongly close. However, most of the papaya genotypes had strongly close petiole sinus shape. The wild relative of papaya genotype *V. cauliflora* was distinct with other genotypes having open petiole sinus. Genotypes *V. cauliflora*, RCTP-I, Pusa Dwarf, Pusa Nanha, P-15-1, P-14-6, and P-9-15-5 were with straight mature leaf teeth shape whereas convex leaf teeth shape was recorded in P-9-25, P-14-9 and P-15-2. Inflorescence stalk colour was also observed light green to green among all the studied genotypes. Flower colour variation was also observed among the 11 dioecious genotypes from cream colour, yellowish-white to white in both female and male sex forms. The smallest female flower was recorded in *V. cundinamarcensis* followed by *V. cauliflora.*

Twenty Simple Sequence molecular markers were also used to assess the genetic diversity of 23 genotypes to determine levels of heterozygosity, genetic differentiation, and population structure. The gene diversity ranged from 0.29 to 0.73 with an average of 0.59. The maximum gene diversity (0.73)

UPGMA dendrogram of 23 papaya genotypes based on genetic similarity matrix calculated from SSR markers

was observed with primer P3K2981YCO followed by (0.66) in primer CPM1606CC and (0.65) in primer P3K2696CC. Marker P3K2981YCO produced the highest PIC value of 0.68 followed by CPM1606CC with 0.58, while CPM1774CC had the lowest (0.25). The maximum observed heterozygosity (0.43) was in two marker ctg27cc and P3K2696CC. The higher level of heterozygosity (48%) was recorded within the individuals among population. *V. cauliflora* and *V. cundinamarcensis* were grouped in same sub-cluster. The genotypes were divided into two broad clusters represented by six and seventeen genotypes, respectively. The radiant coeffi cient ranged from 0.05 to 1.00. Cluster 'I' had 6 papaya genotypes. P 7-15 genotype was the most diverse among the dioecious and gynodioecious populations based phenotypic and genotypic traits within *Carica papaya* genotypes. Comparison between inbred lines and varieties indicated a higher amount of genetic diversity existing within the populations.

At IARI Regional Station, Pune, the selections PS 3 and PS 5 were the tallest (193 cm) and shortest (154cm), respectively. Plant height was decreased in gynodioecious lines as compared to their dioecious parents. Stem girth was maximum in PS 2 (37 cm) and varied from 30 to 33 cm in gynodioecious lines. Average proportion of productive plants (PPP) was 71% in gynodioecious lines as compared to 62% in dioecious lines. Average papaya ring spot virus intensity was comparable in dioecious (9.34%) and gynodioecious (11.73%) lines. The lowest PRSV intensity was found in PS 2 (5.82%).

Maximum plant height (165 cm) and stem girth (41 cm) was observed in Pusa Majesty and minimum plant height (103 cm) and stem girth (29 cm) was in Pusa Nanha at IARI Regional Station, Pune. There was 20% increase in the plant height in all gynodioecious lines. Pusa Delicious-I was the tallest (189 cm) and Pusa Nanha-I was the shortest (134 cm). Stem girth also increased in the gynodioecious lines Pusa Nanha-I (21%) and Pusa Delicious-I (14%). The average proportion of productive plants was 43% in dioecious varieties and 75% in gynodioecious. Maximum fruit

production was observed in Pusa Majesty followed by CO 2. Average PRSV intensity was 21% which came down to 8% in their gynodioecious lines.

2.2.1.5 Temperate fruits

Promising genotypes. IARI Regional Station, Shimla identified a walnut variety Pusa Khor which bears fruits after second year of its grafting having both lateral and terminal bearing habit. It bore 60.91% laterally and 39.09% fruits terminally. The oil per cent as well as shelling per cent was recorded 55.4 and 49.8, respectively. It showed semi-vigorous in nature.

IARI Regional Station, Shimla identified a compatible rootstock suitable for different stone fruits. *Prunus japonica* could be used as a dwarfing rootstock for temperate stone fruits e.g. apricot, peach, plum, nectarine, prune, almond and cherry in addition to use as an ornamental shrub. This selection has a potential for use as a dwarfing rootstock for high density plantings as well as for kitchen gardening of stone fruits. Even it can be grown in pots. It is dwarf, graft compatible, precocious and gave fruiting with all temperate stone fruits.

Prunus japonica

Peach

Plum

2.2.2 Orchard Management

Performance of mango varieties on polyembryonic rootstocks. Growth, yield and quality performance of three semi-vigorous mango varieties released from IARI, viz., Pusa Arunima, Pusa Surya and Amrapali were evaluated on five polyembryonic rootstocks, i.e., K-5, K-3, K-2, Kurakkan and Olour. The maximum fruit weight (298.68 g) and pulp:stone ratio (6.09:1) was recorded when Pusa Surya raised on K-2 rootstock. TSS was influenced significantly due to rootstocks in Pusa Surya being higher either on K-2 or K-3 rootstocks. Significantly lowest acidity was found on K-3 rootstock for Pusa Arunima (0.08%). Tree height was recorded significantly higher in Pusa Arunima on K-3 (3.29 m). Fruiting efficiency and yield efficiency were found highest when K-2 was used as rootstock in all three varieties.

Similarly, growth, yield and quality performance of two commercial vigorous mango varieties were assessed on the above rootstocks. The heaviest fruit in Mallika (322.05 g) and pulp: stone ratio (7.30:1) was recorded on Olour rootstock. In Mallika, significantly lowest acidity (0.17%) was recoded on K-5 followed by Olour (0.22%) rootstock, while in Dushehari it was measured lowest in trees grafted on Olour rootstock (0.12%) which was at par with Kurakkan. The maximum tree height in Mallika (3.03 m) was recorded on Kurakkan, while in Dushehari (2.84 m) it was on Olour rootstock.

Effect of rootstocks on fruit quality parameters of Kinnow. Kinnow raised on seven different rootstocks

Quality parameters of medium vigorous mango cultivars on five polyembryonic rootstocks

Cultivar/ rootstock	Fruit weight (g)	Pulp (%)	Pulp: stone ratio	TSS (^{0}Brix)	Acidity (%)
Pusa Arunima					
K-5	205.55^{ed}	63.29^{ba}	3.94^{fe}	21.05^{ebdac}	0.11^{dgfe}
Kurakkan	206.90^{ed}	55.91^{b}	3.70^{f}	21.68^{bdac}	0.12^{dfe}
Olour	196.58^{ef}	63.47^{ba}	3.93^{fe}	21.83^{bac}	0.10^{dgfe}
K-3	182.83^{efg}	61.73^{ba}	3.69^{f}	19.08^{bedfcg}	0.08^{g}
K-2	254.88^{bac}	64.69^{ba}	4.89^{bdec}	23.33^{a}	0.09^{gf}
Pusa Surya					
K-5	250.10^{bdc}	61.11^{ba}	5.90^{bac}	18.80^{edfcg}	0.19^{a}

Cultivar/ rootstock	Fruit weight (g)	Pulp (%)	Pulp: stone ratio	TSS (°Brix)	Acidity (%)
Kurakkan	223.88^{edc}	64.68^{ba}	5.57^{bdac}	17.00^{fg}	0.18^{ba}
Olour	284.05^{ba}	62.77^{ba}	5.27^{bdac}	20.40^{ebdaca}	0.14^{dc}
K-3	268.78^{bac}	67.61^{a}	5.96^{ba}	22.10^{ba}	0.15^{bc}
K-2	298.68^{a}	68.48^{a}	6.09^{a}	20.00^{bedfc}	0.13^{dce}
Amrapali					
K-5	148.58^{g}	61.92^{ba}	4.07^{fe}	18.63^{edfg}	0.08^{g}
Kurakkan	151.15^{g}	66.77^{a}	4.61^{fde}	18.13^{efg}	0.10^{gfe}
Olour	155.73f^{g}	60.26^{ba}	4.15^{fe}	16.58^{g}	0.11^{dgfe}
K-3	148.05^{g}	66.33^{a}	4.81^{dec}	19.88^{bedfc}	0.10^{gfe}
K-2	145.15^{g}	65.56^{ba}	4.50^{fde}	20.65^{ebdac}	0.08^{gf}
LSD (P ≤ 0.05)	45.41	9.84	1.11	3.06	0.03

were evaluated for fruit quality parameters. Fruit weight (213.37 g), fruit diameter (77.60 mm) was recorded maximum on *Jattikhatti* followed by sour orange rootstock. The number of seeds/ fruit was recorded minimum in Kinnow mandarin budded on sour orange rootstock (20.33), while number of seeds/ fruit was recorded maximum on *Jattikhatti* rootstock. Non-significant differences were recorded with respect to number of segments. The juice recovery percentage (51.31) and TSS° Brix (9.87) were recorded maximum in Kinnow mandarin raised on Troyer citrange rootstock.

Effect of rootstocks on lemon cv. Kagzi Kalan. Lemon cultivar Kagzi Kalan was evaluated on eight rootstocks for growth, quality, and physiological attributes. Trees on RLC-4 rootstock had the highest fruit weight (73.10 g), while juice recovery was found to be the highest on *Billikichli* (41.12%). Acidity and ascorbic acid were measured highest on Troyer citrange (6.86%) and rough lemon (58.67 mg/100 ml juice), respectively. Significantly maximum transpiration was recorded when Troyer citrange was used as rootstock while photosynthetic rate was recorded maximum on sour orange. Tree height was found maximum on rough lemon (3.26 m). Yield in terms of fruit/tree was recorded highest on rough lemon (322 fruits /tree) and lowest was recorded on *Karna khatta* (108 fruit/tree). However, fruit density was found to be the highest on Attani-2 rootstock (9.51 fruits/ m^3 CV) and lowest was recorded on Troyer citrange (1.63 fruit/ m^3 CV).

Performance of grapefruit on different rootstocks. Marsh Seedless and Redblush cultivars of grapefruit budded on different rootstocks differed significantly in respect of tree growth, nutrient status and fruit quality. Marsh Seedless proved most vigorous on sour orange (123.34 m^3 CV) and *Billikhichli* (114.42 m^3 CV), while the highest canopy volume (CV) of Redblush (102.47m^3) was observed on rough lemon rootstock. Leaf macro and micronutrient concentration varied significantly due to rootstocks in both the cultivars. *Karna khatta* and RLC-4 excelled for N, P and K concentration in the leaves of Marsh Seedless, while similar response for Mg was noticed on Troyer citrange. The foliar concentration of N in Redblush was highest (3.93%) on *Jatti khatti*, whereas plants budded on RLC-4 and *Karna khatta* proved superior statistically for leaf K (1.43-1.46%) to other rootstocks. RLC-4 proved a good micronutrient (Zn, Cu and Mn) accumulator rootstock for Marsh Seedless. Redblush showed highest concentration of Zn, Fe and Cu in trees budded on Attani-2, whereas Mn was highest on rough lemon. Rootstocks Attani-1 and Attani-2 proved superior for the yield efficiency of Marsh Seedless grapefruit (0.60-0.70 kg/ cm^3 CV), while the similar response for fruit weight was exhibited by Attani-2, *Jatti khatti* and *Billikhichli*.

For Marsh Seedless, *Jatti khatti*, *Billikhichli* and sour orange proved similar statistically in respect of high juice content (47.35-48.79%), while rough lemon, Attani-2, sour orange and Troyer citrange showed

the higher juice content (47.15-49.95%) in the fruits of Redblush cultivar. Significantly low acid content in the fruits of Marsh Seedless was noticed, while budded on rough lemon, Attani-1, *Jatti khatti*, *Billikhichli* and Troyer citrange.

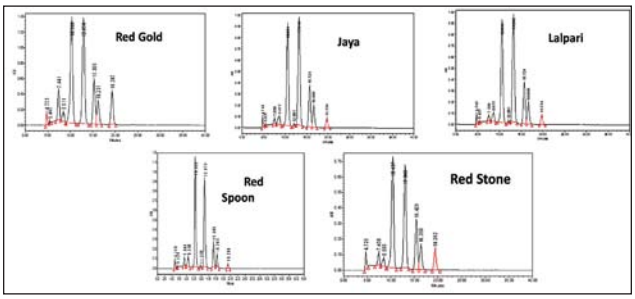
2.3 ORNAMENTAL CROPS

2.3.1 *Chrysanthemum*

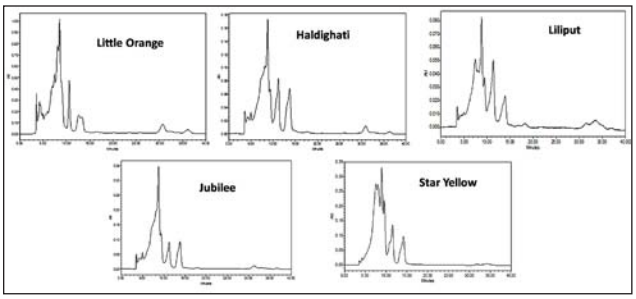
Variety Released. The chrysanthemum variety, Pusa Guldasta is an open pollinated seedling of cv. Lalpari. Plant attains a height of 58 cm with a good spread of 50 cm. It bears semi double medium sized flowers (3.8 cm) with orange red ray florets and yellow disc. The inflorescence is corymb and flowers are borne at almost same height. The flowers (dia. 3.82 cm) stay for longer duration (48 days) under field conditions. The plant is of upright growth habit, very sturdy and branches do not droop down. It does not require pinching and staking. This variety is suitable for spray and pot culture purposes.

A chrysanthemum variety Pusa Guldasta

Profiling of nutraceutical pigments in chrysanthemum. Ray florets of 50 genotypes belonging to shades of red and yellow colour group were utilized for anthocyanin and carotenoids estimation using HPLC. High content of total anthocyanin was observed in Red Gold (212.15 mg/100 g) followed by Lalpari (112.52 mg/100 g), Red Stone (95.27 mg/100 g), Red Spoon (86.33 mg/100 g) and Jaya (69.19 mg/100 g). However, Jubilee (32.82 mg/100 g) exhibited high total carotenoid content followed by Haldighati (26.71 mg/100 g), Little Orange



Chromatograms (wavelength 515 nm) of Cyanidin-3-glucoside of ray florets of chrysanthemum generated by HPLC



Chromatograms (wavelength 450 nm) of lutein and β carotene of ray florets of chrysanthemum generated by HPLC

(22.25 mg/100 g), Liliput (20.77 mg/100 g) and Star Yellow (19.21 mg/100 g). Further, these five promising genotypes were further subjected for quantification of anthocyanins (Cyanidin-3-glucoside: c3g) while another five were subjected for quantification of carotenoids (lutein and b-carotene) using HPLC. The variety Red Gold exhibited highest c3g (2123.60 Eq μg/g) whereas highest lutein was observed in Jubilee (19.90 μg/g) and β carotene in Little Orange (5.51 μg/g).

2.3.2 Gladiolus

Variety Released. Gladiolus variety, Pusa Sinduri is a selection from the open pollinated seedlings of the variety Little Fawn. The variety produces straight and long plants and spikes with more florets per spike. The stem and leaves colour is green. The florets base colour is bright red (44C as per R.H.S colour chart). Two yellowish spots on base of inner tepals with red coloured rainbow type stripe on throat add novelty in colour and make it more attractive. A mid-season variety (105.22 days) with robust and compact spikes. The variety produces long spike (>98.77 cm), having

A gladiolus variety, Pusa Sinduri

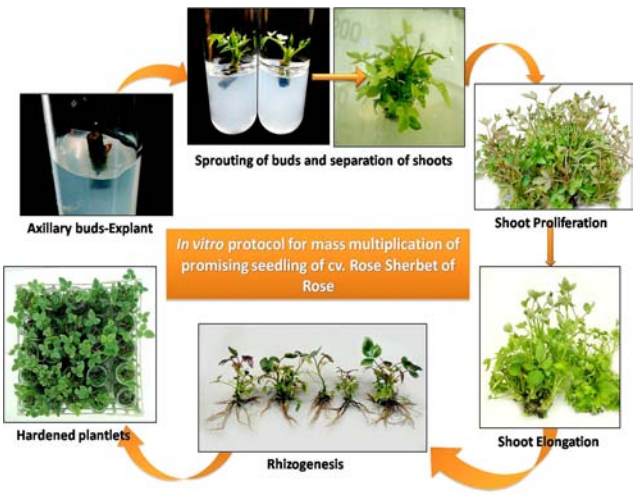
more number of florets per spike (>18.66). In addition, it is a very good multiplier, on an average producing 2.88 corms and 47.77 cormels per corm which makes it more suitable for commercialization. The variety is also suitable for cut flower, bouquet preparation, vase and floral arrangement.

2.3.3 Rose

Promising seedling of Rose Sherbet (SD 6-15). A selection from the open pollinated population of cv. Rose Sherbet. It produces pink (RHS-65-A) coloured large sized blooms. Fragrant flowers, less petal shedding and more flower anchorage. The plants are short and narrow bushy. It is a floribunda type and floriferous. The variety is highly suitable for loose flower purpose in northern plains.

Seedling of cv. Rose Sherbet (SD 6-15)

***In vitro* protocol for mass multiplication of promising open pollinated seedling of cv. Rose Sherbet of *Rosa* × *hybrida* L.** An efficient *in vitro* protocol for mass multiplication of promising open pollinated seedling of cv. Rose Sherbet of *Rosa* × *hybrida* L. was standardized using axillary buds as explant. Out of different pre-treatments for explants, mancozeb-45 (0.2%) + carbendazim (0.2%) + 8-Hydroxy quinolin citrate (8-HQC) (200 mg/l) pre-treatment combination for 4 h agitation on a horizontal shaker (200 rpm) was found optimum. Chemical treatment of pre-treated explants with mercuric chloride ($HgCl_2$) (0.1%) for a duration of 8 minutes followed by 3 washings with autoclaved double distilled water was found effective to reduce contamination in the cultures.Murashige and Skoog (MS) medium supplemented with with 6-benzylaminopurine (BAP) @ 5 mg/l, α-naphthalene acetic acid (NAA) @ 0.1 mg/l and gibberellic acid (GA_3) @ 0.5 mg/l was found most effective for culture establishment, however, MS medium comprising BAP @ 5 mg/l, NAA @ 0.1 mg/l, GA_3 @ 0.5 mg/l, adenine sulphate @ 40 mg/l and sucrose @ 35 g/l along with an additional dose of FeEDTA ($FeSO_4$ @ 27.8 mg/l + Na_2EDTA @ 37.3 mg/l) and nicotinic acid @ 0.9 mg/l, thiamine HCl @ 0.9 ml/l and pyridoxine HCl @ 0.9 mg/l was found to be better for shoot proliferation. Highest shoot elongation was observed in MS medium supplemented with gibberellic acid (GA_3) @ 0.5 mg/l



***In vitro* protocol for mass multiplication of promising seedling of rose cv. Rose Sherbet**

and sucrose @ 35 g/l along with an additional dose of FeEDTA ($FeSO_4$ @ 27.8 mg/l + Na_2EDTA @ 37.3 mg/l) and nicotinic acid @ 0.9 mg/l, thiamine HCl @ 0.9 ml/l and pyridoxine HCl @ 0.9 mg/l. Rhizogenesis was induced on half strength MS basal medium supplemented with NAA (1.0 mg/l) and sucrose (60.0 g/l). The regenerated plantlets were effi ciently hardened in glass jars filled with sterilized coco peat + Soilrite + perlite (1:1:1) supplemented with half strength MS inorganic salts and covered with polypropylene lids, thereafter plants were successfully transferred to the glasshouse with good survival.

2.3.4 Marigold

Promising genotypes. Forty two selections of marigold of *Tagetes patula* and *Tagetes erecta* groups were evaluated during rainy season crop. Among *Tagetes patula* group, five selections Fr. /R-2, Fr. /R-5, Fr. /R-5-1, Fr. /R-5-2 and Fr./R- 14-6 were found very promising for loose flower production fetching good price in the market as they flower during October-November. Among *Tagetes erecta* selections Af/SR-12, Af/SR-15-1, Af/SR-47, Af/SR-49, Af/SR-50, Af/SR-53 and Af/SR-55 were found promising for bedding and loose flower production. Twenty selections of marigold (*Tagetes erecta)* were evaluated in winter season. Among them, selections numbered as Af./w-2, Af./w-4 and Af./w-7 were found promising for loose flower/ bedding purpose whereas selection Af/w-1 showed high carotenoid content.

Profiling of genotypes for antioxidant activities. Among the various genotypes, selection Af/w-6 had highest total carotenoids on fresh weight basis followed Pusa Narangi Gainda and Pusa Arpita. The selections Af/w-6 had highest antioxidant activities measured by DPPH radical scavenging activity (82.17%) and Ferrous Reducing Antioxidant Power (FRAP: 891.12 µmol $FeSO_4$/g fresh weight) followed by Af/w-4 (DPPH: 81.55%; FRAP: 809.30 µmol $FeSO_4$/g) and Pusa Narangi Gainda (DPPH: 76.02%; FRAP: 711.39 µmol $FeSO_4$/g). Af/w-4 (136.17 mg GAE/g fresh weight) showed highest phenolic content followed by Af/w-6 (125.48 mg GAE/g fresh weight) and Af/w-3 (119.83 mg GAE/g fresh weight). The selection Af/w-4 showed highest total flavonoid content (65.13 mg RE/g fresh weight) followed by selection Af/w-6 (55.17 mg RE/g fresh weight) and Af/w-3(50.89 mg RE/g fresh weight). This has provided useful information for effi cient utilization of pigments of marigold flowers for further industrial use viz., carotenoid extraction, marigold powder production, food colourant, etc.

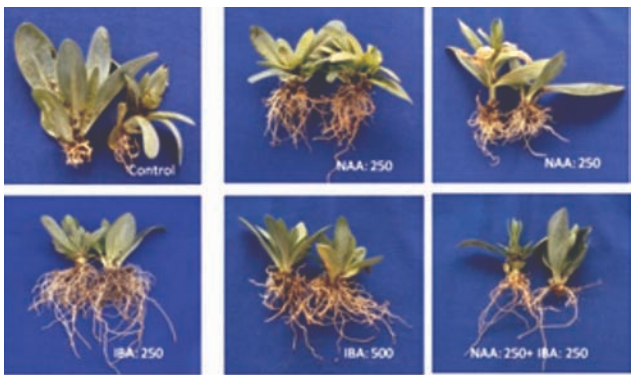
2.3.5 Eustoma

Standardization of planting time. Under poly-house conditions at Kullu, it was found that April was the best time to transplant Eustoma. The maximum plant height (51.0 cm), stem length (42.9 cm) and the maximum number of flower buds per stem (9.7 buds/ stem) was observed in April transplanted crop. The July transplanted crop took minimum (62.7 days)

Effect of pinching on the growth and flowering of Eustoma genotypes: a: Non pinched plants; b: Single pinching done one month after transplanting

days to flower, whereas, September transplanted crop took maximum (235.5 days to flower). Rosetting of plants was more prevalent in September/ October transplanted crop. By adjusting the time of transplanting, flowering in Eustoma can be obtained from April to November. The effect of pinching was studied on growth and flowering of seven different Eustoma genotypes. The earliest flowering (73.3 days) and maximum stem length (45.3 cm) was observed in non pinched plants of Echo Double Champagne and Echo Double Blue, respectively. The number of flowering stems was significantly increased on pinching in all the genotypes. However, flowering was delayed and plant height and stem length were significantly reduced on pinching.

Effect of growth regulators on vegetative propagation. Treatment of Eustoma cuttings with 250 ppm Indole-3-butyric acid (IBA) for 10 minutes induced maximum rooting. The maximum rooting was observed in Echo Double Pink Picotee (78.8%) followed by Echo Double White (71.9%). Echo Double Yellow (48.9%) and Echo Double Lavender (55.3%) showed poor rooting. IBA induced roots were long, whitish with well distributed root hair all through the roots. NAA induced roots were short, brownish with less number of root hairs. The combination of IBA and NAA drastically reduced the number of roots per cutting.



Effect of various growth regulators on vegetative propagation of Eustoma 'Echo Double Pink Picotee'

2.3.6 *Lilium*

Inter-specific crosses. With the objective to know the potential significance of triploid for lily breeding, different interploidy crosses (3x×2x/4x) were attempted. Percent seed germination ranged from 0.50% (*Lilium lancifolium* × Asiatic cv. Tresser) to 100% (*Lilium formosanum* × Oriental cv. Sorbonni). Shiraj × Pollyanna cross took minimum number of days to germination (15.0 days). Minimum number of days (80.0 days) for true leaf emergence was observed in a cross between Asiatic hybrid lily cv. Pollyanna × OT cv. Yellow Ween. Maximum viable seeds (1088.0) were counted in a cross between Eyeliner × Pollyanna.

Interspecific crosses of *Lilium* were evaluated for different growth and development parameters. The crosses between KILH-13 × Prato and KILH-13 × Brunello showed significantly early flowering. These crosses took 322.0 and 349.3 days, respectively, from seed sowing to flowering. These two interspecific crosses took 298.0 and 311.3 for bud formation and had flower size of 9.8 and 8.7 cm, respectively. Maximum average bulb size (12.09 cm) was recorded in Cl-8, a cross between KILH-13 x Prato followed by Cl-60 (10.99 cm). Cl-17 of the same cross produced more number of bulbs (4.0) with an average size of 8.95 cm. The results demonstrate favourable possibilities for interspecific cross-combinations in *Lilium* and have offered opportunities for the introduction of desired new traits in other *Lilium* cultivars.

Interspecific progenies of a cross between 'KILH-13 x Asiatic hybrid cv. Prato (A) and KILH-13 x Asiatic cv. Brunello (B)', and C. Bulb size (KILH-13 x Asiatic hybrid cv. Prato)

Non-vernalized bulbs of 46 *Lilium* hybrids were evaluated for various growth and flowering traits under open field. Significantly, early flowering was recorded in cv. Salmon Classic (227.0 days) followed by Best Seller (230.0 days). Maximum number of flowers

(16.1), inflorescence length (37.9 cm), number of bulbs (2.7), and number of bulblets (13.01) were recorded in cv. Eyeliner. The cultivar Yellow Ween produced largest sized bulb (22.39 cm). Maximum bulblet size (10.05 cm) was noticed in cv. Pavia.

2.3.7 Alstroemeria

Periodicity of growth in Alstroemeria. A wide range diversity for days to flowering (137.15-176.67), plant height (35.33- 105.13 cm), spike length (26.67-94.17 cm), number of leaves (18.43-38.02), rachis length (7.27-19.30 cm), leaf length (7.77-14.20 cm), number of flowers per spike (4.33-14.83), inflorescence longevity (12.00-30.92 days) and number of shoots per plant (6.75-32.33) was observed in nine diverse genotypes of *Alstroemeria*.

2.4 SEED PRODUCTION OF HORTICULTURAL CROPS

The Division of Vegetable Science, Seed Production Unit, IARI, New Delhi, IARI Regional stations at Karnal, Katrain, Pune and Pusa (Bihar) produced nucleus, breeder, and IARI-TFL seeds of different horticultural crops during the period under report. In addition to seed production, 23288 saplings of fruits trees were also produced at IARI regional stations, Karnal and Pusa (Bihar).

Seed production of horticultural crops

Division/Unit/Stations	Seed production (tonnes)			
	Nucleus	Breeder	IARI-TFL	Total
Division of Vegetable Science				
Vegetable crops		0.05	1.41	**1.46**
Seed Production Unit, New Delhi				
Flower crops	0	0	0.05075	**0.05075**
Vegetable crops	0.00825	0.0972	2.4712	**2.57665**
Regional Station, Karnal				
Vegetable crops	0.15	5.60	2.28	**8.03**
Regional Station, Katarin				
Vegetable crops	0.093	0.016	3.5	**3.609**
Regional Station, Pusa				
Papaya			0.016	**0.016**
Total	**0.25125**	**5.7632**	**9.72795**	**15.7424**

Propagation of Horticultural crops

Division/Unit/Stations	Number of saplings
Regional Station, Karnal	8,382
Regional Station, Pusa	14,906
Total	**23,288**

3. GENETIC RESOURCES AND BIOSYSTEMATICS

The Institute has a vibrant programme not only on collection and maintenance of germplasm but also on utilization of germplasm for enhancement of yield and other desirable traits. A large number of germplasm lines including some wild species were maintained, evaluated and utilized in pre-breeding and genetic enhancement in various crops. The chapter also includes biosystematics and identification services related to pathogens, insects and nematodes to explore, conserve and enrich the culture collections.

3.1 CROP GENETIC RESOURCES

3.1.1 Wheat

Maintenance and utilization of wild and related species of wheat. More than 250 accessions of wild and related species from primary, secondary and tertiary gene pool were maintained and some of them were utilized in alien introgression programme. The cytologically stabilized introgression lines from *Aegilops markgraffi*, *Aegilops speltoides* and *Triticum militinae* were evaluated against diverse races of leaf rust pathogen and found to provide broad spectrum resistance. One of the *Triticum militinae* introgression line TMD 11-5 having broad spectrum resistance against 15 diverse races of *Puccinia triticina* showed resistant reaction of " ; " to "1^{+}". The gene controlling the resistance has been mapped on 5BL chromosome of wheat and further genotyping is being undertaken to identify closely linked markers for its utilization in MAS.

Promising wheat genetic resources for disease resistance. Wheat genotypes viz., WBM3713 (FLW16+*Yr*5/VL876), WBM3717 (FLW16+*Yr*5/ EC582298), WBM3721 (VL906/FLW13+*Yr*15) and WBM3733 (WBM2112/ FLW13+*Yr*15) developed through bulk-pedigree method of breeding, were found resistant to new virulent stripe rust pathotypes 110S119, 238S119, 110S247 and *Pst* mix under green house conditions. Eighty six advanced bulks of wheat were evaluated for seedling resistance against pathotype 121R63-1 of leaf rust, out of which 19 were resistant. Preliminary Disease Screening Nursery comprising 584 wheat breeding lines were evaluated for adult plant response to stripe rust under natural conditions at rust hot spot Dhaulakuan. The APR score was recorded as, 151 lines (free), 98 lines (TR-10MR), 72lines (5MS-10MS), 178 lines (10S-20S), 81lines (30S-e"40S), 04 lines (NR=Not recorded). To identify Karnal bunt resistant genotypes, a set of 35 genotypes were inoculated artificially. Of these, 11 genotypes showed less than 5% infection hence considered promising.

Pre-breeding and handling of segregating materials of wheat. A total of 3052 segregating breeding lines of wheat were evaluated for rust resistance and agronomic features at rust hot spot, Dhaulakuan, out of which 1787 were selected in the process of developing superior breeding lines. Besides, 1678 segregates representing 123 diverse crosses of wheat were selected for advancing to next generations.

3.1.2 Rice

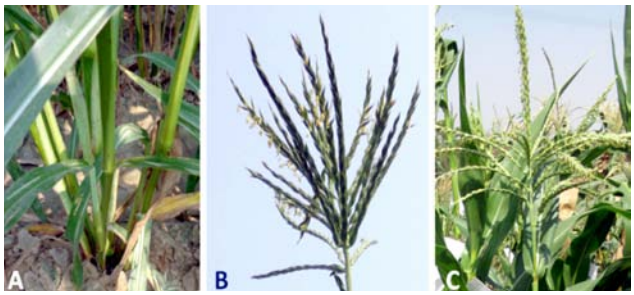
Pre-breeding development and evaluation of introgression lines. A set of 144 F_6 families derived from two wide crosses with *O. rufipogon* and *O. nivara* were evaluated for various agro-morphological traits during *kharif* 2016. Additionally, 50 test crosses involving these introgression lines were also evaluated for agronomic performance, so as to enable identification of heterotic crosses as well as specific introgressions from wild rices for improving productivity in hybrid rice. Additionally, a set of 20 accessions of *O. rufipogon* and *O. nivara* were evaluated and data recorded for different traits.

Evaluation of rice germplasm for yield and other components related to yield stability. A set of 210 tropical *japonica* rice (TPJ) germplasm lines were assessed with gene based/ linked markers for fertility restorer genes, *Rf3* and *Rf4* for identification of potential restorers and maintainers. The identified genotypes were further crossed with *indica* rice genotypes for improvement of parental lines in hybrid rice breeding. A set of 550 rice genotypes, including mega varieties, short grain aromatic rice, NPTs and lines collected from different parts of country were evaluated for yield and components such as number of tillers per plants, plant height, panicle length, days to 50% flowering, days to maturity, number of grains per panicle, spikelet fertility and 1000-grain weight during *kharif* 2016. Further, these lines were also inoculated for screening by different isolates of *Xanthomonas oryzae pv. oryzae* (*Xoo*), causal organism of Bacterial blight (BB), and resistant lines utilised in crossing progamme.

Field evaluation of rice germplasm lines during *kharif*-2016

3.1.3 Maize

Maize × teosinte hybridization. A teosinte accession was evaluated for morphological characteristics such as tillering habits, tassel type, pollen production, prolificacy, seed structure and plant type. Pollens from teosinte were crossed with 19 elite maize inbreds. Viable and fertile F_1s from each cross were successfully raised. The F_1s showed intermediate characteristics, and were backcrossed to elite inbreds.



A: Tillers; B: tassel type of teosinte; C: tassel characters of maize x teosinte hybrid

Genetic resources for nutritional quality and specialty traits. Promising germplasm, genotypes and inbreds with various combinations of genes such as *crtRB1*, *lcyE* (for provitamin-A), *opaque2*, *opaque16* (for lysine and tryptophan), *VTE4* (for vitamin E), *sh2*, *su1*, *sh2*/*su1* (for sweetness), *wx1* (for waxy texture), *lpa1*, *lpa2* (for low phytate), besides CMS-system (for male sterility) were maintained.

Maintenance and generation advancement of segregating populations. Segregating population consisting of 476 progeny rows with different levels of inbreeding were maintained and advanced to their respective next generations. A total of 73 F_3 families consisting of 290 progeny rows were advanced to F_4 generation. Similarly, a total of 186 lines from 65 F_6 families were advanced to F_7 generation. At every level of generation advancement, medium to late maturing progeny rows/lines with high yielding potential were selected. Among the 186 lines, 74 lines were medium maturing and 112 lines found to be late in maturity.

Maintenance and utilization of germplasm. A total of 463 germplasm belonging to different maturity group (200 - early, 122 - medium and 141-late) were maintained by selfing. Among them 25 lines each from medium and late maturing categories are being utilized in developing respective maize hybrids.

DUS Characterization of maize inbred lines. Highly stable, 24 inbred lines were categorized for 31 DUS characteristics. Significant phenotypic

variations have been observed among the inbred lines. After multi-year evaluation, it will be registered in NBPGR for different yield attributing/ special characters.

Identification of biotic stress tolerant genotypes. A set of 100 newly developed maize inbreds were screened against TLB and MLB under artificial epiphytotics. LM13 was found to be highly resistant to TLB. The inbreds, PDM-4641, BLSB-5, CDM-108, DIM-113, PDM-78, PDM-134 were resistant to both TLB and MLB. During the *kharif* 2016, there was heavy incidence of TLB, MLB, common rust, Curvularia leaf spot. This provided opportunity to screen inbreds against these diseases under natural epiphytotics. Fifteen inbreds showed multiple disease resistance. The inbreds such as DDM-306, DIM-307, DIM-308, DIM-309,etc. exhibited multiple disease resistance.

Responses of LM13 against TLB incidence

3.1.4 Pearl Millet

Maintenance of germplasm. A total of 1078 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.

Maintenance Breeding of cytoplasmic male sterile lines. A total of 2110 paired crosses were attempted in 55 CMS lines (A/B) belonging to A_1, A_4 and A_5 cytoplasms for maintenance. About 3050 bulk crosses were made in 6 promising CMS lines for further utilization in developing hybrids with good grain and fodder yields.

Maintenance breeding of restores/inbreds. Four hundred and eighty nine elite inbred lines were maintained by selfing. These inbred lines possessed desirable traits like early maturity, thick spike, compact spike, disease resistance, good tillering and overall agronomic superiority and are to be tested for combining ability. Some of them are also having high lysine, tryptophan, Fe and Zn contents.

Introduction of new cytoplasmic male sterile lines from ICRISAT. Sixty three designated CMS lines selected at ICRISAT field day were evaluated for their suitability to early maturity, disease resistance, spike thickness, compactness and overall agronomic traits. Twenty seven A/B pairs were found promising and further evaluated during *kharif* 2016 and seed of these A/B pairs was also multiplied.

3.1.5 Chickpea

Germplasm evaluation. More than 500 germplasm lines were evaluated for phenology, erect plant type and other morphological traits. These lines will also be evaluated for protein and other quality parameters. Fifty chickpea genotypes consisting of released varieties, newly developed breeding lines of *desi* and *Kabuli* chickpea obtained from ICARDA, Syria and ICRISAT, were estimated for their protein content which ranged from 20.03 to 29.57% with an average of 24.23%.

3.1.6 Pigeon pea

Maintenance of germplasm. About 300 germplasm lines, contrasting for reaction to diseases, have been maintained. Besides, 180 germplasm lines of medium duration and five accessions of wild species were also maintained.

3.1.7 Mustard

Maintenance of germplasm. Total 782 germplasm lines including *B. juncea* (472), *B. carinata* (170), *B. napus* (31), *B. rapa* (44), *B. oleracea* (6), *B. nigra* (15), *B. tournifortii* (2), *B. caudatus* (1), *R. caudatus* (4), *R. sativa* (1), *S. alba* (1), *Eruca sativa* (6), *Crambe* spp. (2), *Lapidium* spp (1), *Camellina* spp. (1) and wild species (25) have been maintained by selfing and used in crossing programme. Twenty new accessions for dwarf plant type and disease resistance were added and used in crossing programme. In addition, a set of 102 genotypes contributed by IARI, DRMR, Bharatpur, PAU, Ludhiana and HAU, Hisar under CRP on Hybrid Technology was also maintained and evaluated.

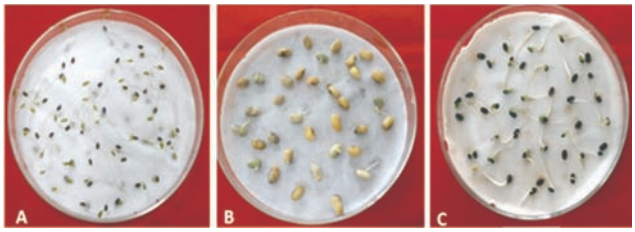
Evaluation and maintenance of introgression lines and exotic genotypes. Twelve introgression lines developed from *Brassica juncea/B. carinata* crosses were evaluated along with *B. juncea* (Pusa Vijay and DRMRIJ 31) and *B. carinata* (Pusa Swarnim and Pusa Aditya) under timely sown conditions. These lines maintained resistant reaction to the white rust disease. One hundred and ten progenies of exotic genotypes (EC 27, EC 28, EC 30, EC 60, EC 61 and EC 62) were raised and 70 progenies selected following pure line selection for their purification and maintenance.

Evaluation of double zero breeding lines. Ten double zero genotypes from advance generations and MAS derived lines in the background of Pusa Mustard 21 and Pusa Karishma were evaluated for their yield performance. Out of these, two promising lines viz., PDZ 7 (LES-1-27 x EC-597325) and PDZ 8 [(LES-39 x EC597325) LES-39*4] were contributed for AICRP Rapeseed Mustard trials during 2016-17.

Breeding for white rust resistance. Well adapted genotypes were crossed with white rust resistant donors like Bio-YSR, BEC-144, BEC-286, Heera and EC-399299 and 486 progenies in F_4, F_5 and BC_1F_4 generations were raised at IARI Regional Station, Wellington, and 359 single plants selected. Progenies of these resistant plants (F_5, F_6 and BC_1F_5 generations) were evaluated and 77 single plants selected for white rust and agronomic traits at New Delhi during 2016-17.

3.1.8 Soybean

Evaluations of RILs for seed coat permeability and germinability. Seeds of about 100 inter-specific (*Glycine soja* x *G max*) recombinant inbred lines (RIL) along with the parental lines were tested for seed coat permeability and germinability after 3 years of ambient storage. Seeds of the wild type genotype (DC2008-1) were impermeable but remained highly viable (83% germination). Contrarily, seeds of the cultivated genotype (DS9712) were permeable but lost viability rapidly (11% germination). Germinability of the RILs ranged from 0-85% with permeability ranging from 0-100%. In general, lines with high permeability were found to have poor viability and *vice-versa*. However, seeds of 4 RILs were found to maintain both high viability (77-85% germination) and permeability even after 3 years of ambient storage. Seeds of these lines are also being tested for biochemical compositions and structural variations in the seed coat.



Variation in seed viability in wild type, cultivated and inter-specific RILs after 3 years of ambient storage. A: wild type (*G soja*) acccession. B: Cultivated type genotype, and C: RILs

3.1.9 Vegetable Crops

Cauliflower. In early group, 78 fertile inbred lines were evaluated and maintained and 15 of them used for hybrid development. Nine self incompatible (SI) lines, namely, cc12, 13, 14, 15, vv, 327-14-8-3, 395aa, 351aa and xx were assessed for curd characters, tested for SI level and selected plants were multiplied through bud pollination. *Ogura* CMS system is maintained in three genetic backgrounds (Pusa Meghna, DC 41-5 and DC 23000) and used in hybrid development. Besides, 8 new CMS converted lines were used again in hybrid development. Field reaction of 78 inbreds and 11 CMS lines to diseases viz., downy mildew, black rot and *Alternaria* blight was recorded. A total of

235 lines of snowball cauliflower along with 35 CMS lines and their maintainers were maintained as core set of Germplasm at Katrain.

In mid-maturity group, five SI lines, namely, cc32, cc35, cc22, ccm-5 and ccm were assessed for curd characters, tested for SI level and advanced through bud pollination. Forty two inbred lines were evaluated; maintained and promising nine inbreds were used for hybrid development. *Ogura* CMS system established in five genetic back grounds was maintained and exploited in hybrid development. Evaluated 35 advance stage CMS conversion lines (with *Ogura* system) for curd and CMS characters and selected seven for further conversion process to use in hybrid breeding for mid-late maturity group. Individuals of advance generations of 143 RILs for black rot resistance were evaluated for disease and horticultural traits and advanced to next generation.

Cabbage. Two inbred lines and two CMS lines of 'no-chill' cabbage were maintained by bud pollination. Conversion process of two new lines of tropical 'no-chill' cabbage into CMS lines was initiated. At IARI Regional Station, Katrain, 180 new exotic collections of cabbage received from NBPGR have been characterized and about 50 already available germplasm lines of cabbage along with 10 self-incompatible lines, 20 CMS lines along with their respective maintainers have been maintained. Seeds of 130 EC lines along with their characterization data have been submitted to the NBPGR.

Broccoli. At IARI Regional Station, Katrain, 15 germplasm and 5 CMS lines along with their maintainer lines were maintained. Twelve new EC lines received from NBPGR have been characterized and being maintained.

Cucumber. A total of 65 germplasm including wild relatives with novel traits consisting of gynoecious lines, carotene rich cucumber, disease resistant, parthenocarpic, gherkin types, and multiple pistillate types collected from NBPGR and other sources were maintained and utilized in the breeding programme. The carotene rich lines IC 420422 and LOM 402 were found to be very promising with dark orange flesh colour on ripening. The Chinese line CL 746 and CL 749 showed tolerant reaction to powdery mildew disease.

Luffa. Fifty five germplasm/advance breeding and virus resistant lines of sponge gourd were maintained. In ridge gourd, 32 advance breeding lines including Satputia and its genetic stock were maintained. Six gynoecious lines showing true gynoecious behaviour were maintained by using Silver thiosulphate (3Mm) twice at 10 days interval.

Pumpkin. Seventy germplasm/advanced breeding lines of pumpkin were evaluated and maintained.

Watermelon. Twenty new germplasm of *Citrullus colocynthis* were collected from *in situ* growing areas of Kutchh district of Gujarat for screening against watermelon bud necrosis virus, salinity and drought.

Long melon and Round melon. Twenty germplasm/advanced breeding lines each of long melon and round melon, respectively, were evaluated and maintained. Long melon line DLM 19-2 with segmented leaf was also maintained.

Brinjal. One hundred thirty working germplasm were purified, evaluated and maintained. Forty one wild accessions of *Solanum* collected from Solanaceae Germplasm Bank, Netherland were grown for seed regeneration and characterization.

Tomato. Four tomato wild species viz., *S. habrochaites* (EC871099, EC803503, EC803504), *S. chilense* (EC803506, EC803507, EC803511), *S. corneliomulleri* (EC871096) and *S. cheesmaniae* (EC803494) were evaluated for resistance to late blight, Tospo viruses and TLCV resistance. All the germinated wild species were characterized for their DSI, mating system, flowering time, flower colour, style exsertion and other vegetative characters. The hand emasculation and pollination work was carried out to maintain each accession of different wild species.

Sweet pepper. A total of 100 new accessions of different Capsicum spp. imported from USDA were evaluated, characterized and maintained for various

horticultural traits. Fifty germplasm lines of capsicum were purified and maintained. Three CMS lines along with their maintainers of capsicum were purified and maintained.

Carrot. Inbred lines of early season carrot (31) and normal season (63) were evaluated for root traits and field reaction to common diseases. The selected roots were planted for maintenance and use in hybrid breeding. One hundred twenty four accessions (from NBPGR) were evaluated for their root traits and roots are planted for multiplication. Two CMS lines in early group and five CMS lines in normal season were maintained.

Onion. Forty nine commercial varieties, 12 exotic, 20 onion germplasm and 2100 combinations comprising of male sterile and fertile lines were planted for test cross production.

Garden pea. Thirty five germplasm lines of garden pea were rejuvenated.

Okra. One hundred twenty cultivated and 21 wild accessions of okra were maintained.

Lettuce. Forty-four lettuce germplasm lines were maintained. Out of these, 3 are Iceberg/ heading type, 7 butter head, 28 loose leaf, 4 cos or romaine and 2 stem lettuce types.

3.1.10 Fruit Crops

Apple. At IARI Regional Station, Shimla, seven types of *Malus baccata* and two types of *Malus sikkimensis* from different agro-climatic regions have been collected. Significant differences for their botanical and horticultural traits have been observed. The crab apples from Shillong and Srinagar exhibited a very good propagation potential, showed a high degree of resistance to powdery mildew and apple scab All the crab apples exhibited a considerably less chilling hour requirement as compared to the standard apple rootstocks M-9, M-26, MM-111 and MM106. The germplasm that holds promise for using rootstock viz., *Malus baccata* (Shillong), *Malus baccata* (Srinagar), *Malus baccata*(Rohru), *Malus baccata* (Lahul), *Malus baccata* (Kinnaur), etc. or in breeding programme for disease resistance or as pollinizers has been identified for the improvement of apple.

Surveyed Lahaul-Spiti areas of upper H.P. and collected different species of *Malus* (02) viz; *Malus baccata* Jalma and *Malus baccata* Lahaul. Besides, elite walnut genotypes (04) were also collected from Udaipur areas of Lahaul. Apricot genotypes (04) suitable for dehydration/drying and thin shelled walnut genotypes (04) also collected from Nichar areas of Kinnaur district.

Pummelo. Five pummelo superior clones of from different farmer's fields, having thin and smooth rind, high TSS (>11.0^{0}Brix) and dark red aril colour were collected and grafted on rough lemon rootstock. Three clones survived and variation in plant height, canopy spread and leaf shape and size was observed, indicating the existence of variability in the seedling. Flowering was observed in three clones, but fruit set observed in two clones only.

3.1.11 Ornamental Crops

Rose. Thirty six varieties (Ahimsa, American Pride, Ametista, Audrey Wilcox, Ave Maria, Black Delight, Bronze Star, Bugatti, Camara, Canary, Charles Mallerin, Cryzia, Figaro, Fragrant Cloud, Ganges Mist, Girija, Hidalgo, High Esteem, Home of Time, Honest Red, Horticolor, Inspiration, Lemon Spice, Madam Violet, Marcel Pagnel, Matt God, Naga Belle, National Velvet, Nefertiti, Pranabanandjee, Red Devil, Red Pirate, Royal Canadian, Scarlet Knight, Stainless Steel, and Valencia) of rose were collected from Midnapore, West Bengal.

Marigold. Two marigold varieties, namely, Hisar Beauty and Hisar Jafari and one accession were procured from Hisar and Ranikhet, respectively.

Other flower crops. Forty six cultivars and 10 species of *Lilium*, 20 species/varieties of *Iris*, 15 hybrids/varieties of *Eustoma*, 25 varieties of Tulip, 22 varieties of *Narcissus*, 20 varieties of *Dahlia*, 10 varieties of *Alstroemeria*, 25 varieties/hybrids of *Gladiolus*, and hybrids/varieties of other bulbous crops like torch lily, wattsonia, *Canna*, *Amaryllis*, crinum, *Freesia*, *Tithonia*,

tuberous begonia, cyclamen, zinger lily, *Lycoris*, *Primula*, primrose, temperate orchids and some wild ornamentals are being maintained.

Turfgrasses. Three species of turf grasses, namely, *Axonopus affinis, Eremochloa ophiuroides* and *Paspalum veginatum* were collected and maintained.

3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Pathogens

Maintenance and Preservation. About 3982 fungal cultures at Indian Type Culture Collection (ITCC) were maintained under different preservative methods.

New additions. The fungal collection was enriched by new addition of 30 different fungal cultures at ITCC.

Culture Supply. In all, 304 authentic fungal cultures were supplied on payment to various scientific and industrial institutions on request.

Identification Services. A total of 233 cultures were identified up to species level. Mostly these are plant pathogens, post harvest pathogens, bio-control agents and industrial use fungi belong to Hyphomycetes, Coelomycetes and Zygomycetes.

Development of DNA barcode for the species identification of Curvularia. Out of different DNA sequences of GPDH, ITS, LSU, SSU and tef-1, ITS was selected as primary barcode and better marker for *Curvularia* species identification.

3.2.2 Insects

Around 3241 insect specimens were examined under identification service sent from different Institutions/Organizations across the Country.

Coleoptera. Survey and surveillance was carried out in North East India covering Assam, Nagaland, Tripura, and Meghalaya, and in North and South India covering Haryana, Tamil Nadu, and Kerala for white grub species diversity. Around 2542 adult specimens of Melolonthinae, Rutelinae and Dynastinae were collected through light traps. The faunistic composition of collected scarabaeid beetles comprised of 86 species under 22 genera of which 39 species under 13 genera belonged to Melolonthinae, 44 species of six genera belonged to Rutelinae and three species under three genera belonged to Dynastinae. Taxonomic studies were carried out on scarab fauna of Meghalaya and Tripura, which resulted in 23 and 35 species under 11 and 13 genera, respectively. Egg morphology and chorionultrastructures of five species viz., *Lepidiota albistigma, Asactopholi* ssp., *Anomala stenodera, Anomala rugosa* and *Anomala* sp. were carried out through SEM studies and species delineating features documented.

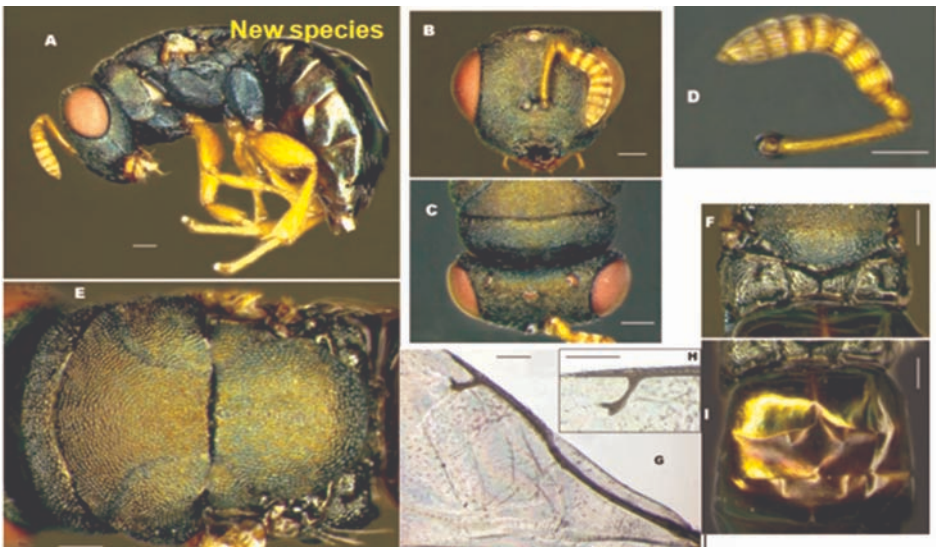
Larval characterization of five white grub species viz., *Leucopholis lepidophora, Leucopholis burmeisteri, Adoretus flavus, Adoretus nitidus, Adoretus excises* were carried out and described through 115 line drawings and 105 photographs. This is the first documentation of larval descriptions of these scarab species. Description of seven species of Rutelinae viz., *Anomala bilunata, Anomala varivestis, Anomala bilobata, Anomala anguliceps, Anomala xanthoptera, Anomala signaticollis, Anomala fulviventris* collected from Meghalaya and Tripura were carried out and documented the characters through 119 line drawings and 112 photographs. Scanning electron microscopy studies of antennal sensilla were carried out in six species of Melolonthinae viz., *Holotrichia serrata, H. nagpurensis, H. consanguinea, Lepidiota mansueta, Leucopholis lepidophora* and *L. burmeisteri* to confirm the diversity, distribution and density of mechanoreceptors and chemoreceptors documented.

Taxonomic studies on longhorn beetles of Cerambycidae of North East region were carried out and documented the faunistic composition, nearly 45 species under 27 genera were documented from Medziphema, Nagaland. DNA barcoding of four major pestiferous species viz., *Batocera rufomaculata, Batocera rubus, Celosterna scabrator, Stromatium barbatum* of Cerambycidae was carried out through partial mt co1 sequencing and sequences submitted to NCBI. Checklist of Prioninae of Cerambycidae was prepared.

Diptera. Studies on diversity of syrphids of Delhi was undertaken based on surveying different habitat (Agroecosystem-IARI, Mesophytic and marsh ecosystem-Govt. Sundar nursery, Mesophytic and Garden Habitats- Lodhi Garden, Ridge forest vegetation-Budha Jayanthi Park) and also based on studying museum specimens which yielded 43 species of syrphids from Delhi, out of which 23 are new records. Fifteen rare ones were photo documented and an illustrative key for syrphids of Delhi was prepared. Redescription of the seven species of genus *Eristalinus* (Diptera: Syrphidae) with color plates, photographs of male genitalia completed. Field surveys were conducted at Palampur (HP), Bharot, (HP), Bhimtal (UK), Mukteswar (UK), Agarthala, Jhorhat (Assam), Metziphema (Nagaland), Tripura University (Tripura), Umaium (Meghalaya) to study the faunistics of syrphids in the Himalayan and the north eastern region and collected 350 specimens of 35 species of syrphids which included 22 new records. Survey at various places of Western Ghats region in four states (Kerala, Karnataka, Goa and Maharashtra) was carried out to collect 70 specimens of syrphids and 160 specimens of other Diptera.

Hemiptera. Survey and collection were carried out in 13 different locations in IARI, Himachal Pradesh, Karnataka and Meghalaya. Collected specimens were sorted, of which 1251 specimens belonging to 9 subfamilies, Deltocephalinae, Cicadellinae, Penthiminae, Coelidinae, Evacanthinae, Typhlocybinae, and Signoretinae. New records for the leafhopper genus *Parabolopona* Matsumura from India are provided with description of *Parabolopona zhangi* sp. nov. Three new species, *Sophonia tridenta* sp.nov. (Sikkim: Gangtok), *Sophonia vidarvya* sp. nov. (Meghalaya: Barapani) and *Sophonia intricata* sp. nov. (Himachal Pradesh: Katrain) from India are described and illustrated. A review of the coelidiine leafhopper genus Mahellus (Hemiptera: Cicadellidae: Coelidiinae) with description of two new species from the Oriental region. Two new species of the genus *Mahellus* Nielson, *M. cordoni* sp.nov. (Indonesia: Sulawesi) and *M. ungulatus* sp. nov. (India: Kerala, Karnataka, Tamil Nadu) have been described and *M. distanti* Nielson is also illustrated with several new locality records.

Hymenoptera. A checklist of fig wasp species (Hymenoptera: Chalcidoidea) recorded from India till 2015 was compiled from different parts of India which includes 115 fig wasp species belonging to 33 genera and 4 families. Seventy six new distribution records were established for different fig wasps within



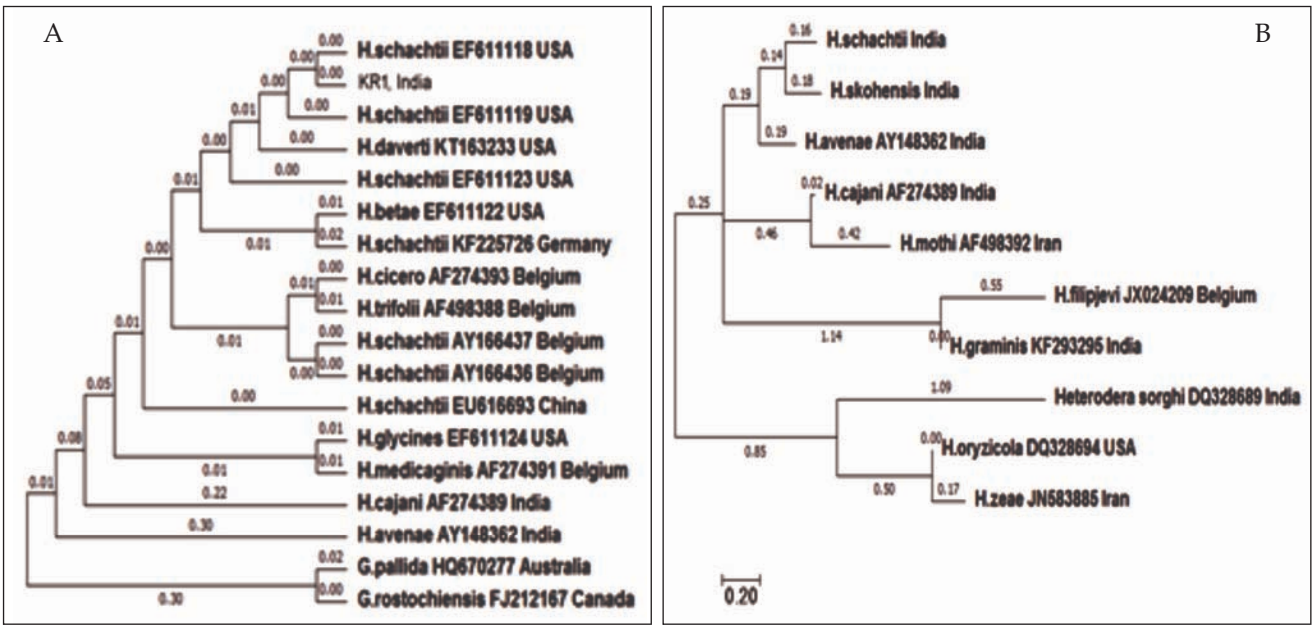
***Walkerella tridentate* sp. nov. Holotype♀: A. habitus, lateral view; B. head, frontal view; C. head and pronotum dorsal view; D. antennae; E. mesosoma, dorsal view; F. propodeum; G. fore wing venation; H. postmarginal and stigmal vein of fore wing (enlarged); and I. first and second gastraltergites. Scale bar 0.1 mm.**

India along with first report of *Ormyrus benjaminae* and *Philotrypesis longicaudata* from India. Two new synonyms were proposed, viz., *Parapilkhanivora nigra* and *P. testacea* syn. nov. for *Sycobiomorphella lacorensis* and *Parasycobia kaurae*, respectively. A new species *Walkerella tridentata* (Otitesellinae: Chalcidoidea, Pteromalidae) reared from fruits of *Ficus amplissima* described. An annotated checklist of genus *Andrena* of India was compiled from all the published literature available. An in depth analysis of the checklist revealed that *Andrena* is represented in India by 23 subgenera and 54 species. All the available synonyms, distribution of subgenera and species have been included along with 27 new distribution records. Species of this genus were found to be distributed in the states of Rajasthan, Punjab, Himachal Pradesh, Gujarat, Uttarakhand, Uttar Pradesh, Bihar, Jammu and Kashmir and Delhi.

Lepidoptera. Survey and collection were carried out at 6 different locations including IARI, New Delhi, Dalang and Katrain (Himachal Pradesh), Jhansi (Uttar Pradesh), Ponmudi (Kerala) and Shivamogga (Karnataka). Collected specimens were sorted, of which 460 specimens belonging to 4 families Noctuidae, Erebidae, Pyralidae and Geometridae processed. Around 40 species of Lepidoptera were augmented to National Pusa Collection and 115 entries of 20 species of Lepidoptera were updated in NPC database. In continuation of previous year work, addition of five species of genus *Mythimna* were studied and 25 photographs were taken showing distinguishing characters on male and female genitalia of *Mythimna* spp. Eight species of *Mythimna* spp. were DNA barcoded and compared with morphological data for authentic identification. Checklist of Genus *Athetis* from India prepared, which includes 3 subgenera and 32 species. Five species of *Athetis* spp. were described.

3.2.3 Nematodes

Identification services. Two cyst forming nematodes (KR1 and KR2) from Kangra and one (KU1) from Kullu district were found in a survey conducted in Himachal Pradesh. Based on morphological, morphometric and molecular characteristics of the cysts and juveniles, KR1 population was identified as *H. schachtii* type, KR 2 population as *H.skohensis* and KU1 population was characterised as morphotype



A. Phylogenetic relationship of *H. schactii* (KR1 population) showing similarity with various populations and (B) Phylogenetic relationship of *H.skohensis* (KR2 population) with other *Heterodera* species present in India

of *H. trifolii.* Evolutionary tree constructed using ITS 2 regions of KR1 and other populations from *H. schachtii* group via maximum likelihood method showed evolutionary closeness of KR1 population with the USA population of *H. schachtii* Phylogentic analysis of ITS from *H. skohensis* showed evolutionary distinctness with other species that occur in India.

Nematode biodiversity in Mizoram. Nematode diversity investigated in Mizoram revealed the occurrence of 12 nematode orders comprising of 35 families and 70 genera, and these 70 genera belonging to the orders Tylenchida (14), Aphelenchida (2), Dorylaimida (26), Mononchida (1), Rhabditida (15), Araeolaimida (3), Monhysterida (1), Triplonchida (4), Enoplida (2), Plectida (2) and Isolaimida (1). Infestation of root knot nematodes (*Meloidogyne incognita* and *M. javanica*) was recorded in some economically important crops of Mizoram. Community analysis of important plant parasitic nematodes in rice-wheat cropping systems indicated high nematode population density of genera like, *Meloidogyne* sp. (35.2), *Rotylenchulus* (8.3), *Hirschmanniella* (56), *Helicotylenchus* (55.4), *Aphelenchus* (13.9) and *Aphelenchoides* (7.9).

Digitization of National Nematode Collection of India (NNCI). Ninety five specimens were digitized using programmable motorized Axioimager microscope. Digitization was done at 63x oil objective at 0.5 µm depths and at 40x for large nematodes.

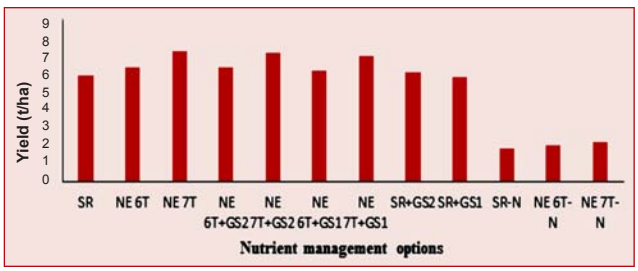
4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

The issues of crop and resource management are being effi ciently addressed through the research in various disciplines of Natural Resource Management (NRM). The significant accomplishments towards the challenging tasks like enhancing crop productivity and farm profitability, improving nutrition and food quality, generating possibilities of higher land utilization, more output per unit of input used and maintaining environmental stability have been made. The research has been focused on the development of energy effi cient, climate smart, multi-enterprise and high input responsive technologies. The need based technological interventions in food quality and post-harvest management of field crops and agri-horticulture based products, value addition and farm mechanization, both for conventional and conservation systems have been the priority area. The effective management of rhizospheric diversity, crop husbandry, farm mechanization, energy management and budgeting, precision nutrient management have been the leading research priorities for NRM. The impact analysis of this technological driven development is also being made through out-reach and extension modules.

4.1 AGRONOMY

4.1.1 Development of Precision Nutrient Management Strategies in Maize under Maize-Wheat System

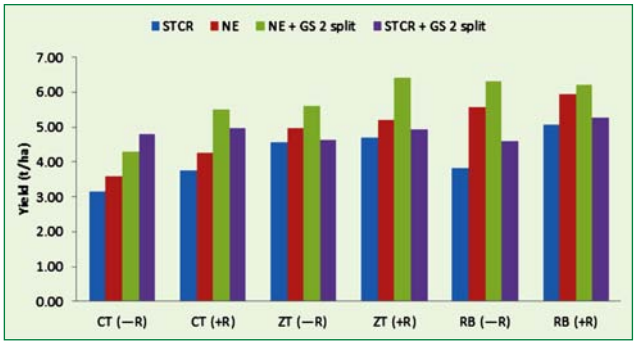
Combined use of decision support tool (Nutrient Expert®, NE) and Green Seeker (GS) was studied during 2016-17 in order to enhance nutrient use efficiency under maize-wheat system at different targeted maize grain yield (6 and 7 t/ha) over existing *Ad-hoc* state recommendation (SR). Result reveal the application of nutrients as per NE had significantly higher maize grain yield along with savings of 12 to 25 kg N/ha and 16-29 kg P_2O_5/ha over SR. Grain yields were maximum with fertilizer applied for the target of 7 t/ha in maize. Further, real time N scheduling at 25 and 42 days after sowing (DAS) through GS along with NE recommendation for 7 t/ha grain yield curtailed 25 kg N/ha over SR with highest agronomic N use effi ciency (31.56 kg grain/kg N).



Effect of different nutrient management options on grain yield of maize under maize-wheat cropping system: 6 T and 7 T= 6 t/ha and 7 t/ha yield target; GS 1= Green Seeker based N application at 42 DAS and GS 2= Green Seeker based N application at 25 and 42 DAS

4.1.2 Developing Nutrient Management Options for Conservation Agriculture (CA) Based Maize-Wheat System

Growing maize on raised bed along with residue retention on surface had significantly higher grain yield as compared to zero tillage and conventional



Effect of crop establishment (with and without residue) and nutrient management options on grain yield of maize under maize-wheat cropping system :CT= conventional till; Zt= zero till; RB= raised bed; (+R)= residue retained on surface; (-R)= no residue

tillage with or without residue management options. Fertilizer applications as per Nutrient expert® (NE) enhanced grain yield by 17.7% over soil test based crop response (STCR) with economizing the nitrogen and phosphorus use. Further, combined use of NE and GS resulted in higher grain yield (16.2%) with higher nitrogen use efficiency (NUE) over Green Seeker (GS) alone. Further, study infer that raised bed planting of maize along with residue retention on surface and fertilizer application using Nutrient Expert® combined with N scheduling through GreenSeeker can bring sustainable high yield of crop and nutrient use productivity.

4.1.3 Improving Sustainable Crop Production and Income under Conservation Agriculture (CA) in Wheat-based Cropping Systems

A medium term study conducted under three major non-rice cropping systems, viz., cotton-wheat (C-W), pigeonpea-wheat (P-W) and maize-wheat (M-W) along with different crop establishment practices namely, zero-till permanent narrow bed (70 cm), broad bed (140 cm) and flat bed with both seasons crop residue and 100% & 75% N applications to the residue-laden plots since fourth year. Results indicate that maize-wheat system productivity and net returns were higher over other cropping systems. System productivity (SP) and net returns (NR) in all Zero till (ZT) (broad, narrow and flat beds) with residue retention during both seasons were higher as compared to their respective no residue plots. In the residue-laden ZT broad, narrow and flat beds plots of the maize-wheat system, the 100% recommended dose of N gave higher SP and NR than 75% recommended dose of N. On the other hand, cotton-wheat system had slightly higher SP in 75% N over 100% N use. Results infer that growing of maize-wheat system is more sustainable in terms of productive profitability under CA based system.

System of wheat equivalent yield (SWEY) and net returns of different wheat-based systems under various tillage and crop establishment options

Treatments	SP (WEY) (t/ha)			NR (Rs x 10^3 /ha)		
	C-W	M-W	P-W	C-W	M-W	P-W
CT	6.65	7.58	6.70	85.28	133.79	111.8
ZT NB	7.57	8.53	7.51	109.88	162.17	134.7
ZT NB+R (75% N)	8.04	9.25	-	108.63	163.97	-
ZT NB+R (100% N)	8.07	9.65	8.29	109.28	173.63	142.7
ZT BB	8.42	8.78	8.12	126.54	167.21	149.3
ZT BB+R (75% N)	8.61	9.94	-	121.68	181.80	-
ZT BB+R (100% N)	8.47	10.10	8.58	119.26	185.35	150.0
ZT FB	8.06	9.42	8.58	120.48	181.49	115.9
ZT FB+R (75% N)	8.10	9.33	-	111.94	168.44	-
ZT FB+R (100% N)	7.21	8.37	7.14	90.87	145.17	150.9

CT = conventional till, ZT = zero till, NB = narrow bed, RB= raised bed, and +R = residue retained

4.1.4 Improving Agro-Management for GHGs Mitigation and Enhancing Soil Organic Carbon Pool in Wheat through Conservation Agriculture

The effect of conservation agriculture on soil organic C status and GHGs emission in wheat was evaluated among six treatments, comprising different tillage and crop residue management options with 100% or 75% N along with Green Seeker®. Results reveals that ZT + 5 t/ha maize residue+ 75% N + the rest N based on Green Seeker had 18.3% lower global warming potential(GWP) as compared to conventional tilled plots without residue but fertilized with 100% N. This CA-based option also resulted in relatively 17.1% lower CO_2 emission over CT-R+100% N treatment. A slightly higher non-labile C but relatively lower labile C than CT-R+100% N treatment was also noticed under ZT based system.

Effect of tillage, residue and N management on GHGs emission and global warming potential (GWP) and soil organic carbon pool in wheat at 0-15 cm soil depth (using Info RCT model)

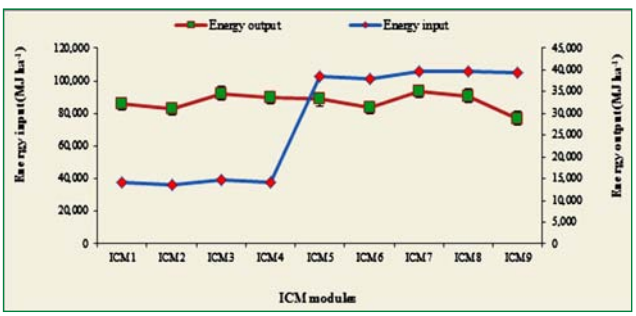
Treatment	N_2O-N (kg/ha)	CO_2-C (kg/ha)	GWP (kg CO_2 eq./ha)	Very labile carbon (%)	Labile carbon (%)	Less labile carbon (%)	Non-labile carbon (%)
CT-R+100N	380abc	321a	584a	0.24a	0.09a	0.20a	0.16a
CT+R+100N	360bc	318a	581a	0.22b	0.10a	0.21a	0.17a
CT+R+75N+GS	330c	301ab	565b	0.29a	0.05b	0.22a	0.17a
ZT-R+100N	440a	289b	513c	0.28a	0.09b	0.20a	0.18a
ZT+R+100N	420ab	280bc	503c	0.24a	0.08b	0.18a	0.17a
ZT+R+75N+GS	390abc	266c	477d	0.30a	0.14a	0.21a	0.18a

4.1.5 Use of Calcium Cyanamide for Enhancing Nitrogen Use Efficiency in *Basmati* Rice Cultivation

A field experiment was conducted to evaluate efficacy of calcium cyanamide (CC) on enhancing nitrogen use efficiency in *basmati* rice indicates significantly higher grain yield 3.3 t/ha with the application of 60 kg nitrogen in combination of 24 kg N as DAP + 30 kg as CC + 6 kg N as neem coated urea (NCU) over control. Such combination gave higher yield by 35.1% over 40 kg N NCU + 20 kg N as CC, 9.5% over 30 kg N as NCU + 30 kg N as CC and 32% over 24 kg N as DAP + 20 kg N as CC + 16 kg N as NCU. The harvest index was also maximum under 30 kg CC based treatments.

4.1.6 Integrated Crop Management Modules for Enhancing Productivity, Profitability and Resource-Use-Efficiency in Soybean

Field study comprising nine different integrated crop management (ICM) modules in soybean, showed that ICM_7 having [Zero-tilled (ZT)-permanent raised bed (PRB) + crop residue retention of wheat (CRR) @ 3 t/ha + 100% recommended dose of fertilizers (RDF) + (Glyphosate-PP fb Pendimethalin-PE fb Imazethapyr-POE + 1 hand-weeding (HW)-mulch) + 4 irrigations + need based integrated disease management (IDM)/ Integrated pest management (IPM) had in highest seed yield (1.92 t/ha), NPK uptake, oil yield and net return (Rs./52067/ha). In addition, this treatment also showed improved resource-use efficiency (RUE) in terms of partial factor productivity of applied nutrients (NPK), profitability, soil physico-chemical and biological properties, total and economic water productivity. On an average, CA based ICM modules showed higher energy input with relatively smaller output over the CT based ICM modules.



Effect of different ICM modules on the energy input and output dynamics in soybean crop

4.1.7 Crop Diversification under Rainfed for Higher Yield and Economics

Field experiment was carried out to study the feasibility of growing crops like pearlmillet, green gram, vegetable cowpea, bottlegourd, okra and babycorn under rainfed situations of trans-Gangetic plains. Among different crops grown maximum pearl millet equivalent yield (14.5 t/ha) was recorded with babycorn followed by bottle gourd (9.47 t/ha). The maximum net return, B:C ratio, income (₹/day) and land use effi ciency were also realized with babycorn followed by bottle gourd and vegetable cowpea.

4.1.8 Crop Diversified Options for Higher Production and Profit under Limited Water Situation

In order to assess the production profitability different vegetable based sysems were evaluated under limited water situations (Drip irrigation) during 2016-17. Among different cropping systems studied, babycorn-spinach cropping system resulted in highest net returns (₹ 2,37,555.00) followed by bottle gourd-green vegetable onion (₹ 2,09,971.00). The B:C ratio (2.25) and income /day (₹ 1170.00) was also obtained with baby corn-spinach cropping system. Baby corn-spinach was the next best cropping system to realize higher B:C ratio (2.16) and income/day (₹ 963.00). The maximum income (₹ 1170/day) and system production effi ciency (112.7 kg/ha/day) was recorded with baby corn-spinach cropping system. On the other hand, okra-garden pea cropping system gave minimum net system returns (₹ 39072/ha), B:C ratio (0.45), income (₹ 215/day) and system production effi ciency (46.02 kg/ha/day).

Performance of different crops under rainfed situation

Effect of crop diversification on yield and economics of different cropping systems under limited irrigation

Cropping systems	Okra equivalent system yield (t/ha)	System net return (₹/ha)	B:C ratio	Income (₹/day)	System production effi ciency (kg/ha/day)
Bottle gourd (Pusa Naveen)-green vegetable onion (cv. Pusa Ridhi)	20.47	2,09,971	2.16	963	93.9
Baby corn (cv. G 5414)-spinach (Pusa All Green)	22.87	2,37,555	2.25	1170	112.7
Okra (cv. Arka anamica) -garden pea (Pusa Pragati)	8.33	39,072	0.45	215	46.02
Bottle gourd (cv. Pusa Naveen)-Sarsonsaag (cv. Pusa sarsonsaag)	16.40	1,69,274	2.20	877	84.97

Crop productivity and economics as influenced by crop diversification under rainfed condition

Crops	Yield (kg/ha)		PEY (t/ha)	Net returns (₹/ha)	B: Cratio	Income (₹/day)	Production effi ciency (kg/ha/day)
	Seed/pod	Fodder yield					
Pearlmillet (cv. HHB 67)	1.28	3600	1.55	9064	0.78	129.48	22.14
Green gram (cv. SML 668)	0.810	1425	3.29	31975	2.52	456.78	47.00
Cowpea vegetable (cv. Kashikanchan)	6.30	8200	7.72	80900	3.71	1244.61	118.77
Babycorn (cv. G 5414)	7.91	34,700	14.47	165020	6.00	2357.43	206.71
Bottle gourd (cv. Pusa Naveen)	21.00	-	9.47	95625	3.15	1366.08	135.29
Okra (cv. Arkaanamica)	3.50	-	3.95	12633	0.37	168.44	52.67

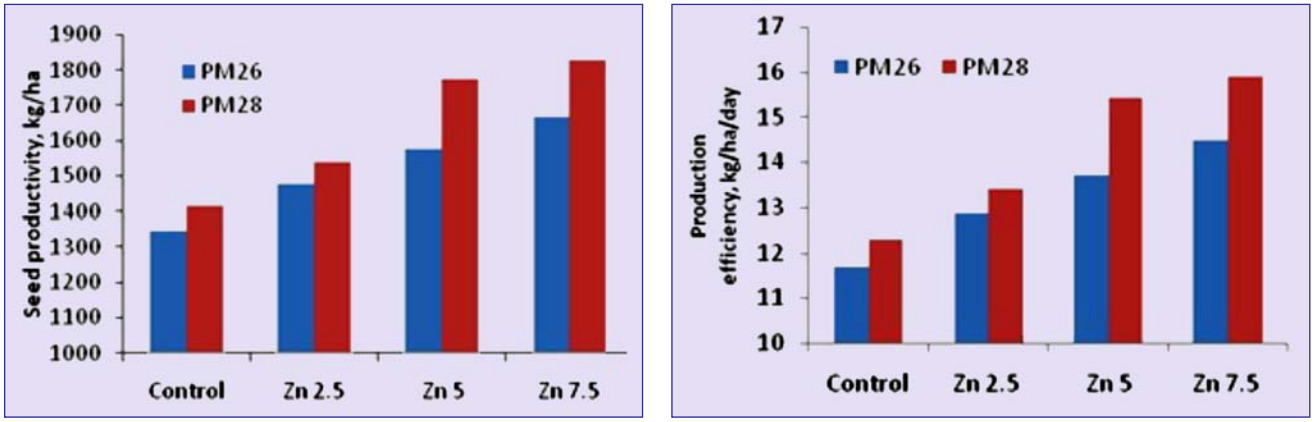
A field view of crops grown under drip irrigation situation

4.1.9. Diversification of Maize based Cropping System for Sustained Higher Production Profitability

An experiment was conducted in the view of sustainable higher yield and profits through diversification of maize based cropping system. Among different cropping systems, maximum system productivity, net returns and B:C ratio was noted under maize (fodder)-mustard (PM28)-onion system. Application of 7.5 kg Zn/ha had higher maximum seed yield and production effi ciency.

4.1.10 Integrated Farming System Model for Ensuing Livelihood Security of Small and Marginal Farmers

A study was undertaken to develop integrated farming system (IFS) model for small and marginal farmers in north Indian situations under irrigated ecologies.



Effect of Zn on the performance of different mustard cultivars

A view of duck cum fish enterprise integration under IFS model

Different land-based enterprises, viz., Crops (horticultural and field crops) + dairy + fishery + duckery + poultry + biogas + agro-forestry were taken in the IFS model with 1.0 ha area. Results revealed that from one ha area of IFS model, a gross and net returns of ₹ 8,12,984 and ₹ 3,40,787, respectively, can be obtained with labour requirement of 675 man days. Such IFS model helps in recycling of cow dung in the form of biogas slurry in crops and fish pond, thus it saved cost on nutrients as well as on fish feed. Besides, the pond served as water and nutrient harvesting structure and allowed for multiple use of water.

4.1.11 Evaluation of Timely Sown *Durum* Wheat Genotypes

The field study was conducted at IARI Regional Station, Indore to evaluate five wheat genotypes {HI 8759(d), HI 8498 (d), HI 8737 (d), HD 4728 (D) (I) and MPO 1215 (d)} at two date of sowing (timely and late) under irrigated conditions. Result showed decline in yield (7.04%) under late sown crop compared to timely sown crop (6.11 t/ha). Among genotypes, grain yields in HI 8737 (6.29 t/ha) and HI 8759 (6.20 t/ha) were at par and significantly higher than other genotypes.

4.1.12 Evaluation of Wheat Genotypes for their Suitability to Delayed Sowing

The wheat genotypes HD 3209, HD 2932, HD 2864, Raj 4083 and MP 3336 were evaluated at two date of sowing (late and very late) under irrigated conditions. Data indicated significant reduction in the grain yields (10.9%) while sowing delayed from late (5.06 t/ha) to very late (4.51 t/ha). Among genotypes, grain yield of cv. HD 2932 (5.12 t/ha) was at par with cv. Raj 4083 (5.01 t/ha), and it was significantly higher than other varieties.

Economics of IFS model for small and marginal farmers under irrigated situations in north India (Area –1.0 ha)

Enterprise	Area/unit	Gross Returns (₹)	Production cost (₹)	Net returns (₹)	Labour requirements (man-days)
Crops	0.7 ha	1,65,354	72,156	93,198	150
Fishery	0.1 ha	90,000	45,544	44,456	26
Duckery	35 birds	50,590	30,781	19,809	52
Dairy	3 Cross bred cow (11,151 litres milk)	4,46,040	2,93,716	1,52,324	365
Fruits	Lemon + Kinnow (0.03 ha)	16,000	6,000	10,000	15
Fence area	Country bean (0.03 ha)	30,000	18,000	12,000	50
Agro-forestry	0.02 ha	6,000	2,000	4,000	5
Biogas	KVIC model (2 m^3)	9,000	4,000	5,000	12
Total	1.0 ha	8,12,984	4,72,197	3,40,787	675

4.1.13 Evaluation of Wheat Bio-fortified (WB) Genotypes

Three wheat genotypes, namely, HPBW 01, HPBW 02 and WB 02 were evaluated against four checks (K 0307, GW 322, DPW 621-50 and MACS 6222) at two date of sowing (timely and late) under irrigated conditions. Results showed significant reduction in the grain yields (12.58%) compared to timely (4.37 t/ha) sown genotype. Among genotypes, check variety MACS 6222 recorded maximum grain yield (4.36 t/ha), which was statistically at par with two test varieties HPBW 02 (4.24 t/ha) and HPBW 01 (4.17 t/ha), and one check variety GW 322 (4.13 t/ha), whereas significantly higher over the rest of the varieties including one test genotype WB 02 (3.93 t/ha).

4.1.14 Comparative Performance of Wheat Sowing Methods

In a field experiments, five seeding methods with different stand establishment were evaluated on two wheat varieties HI 1544 (bread-wheat) and HI 8737 (*durum* wheat). Results showed that grain yields (5.96 to 6.06 t/ha) were significantly higher under dibbling methods of sowing compared to line sown crop. In case of varieties, HI 8737 recorded significantly higher grain yield (6.1 t/ha) compared with the variety HI 1544 (5.65 t/ha).

4.1.15 Effect of Row Spacing and Seed Rate on Wheat Productivity

In a field experiment, interaction of row spacing with seed rates was studied. Results revealed that spacing of 22.5 cm apart recorded highest grain (6.28 t/ha) and biological (13.87 t/ha) yields. While among seed rates, increase in seed rates was not beneficial and even slightly decreased the wheat yields. Hence, it may be inferred that for getting higher productivity of wheat, seeding should be done at 22.5 cm apart rows with the normal seed rate.

4.1.16 Effect of Method of Sowing and Seed Rate on the Productivity of Wheat

Field investigation was carried out to evaluate three sowing methods and four seed rates in wheat. Results indicated that grain yields observed under line (6.06 t/ha) and broadcast sown method (6.07 t/ha) were at par but significantly higher over cross sowing (5.73 t/ha). In case of seed rates, maximum grain and biological yields (6.00 and 13.94 t/ha) were with normal seed rate. Therefore, it can be concluded that cross sowing is not beneficial in vertisols of Central India and line sowing along with normal seed rate holds promise to provide higher wheat yields.

4.1.17 Effect of High Dose of N Application on the Productivity of Wheat Varieties

Response of high dose of N on the productivity of different wheat varieties were evaluated. Results showed that high dose of N @ 180 kg/ha slightly decreased (2.19%) the grain yield compared to recommended dose of 120 kg N/ha (5.48 t/ha), although, there was a slight increase (1.59%) in biological yield (12.78 t/ha). In case of varietal response, high dose of N had slight increase in grain yield of varieties HI 1544 (5.54 to 5.64 t/ha) and HI 8737 (5.41 to 5.56 t/ha) compared to 120 kg N/ha. Therefore, it may be concluded that higher N application rate beyond 120 kg/ha is not beneficial for different wheat varieties grow in vertisols of Central India.

4.1.18 Effect of Different Seedling Age on Seed Productivity and Quality of Rice Variety Pusa Basmati 1509

Study on staggered planting of 20, 23, 26, 29, 32, 35 and 38 days old of paddy (cv Pusa Basmati 1509) seedlings reveals that 20 and 23 days old seedling produced significantly higher yield and yield attributes compared with 35 and 38 days old seedlings. Number of panicle/m^2 and number of filled seeds/panicle showed a reduction of 35.3 and 15.8% in 35 days and 37.8 and 16.7% in 38 days, respectively, compared to 20 days old seedlings. Reduction of seed yield by 19.6 and 24.9% in 35 and 38 days old seedlings, respectively, was recorded as compared to 20 days old seedlings. Seed quality remained affected due to different aged seedlings.

4.2 SOIL MANAGEMENT

4.2.1 Estimation of Different Soil Carbon Pools in Different Crop Establishment Methods under Conservation Agriculture

Changes in soil organic and inorganic (SOC and SIC) due to different crop establishment method was studied after six years of rice-wheat rotation in a calcareous soil of eastern Indo-Gangetic plains. Results showed highest total SOC concentrations at zero tilled-direct seeded rice followed by zero till wheat with residue retention (ZTDSR-ZTW+R) in both 0-15 and 15-30 cm soil layers which were (20 and 40%) higher ($P<0.05$) than conventional tilled rice and wheat (CTR-CTW) plots, respectively. On the other hand, total SIC decreased ($P<0.05$) by 11 and 15% in the surface and the sub-surface layers, respectively, under ZTDSR-ZTW+R compared with CTR-CTW. Among SOC pools, non-labile SOC was the largest, followed by very labile, labile and less labile pool. Benefits of ZT and residue retention were maximum in case of very labile SOC, which showed a significant ($P<0.05$) increase in 0-15 and 15-30 cm soil layers, respectively, under ZTDSR-ZTW+R compared with CTR-CTW plots.

4.2.2 Long-Term Effect of Manuring and Fertilization on Stability of Soil Organic Carbon

Soil humus stability was quantified at three depths of soil (0-15 cm, 15-30 cm and 30-60 cm) in six different treatments under rice-wheat cropping system of a long term integrated nutrient management experiment being carried out at Pantnagar. Carbon content of a soil humus complex, C_t, at a time t, after desorption of humus from soil-humus complex was fitted to a simple first order equation $C_t = C_o \exp(-kt)$, where, C_o is the initial carbon content and k is the humus desorption rate constant. The inverse of k will give the retention time i.e., stability of soil humus carbon. Results showed highest Walkley-Black Carbon (WBC) as well as Total Organic Carbon (TOC) in the 0-15cm soil depth with T_6 (50% recommended NPK dose through fertilizers + 50% N through FYM). Treatments T_8 (50% recommended NPK dose through fertilizers+ 50% N through straw) as well as T_{10} (50% recommended NPK dose through fertilizers+ 50% N through GM) showed higher soil humus stability in the 0-15 cm and 15-30 cm depth than other treatments whereas treatment T_6 (50% recommended dose of NPK through fertilizers + 50% N through FYM) showed higher soil-humus stability in the 30-60 cm soil depth.

4.3 NUTRIENT MANAGEMENT

4.3.1 Improvement in Pusa Soil Test Fertilizer Recommendation (STFR) Meter

Pusa STFR meter has been improved, which is now capable of analyzing fourteen parameters viz., pH, EC, OC, available nutrients [(derived N), P, K, S, Zn, B, Fe, Mn and Cu], and gypsum and lime requirement. Provision of making fertilizer recommendation was made for 100 crops including field crops, horticultural crops and spices. It could be connected to PC through a computer-interface and the results can be communicated to the farmers through instant SMS on a pre-registered cell phone. So far, it has been licensed to fourteen firms for commercial production. At present, the kit for determination of 12 soil parameters is available in the market.

4.3.2 Effect of Nanoclay Polymer Composites (NCPC) Loaded with Nitrogen and Nitrification Inhibitors (Nis) on N_2O Emission from Soil under Elevated CO_2 and Temperature Condition

Emission of N_2O as inhibited by NIs under elevated CO_2 (600 ±10 ppm) and elevated temperature (+ 3°C) condition was studied using NIS. Results showed 12.2% higher cumulative emission of N_2O-N with urea fertilization than NCPC + DCD inhibitor treatments. The total emission of N_2O-N in rice crop reduced from 7.32 N_2O-N g/ha day of applied urea-N to 6.54 N_2O-N g/ha day with NCPC + DCD + Urea treatment. The N_2O-N emissions in rice crop was higher at elevated CO_2 (9.52%) and elevated temperature (14.8%) while 11.13% and 15.29 %, respectively, under wheat crop. In wheat crop, average N_2O fluxes across the growth

stages from 4.13 N_2O-N g/ha day to 6.93 N_2O-N g/ha day during 60 days of growing period and were comparatively lower than that of rice crop.

4.3.3 Impact of Polymer Coated DAP on Performance of Wheat in Alluvial Soil

A field experiment was conducted to evaluate the efficacy of polymer coated di-ammonium phosphate (DAP) in increasing phosphorus (P) availability to wheat in alluvial soil. Results indicated similar efficacy by the application of 75% of recommended dose of P (RDP) through polymer coated DAP and 100% RDP through uncoated DAP, in maintaining the yield of wheat (5.13 t/ha and 4.93 t/ha, respectively). This may be attributed to the fact that the polymer coating on DAP fertilizer granule imparts slow P release property in fertilizer, leading to sustained and prolonged release of P in soil for the crops.

4.3.4 Dynamics of Phosphorus in Maize-Wheat under Conservation Agriculture

A field experiment on maize - wheat cropping sequence with crop residue and various phosphorus doses along with PSB & AM was initiated during *rabi*-2013 at the IARI farm. Results indicated that application of 50% of recommended P along with microbial inoculation (AM+PSB) increased P availability, total P uptake, use efficiency, agronomic efficiency and grain yield of maize. Results also indicated that microbial inoculation helped in curtailing fertilizer P demands by mobilizing native and applied P and 50 % recommended doses of phosphorus can be saved through combined inoculation of AM and PSB, whereas crop residue retention @ 50% crop residue (CR) recorded the maximum grain and straw yield of maize, total P uptake and phosphorus use efficiency (PUE). Crop residue retention had negative effect on Al-bound P, Fe-bound P, Ca-bound P and reductant soluble-bound P fraction, but had positive effect on soluble and loosely-bound P. The crop residue retention rate decreased total inorganic P significantly from 468 (No-CR) to 404 mg/kg (75% CR in surface soil. However, organic-P fraction increased significantly with increasing rates of crop residue retention over control. The highest (329 mg/kg) and lowest (243 mg/kg) organic- P fraction was recorded in 75% CR and No-CR, respectively. Crop residue retention increased the organically bond P whereas reduce the Ca-P in soil.

4.3.5 Assessment of Maturity Indices of Rock Phosphate Enriched Composts using Variable Crop Residues

Assessment of maturity indices of rock phosphate enriched composts was studied using different crop residues, namely, rice straw, wheat straw, mustard stover, chickpea stover and tree leaves. There were distinct differences in concentration of NH_4^+-N, NO_3^--N, Olsen-P and NH_4OAc-K for composts generated from different crop residues, the highest being in rice straw. Water soluble P varied from 3.47–4.45% of total P, while citrate soluble P varied from 32.7–54.0% of total P. Rice straw composts showed lower C/N, WSC/Org-N and E_4/E_6 ratio and higher germination index indicating that they are well-matured and stabilized compost. Compost quality was better with crop residues from chickpea stover, rice straw, mustard stover, wheat straw and tree leaves.

4.3.6 Impact of Sludge Application on Soil Health and Crop Productivity under Maize-Wheat Cropping System

A field experiment on assessing the impact of sewage sludge (SS) application on soil health and crop productivity was initiated at the Institute research farm with maize - wheat cropping system in 2014. Results showed the highest yield of wheat with 100 % NPK combined with 2.5 t/ha SS, which was more or less equal to that of 25% or 50% N substituted by SS with NPK fertilizers. Incorporation of SS marginally improved soil available N, P, K, Zn, Fe and Cu. Nickel and cadmium contents in sludge amended soil increased slightly, which is within permissible limit.

4.3.7 Impact of Organic Ligands on Manganese Release in Inceptisol

Release kinetics of soil Mn in presence of different organic ligands was studied in an incubation

experiment. Manganese deficient soil (Inceptisol) was treated with Mn (0 and 8.0 mg Mn/kg soil as $MnSO_4$. H_2O), oxalic acid (@10 and 20 mg/kg soil), citric acid (@10 and 20 mg/kg soil) and farm yard manure (@ 0 and 2.5 g/kg soil). The results showed that combined application of Mn with organic acid was more effective in maintaining higher concentration of Mn up to 90 days as compared Mn alone. The most effective treatment for mobilizing Mn was found to be oxalic acid (20 mg/kg) + Mn (8.0 mg/kg).

4.3.8 Development of Soil Test Crop Response based Integrated Plant Nutrition System for the Targeted Yield of Marigold (*Tagetes Patula* L.) Flower

A field experiment was conducted following Ramamoorthy's 'inductive cum targeted yield model' for the development of a soil test based integrated fertilizer prescription of primary nutrients for marigold (var. Pusa Arpita). Results indicated requirement of 0.47 kg N, 0.07 kg P and 0.49 kg K for one quintal of marigold flower in Inceptisols of New Delhi. The contributions from soil, fertilizer and FYM nutrients were 48.07%, 41.0% and 12.32% for N; 58.30%, 20.59% and 7.57% for P and 48.91%, 80.68% and 6.88% for K, respectively. Using the generated basic data, fertilizer prescription equations were developed, which could be used for the formulation of fertilizer doses based on soil test values, availability of FYM and desired yield targets (± 5-10%) of potential flower yield of the marigold variety.

4.3.9 Functionalized Clays for Immobilization of Heavy Metals

In a study, Al-pillared smectite was used to trap metals like Zn, Cu, and Ni. The maximum monolayer adsorption capacity of pillared bentonite was 61.4, 32.3 and 50.3 mg/g for Cu (II), Zn (II) and Ni (II), respectively. The immobilization efficiency of pillared smectite was assessed in a greenhouse pot culture experiment with amaranth as the test crop in metal spiked soil. During the first harvest, copper content of amaranth was reduced from 48.5 in the control to 33.5 mg/ kg by amending the soil with 2.5% Al-smectite, respectively. Similarly, during the second harvest, the copper content was reduced to 26.8 mg/kg from the control of 40.2 mg/kg as a result of Al-smectite application at 2.5% loading (w/w). Amendments of soil with Al-smectite at 2.5% loading reduced the plant zinc content by 24% during the first harvest, and 25% during the second harvest of amaranth, respectively. Similarly, the plant nickel content was reduced by 53 and 46% over the control during the first and second harvest, respectively.

4.4 WATER MANAGEMENT

4.4.1 Irrigation Water Management

4.4.1.1 A green technology for treating municipal and industrial wastewater entering rivers and streams

Husk from coarse rice was collected and pyrolysed at 400, 550, 600 and 700°C temperature maintaining a continuous flow of nitrogen (N). Biochar prepared at different temperatures was analyzed for various physico-chemical properties and function groups present in it. With increase in pyrolysis temperature from 400 °C to 600°C, pH of rice husk biochar (RHB) increased while CEC decreased. Spectral analysis carried by using FTIR spectroscope indicated the presence of dominant IR peaks appeared between 1421/cm to 1428/cm which correspond to phenolic OH bending and the peaks between 1578/cm to 1617/cm referring to COOH group stretching vibration or C=O and C=C plane aromatic vibrations. Similarly the peaks between 1105/cm and 800/cm indicate the presence of calcium carbonate. The peak corresponding to aliphatic C-H stretching vibrations (2923-3045/cm) disappeared with progressive increase of pyrolysis temperature.

4.4.1.2 Heavy metal dynamics in wastewater irrigated soil amended with lime and clay

Field experiment on heavy metal dynamics in wastewater irrigated soil amended with lime and clay in test crop cabbage (var. Indu) was conducted. With the objective to find out the suitable amendment which can mitigate the adverse effect of multi-metal polluted

Cabbage crop under waste water irrigation

wastewater. The results showed that wastewater irrigated plots recorded 25- 30% increased yield as compared to ground water irrigated plots. While clay applied plots have shown significantly higher yield (62.5 t/ha) as compared to lime applied plots (59.4 t/ha). It was also observed that wastewater irrigation (3%) significantly increased the N content as compared to the ground water irrigation (0.5%). While, lime and clay applied plots recorded significantly lower N content as compared to the control plots.

4.4.1.3 Water balance in direct-seeded rice grown under a conservation agriculture (CA)-based rice-mustard cropping system

A field experiment consisting of eight treatments in CA with ZT direct seeded rice (ZT-DSR), brown manuring, and mustard and moongbean residues combinations laid-out in a continuing experiment (6th year) at ICAR-IARI during *kharif* 2015 to estimate various water balance parameters. The results revealed that soil moisture content (SMC) in moongbean residue + zero tillage DSR-rice residue+ ZT mustard-mustard residue+ summer moongbean (MBR+ ZT DSR -RR+ ZTM - MR + SMB) treatment was ~12 to 51% and 2 to 32% more than TPR-ZTM and TPR-CTM treatments plots, respectively, leading less irrigation water application and deep percolation in DSR with CA than TPR, and also higher yield and water productivity. The total amount of irrigation water applied in rice ranged 893.4 to 954.3 mm in DSR plots and 1418.2 - 1464.6 mm in TPR plots. The amount of water used for puddling and ponding in TPR were 135 and 94-98 mm, less than that of the FAO assumed values of 200 and 100 mm, respectively. The best treatment (MBR+ ZT DSR- RR + ZTM - MR + SMB) showed deep percolation of 5.8 mm/day that was 25.6% lower than TPR-CTM treatment (7.8 mm / day).

4.4.1.4 Conservation agriculture in maize based cropping systems for improving resource-use efficiency, crop productivity and soil health

An attempt was made to develop and evaluate the performance of different tillage, crop establishment practices (TCE) [permanent bed (PB), zero tillage (ZT) flat and conventional till (CT)] under four intensified irrigated maize systems [maize-wheat-mungbean (MWMb), maize-chickpea-*Sesbania* (MCS), maize-mustard-mungbean (MMuMb) and maize-maize-*Sesbania* (MMS)]. The highest yield of *kharif* maize was recorded with PB planting and was 18.8% higher over to CT flat. Among different cropping systems, MCS/MWMb resulted 9.3 and 13.0% higher yield, compared to MMuMb and MMS plots, respectively. The different TCE methods recorded 2.4 and 32.3% and 5.1 and 28.9% higher net returns and water-use efficiency in PB plots compared to ZT and CT, respectively. The diversified crop rotations also had significant impact on net returns and water-use efficiency of *kharif* maize crop and were 13.7 and 21.2% and 9.3 & 13.0 % higher in MCS/MWMb plots compared to MMuMb and MMS, respectively.

4.4.1.5 Water use efficiency under SRI drip rice

A field experiment was carried with planting methods of rice,namely, system of rice intensification (SRI) with drip irrigation and conventional method as control. Total water expense was higher under puddle transplanted followed by SRI and the lowest with drip system. Irrigation use efficiency in the study period range from 0.67 to 1.44 kg/m^3 and field water use efficiency varied from 0.45-0.75 kg/m^3, and water saving value from 42%-59%. Last year 2016-17 field experiment was conducted with SRI sub-surface drip method (SDI) under rice cv. Pusa 1509. The study revealed that irrigation water use efficiency (1.03 kg/m^3) and field water use efficiency (0.52 kg/m^3) was found to be highest in SRI method with SDI drip. The rice variety Pusa 1509 produced significantly higher yield (4.58 t/ha) in SRI with SDI drip.

4.4.1.6 Development of indigenous sensor network based irrigation system

A decision support system (DSS) integrated with soil moisture sensor based on tensiometric principle was developed and tested for real time irrigation scheduling either on time basis or soil moisture sensor basis during the years 2013-15 in six vegetable crops viz. okra, tomato, brinjal, broccoli, potato, and knol-khol. The reference evapo-transpiration and water requirement of vegetable crops was estimated from DSS and further verified and tested with CROPWAT model. Water level fluctuation in modified tensiometer provides a quick visual means of observing trends in soil moisture as influenced by rainfall and irrigation application. The performance of modified tensiometer for soil moisture measurement was calibrated with gravimetric method and compared with FDR, Watermark and regular tensiometer. Irrigation water productivity (control and automated system) under different irrigation methods for vegetable crops varied 1.67-12.55 kg/m^3, and 2.74-19.56 kg/m^3. Water savings of 39.6-48.7% was achieved using automated drip irrigation over manually controlled check basin irrigation for all the six vegetable crops.

4.4.1.7 Sensor based irrigation scheduling in maize-wheat and mungbean-mustard cropping systems

Irrigation scheduling was based on different threshold of soil water tension using tensiometer, gypsum block (GB), TDR and FDR; the sensors were installed in each plot of sandy loam soil at the depth of 30 cm from the soil surface. Sensors values were compared with the moisture content measured by the gravimetric method. Tensiometer gives consistent readings up to 60 kPa SMP. Whereas, gypsum block sensor was found performing better up to 90 kPa SMP but inaccuracy was observed because of variation in temperature. Soil moisture sensors performed differently in different soil depths. TDR is the best among the tested sensors according to mean and RRMSE (0.0011 and 9.6 %). Correlation values with soil moisture content and RWC were higher in flowering stage as compared to vegetative and post flowering stage. Accordingly, crop was irrigated on the basis of the relative water content which was between 65-70% in all the three crops.

4.4.2 Climate Change and Modelling

4.4.2.1 Energy consumption and CO_2 emission from groundwater irrigation in Gomti basin

Assessment of energy consumption and CO_2 emission from groundwater irrigation in Gomti basin was done for the baseline year-2011. Total CO_2 emission from groundwater irrigation in the basin was 442731 Mt. Of this 355215 Mt was from diesel operated pumps and 87516 Mt was from electric operated pumps. Evaluation of management alternatives revealed that, it is possible to reduce CO_2 emission by 12%, 23%, 7%, 41%, 5% and 8% by adopting laser leveling, alternate wetting and drying (AWD) in rice, SRI, use of efficient pumps, drip irrigation (in sugarcane, potato and peas) and sprinkler irrigation in wheat, respectively.

4.4.2.2 Performance evaluation of Aqua Crop model for direct seeded rice (DSR) grown in conservation agriculture

A field experiment was carried out to simulate rice yield under conservation agriculture based

direct seeded rice (DSR) using Aqua Crop model. The experiment was laid out in RBD in continuing experiment (6th year) with eight treatments and three replications on rice variety PRH 10. The validated model prediction error statistics i.e., root mean square error (RMSE), model efficiency (ME), index of agreement (d) and coefficient of determination (R^2) for grain yield, were 0.58, 0.72, 0.93, 0.96, and for biomass 1.11, 0.85, 0.95, 0.96, respectively, for all the treatments. It was observed that the grain yield and biomass predictions by the AquaCrop model for DSR treatments were better correlated to the TPR treatments.

4.4.2.3 Modelling of climate change impact on water resources availability in Ramganga river basin in Indo-Gangetic plains (IGP)

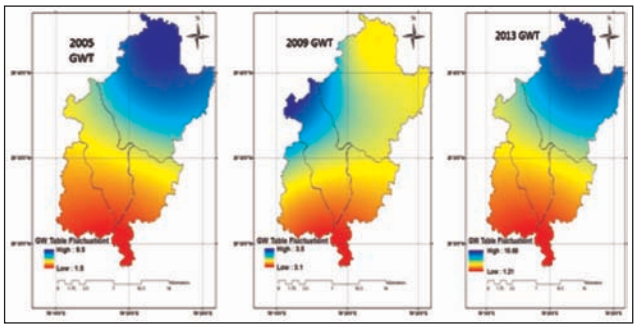
Impact of climate change on water availability in Ramganga river basin in Indo-Gangetic plains was studied using soil and water assessment tool (SWAT) model. The model was parameterized for stream flow at five spatially distributed gauging stations (GS) of Bareilly, Moradabad, Rampur, Fatehgunj and Dabari using their observed monthly average stream flow data. The SWAT simulation using initial three years data (1981-1983) was used to stabilize the initial conditions of the model. Ten years (1981-1991) and another next ten years (1992-2001) data were used to calibrate and validate the model, respectively. Out of 17 hydrological parameters, 14 were identified as the most sensitive flow parameters which were used for calibration. The calibrated and validated SWAT model was used for future analysis with emission scenario RCP (2020s, 2050s, and 2080s) data. The % change in mean monthly water yield over the base line and under climate change RCP (2.6, 4.5, 6.0, and 8.5) scenarios 2020s, 2050s, and 2080s, whereas maximum mean monthly water yield increase by 8 to 41 % in monsoon months except RCP 4.5(2050s) during the 2020s, 2050s and 2080s. However, in the month of March, October and December maximum decrease in mean monthly water yield by 1-59 % except RCP 8.5 during the 2020s, 2050s and 2080s.

4.4.2.4 Comparison of SPI and SPEI for predicting drought conditions in Hamirpur district of Uttar Pradesh

The two drought indices viz., SPI and SPEI were calculated with the SPEI-R package at different time scale i.e., 1, 3, 6 and 12 based on monthly meteorological data (1969-2013) for Hamirpur district of Uttar Pradesh, India. SPI and SPEI both showed almost same number of drought events but difference in the severity of drought was noticed within the same year because of parameters used for calculating indices. For the monsoon months, the correlation was very high (0.80-0.99) between indices for all time scale (1,3,6 and 12 months) while during summer i.e., March, April and May, the poor correlation (0.44-0.78) was observed at 1, 3 and 6 months time scale. Further the yield data (kg/ha) of sorghum and groundnut from 1997-98 to 2013-14 were used for validation of SPI/SPEI at 3 month time scale for the respective years. The crop yields are not only affected by moisture deficiency, but also by abnormally high temperatures (i.e., heat waves) during the grain filling period. It can be concluded that ET bases indices like SPEI is more applicable than the SPI especially to assess smaller variations in agricultural drought.

4.4.2.5 Studies on ground water table fluctuation in Pitamberpur watershed, Jyotiba Phule Nagar

GIS based estimation for study of the temporal-spatial changes in the ground water table was conducted. The ground water table fluctuated between 1.5 m below ground level (bgl) and 8.5 m bgl during the year 2005 has declined to 1.21 to 10.88 m bgl during the year 2013. The spatial dynamics revealed that the Northern and NW side of the watershed had experienced rapid fluctuations in GW table while the Southern and Se portion had shown relatively stable GW table. However, during the year 2009, this fluctuation was between 3.1 to 3.5 m bgl showing a remarkable



Spatio-temporal dynamics of the ground water table behaviour in Pitamberpur watershed, Jyotiba Phule Nagar, U.P.

positive shift mainly due to good rainfall that restricted the pumping of the tube wells whereas, increasing the recharge has also been the main reason for the same.

4.4.3 Water Conservation under Rainfed Conditions

4.4.3.1 Water balance and legume productivity under different moisture conservation

An experiment was carried out on a sandy loam soil under horti-agri system with three legume crops (soybean, cowpea, and mungbean) grown under *Bael* trees with three different moisture conservation practices of trench, micro-catchment (MC), ring basin (RB) under *Bael* tree and no *Bael* tree (NT). Higher soil moisture content was observed in trench under soybean and mungbean plots, whereas, micro-catchment in cowpea plots. Soil moisture balance depicts that there were soil moisture deficit in soybean during pod formation stage. Irrespective of the moisture conservation practices, the *Bael* yield was in order of cowpea plots > green gram > no crop plots > soybean plots. *Bael*, cowpea and mungbean yields were found to be 1.2-3.4, 2.4-3.4 and 0.2-0.5 t/ha under this legume based alternate land use (LALU) system. Overall, *Bael* tree intercropped with cowpea along with trench moisture conservation practice can fetch more income and enhancing soil fertility under rainfed conditions of arid and semi-arid climate.

4.5 PROTECTED CULTIVATION TECHNOLOGY

4.5.1 Evaluation of Different Parthenocarpic Cucumber Varieties/Hybrids on Varying Dose of NPK under Forced - Ventilated Polyhouse Condition during Off-Season

An experiment was conducted on cucumber crop to identify suitable dose of nutrient and varieties/ hybrids. The crop seedlings were transplanted in paired rows keeping 50x30cm spacing apart during

Cucumber production under forced-ventilated polyhouse

Cowpea grown under *Bael* - based horti-agri system with different water conservation practices

last week of August 2016 under forced-ventilated polyhouse with drip irrigation system. Parthenocarpic cucumber variety Fadia produced highest total fruit yield of 95.7 kg alongwith net return of ₹1122.5 and B:C ratio 2.09 based for 50 m^2 area per crop with combination of the optimum NPK dose @ 25:17:26 kg/1000 m^2 during off-season.

4.5.2 Standardization of Agro-Techniques for Bitter Gourd Production under Net-House Condition

An experiment was conducted on bitter gourd production in insect-proof net-house under protected condition. The maximum fruits yield (18.20kg), net return (₹295.50) and B: C ratio (1: 3.30) per m^2 were recorded in the best combination of 2nd week of August planting with optimum dose of NPK @25:17:26 kg/1000m^2. A new variety Pusa Rasdar was found economically suitable for growing under insect-proof net-house in the plain area.

Bitter gourd production in insect-proof net-house

4.5.3 Development of Agro-Techniques for Off-Season *Sarda-Melon* Production under Protected Structures

An experiment was conducted on *Sarda-melon* production at CPCT farm under insect-proof net-house and polyhouse protected structures. Newly developed variety Pusa Sarda (yellow fruits) was transplanted on different dates i.e., 14thAugust, 1stSeptember and 15thSeptember on the spacing of 100x50cm along with drip irrigation system. Four doses of NPK fertilizer i.e., @15:7:16kg, 20:12:21kg, 25:17:26 kg and 30:22:31kg/1000m^2 were tested. Hand pollination was done daily before 8 AM during flowering. The maximum fruits yield (5.70 kg), net-return (₹445.50)

***Sarda-melon* production under protected structures**

and B:C ratio(1:3.35) per m^2 were recorded in the best combination of 2ndweek of August planting with optimum dose of NPK 25:17:26 kg under insect proof net-house.

With economical potential under polyhouse condition, the fruits yield (6.50kg), net return (₹555.50) and B:C ratio(1:3.50) per m^2 were recorded in the best combination of 2ndweek of September planting with the same optimum dose of NPK (25:17:26 kg) as compared to others treatment combinations. The fruits were produced up to November month with 12.8% TSS under net-house condition ,while under polyhouse condition, fruits produced up to December month with TSS of 13.5%. Newly developed musk melon variety Pusa Sarda was found economically suitable and highly profitably in polyhouse condition due to off-season produce availability.

4.5.4 Estimation of Yield and Crop Water Productivity for Greenhouse Capsicum under Drip Fertigated Mulched Condition

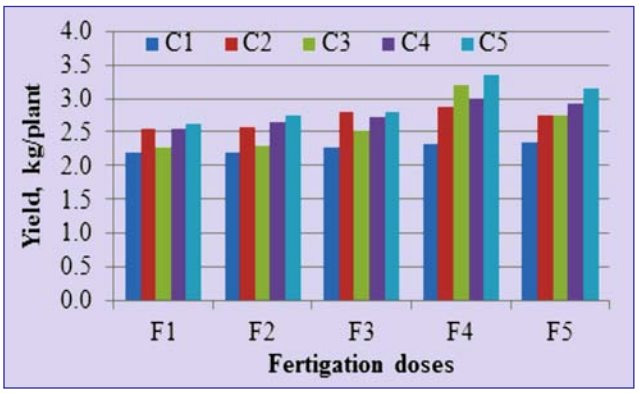
An experiment was laid out inside 1000 m^2 semi-climatic greenhouse with low pressure drip fertigated mulched condition using three colored mulches, namely, silver, yellow and brown with three evapo-

transpiration levels 100, 80 and 60%. Maximum yield (63 t/ha) and water productivity (35.33 kg/m^3) was found from the silver mulched condition under 100% ET_c which was significantly different from other mulched and control conditions. Whereas, minimum yield and crop water productivity were noted from plants grown under control with 60% ET_c.

4.5.5 Standardization of Drip-Fertigation Technology for Growing Off-Season Cucumbers in Naturally Ventilated Polyhouse

A study was conducted to standardize the fertigation doses for different cucumber varieties grown in off-season under naturally ventilated polyhouse. Nursery of 25 days old plants was transplanted in the crop geomtery of 60cm x 60cm, accommodating 27,778 plants per ha during October 31, 2016. Five doses of fertilizers (F_1=100:75:125; F_2= 150:112:188; F_3=200:150:250; F_4= 250:188:312 and F_5= 300:225:375 kg/ha) were applied two times in a week in all five varieties of cucumber (C_1= Aviva; C_2= Mini Sri Ram; C_3= Terminator; C_4= Sania and C_5 = Oscar) throughout the cropping period. Total 6 pickings were done and crop cycle completed on March 23, 2017. Maximum yield (3.34 kg/ plant) 92.8 t/ha was obtained in the variety Oscar by applying N:P:K:: @250:188:312 kg/ha.


Cucumber crop inside polyhouse



Yield observed in different fertigation doses

4.5.6 Soil-less Cultivation for Production of Vegetables

Technology was developed to standardize the pot size for growing different vegetables using soil less media having coco peat, vermiculite and perlite in the ratio of 3:1:1 and nutrients solution. Among different size of pots used, four inch pots were found suitable for growing spinach and Amaranthus, 6 inch found best for *kale*, lettuce, garden mint, pokchoi, Swiss chard, and 9 inch pots for tomato, broccoli and cabbage.

Yield recorded in dirrerent pots

Crop	Yield (kg/m² area)		
	Pot diameter 4 inch	Pot diameter 6 inch	Pot diameter 9 inch
Amaranths	9.5	8.5	8.0
Spinach	5.7	5.0	4.5
Lettuce	0.51	0.6	
Kale	5.0	6.7	6.5
Garden mint	0.8	1.7	1.5
Pokchoi	7.2	11.5	9.5
Swiss chard	5.0	10.5	6.5
Tomato		2.5	5.5
Broccoli		6.5	13.4
Cabbage		7.8	14.0



Crops grown in different pots using soil-less media

4.5.7 Evaluation of Microclimate inside Various Protected Structures

The microclimate profile inside the greenhouse with tomato under different operating conditions was evaluated. It was observed that forced ventilation

reduced the canopy temperature by 5-6°C compared to natural ventilation. Thermal screen reduced the canopy temperature by 3-4°C in forced ventilation greenhouse. There was 70-80% reduction in PAR at 1m height and 2-3°C difference in temperature was observed along the height of canopy.

4.5.8 Studies on Plant Densities in Chrysanthemum under Naturally Ventilated Greenhouse

Chrysanthemum varieties, namely, Thai Chen Queen, White Star, Yellow Star and Zembla were planted under naturally ventilated greenhouse in plant densities of 24, 32, 48 and 64 plants/m^2 to study the response on growth and flower quality parameters. A maximum plant height (134 cm) was attained by the plants in variety Zembla planted with the density of 64 plants/m^2 followed by planting density of 48 plants/m^2 and a minimum (43 cm) in Thai Chen Queen. Flower size remained highest (12.4 cm across diameter) in variety, Yellow Star followed by White Star (11.7cm across diameter) and Zembla (11.5 cm) planted with 36 plants/m^2. However, leaf area could vary significantly among them.

Performance of Chrysanthemum at different density under greenhouse

4.5.9 Evaluation of Gerbera Varieties for Growth and Flowering under Semi-Climate Controlled Greenhouse

Five varieties of gerbera, namely, Feliks, Kormoran, Konstancja, Miria and Merzena planted @ 16:3:30 drip laterals on 40 cm raised beds and evaluated for growth and flowering under semi-climate controlled greenhouse. It was observed that Kormoran produce highest number of leaves (23) per plant and early flowering (55 days after transplanting) whereas flower stalk length remained longest (83.5 cm) having smallest size (5.3 cm diameter). Feliks could produce maximum flower size (9.7cm diameter) on smallest flower stalks (36.3 cm) and took longest time (92 days) as compared with other varieties.

Performance of gerbera varieties under semi-climate controlled green house

4.5.10 Studies on Diurnal Response of Chrysanthemum Varieties

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

4.6 AGRICULTURAL ENGINEERING

4.6.1 Design and Development of Gladiolus Planter

A gladiolus planter was designed based on the optimum parameters of the planting materials. The planter was operated at a forward speed of 0.56 km/h. The average spacing between corms was found to be 20.7cm and average depth of planting was 10.8cm. The quality of feed index, miss index and multiple index were 78.8, 8.3 and 12.9%, respectively. The draft of the planter was 821±50.3N.


Prototype gladiolus planter

4.6.2 Design and Development of Planter for System of Wheat Intensification

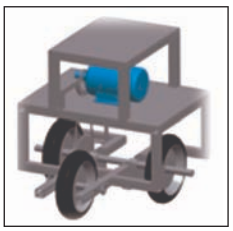
A six row tractor drawn planter was designed and developed to plant the wheat seeds in hills for system of wheat intensification (SWI). Its row-row distance was adjustable from 20 to 25 cm. It open furrows, place seed at 5 cm depth and cover them with firm compaction. The tractor drawn SWI planter is being evaluated in the field at three speeds (1.1, 1.6 and 2.3 km/h), with soaked and normal seed and with and without press wheel to find its crop uniformity and performance in comparison to traditional tractor drawn seed drill. The draft requirement was 200 kgf.

Tractor operated planter for SWI

4.6.3 Design and Development of Integral Power Equipment for Small Farm Mechanization

Preliminary survey was carried out in Karnataka, Punjab, Haryana and western UP and information on farm equipment available for small farm

Experimental setup in soil bin



3-D view of experimental setup

Walk behind type research prototype


Riding type research prototype during field evaluation

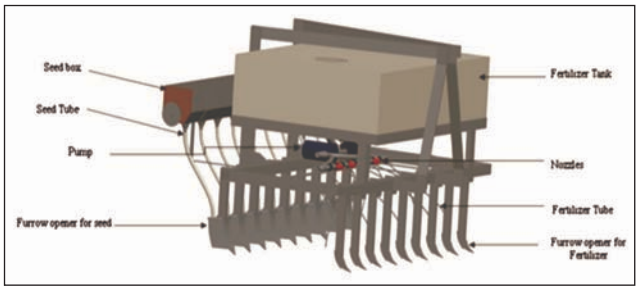
mechanization was collected from farmers and manufacturers. The field evaluation of existing small farm equipment was done and problems in terms of balancing, maneuverability, human discomfort were identified. To overcome the existing problems, chassis design and tri-wheel system was conceptualized. Based upon the design considerations, an experimental setup for optimization of parameters was developed. Initially, walk behind type research prototype with independent rotary power, varying wheel base and track width, depth control system, etc. was developed and tested. For commercialization of final product, an MOU with industrial partner (SAS Motors) was signed, and through joint efforts three wheel riding type small farm equipment for multiple field operations was developed.

4.6.4 Design and Development of Urea Ammonium Nitrate (UAN) Applicator

Urea Ammonium Nitrate placement by manual operation is time consuming, labour intensive and involved drudgery when application is deeper. Therefore, a liquid fertilizer applicator was developed and retrofitted on the direct paddy seeder having inclined plate type metering system for precise sowing of paddy seeds.

Retrofitted UAN applicator on direct paddy seeder

Based upon manual application of UAN and retrofitted UAN applicator, selection of different components along with their design values was done. The research prototype for basal application of UAN was designed and developed. The main components



Isometric View of UAN Applicator

Wheat sowing with developed UAN Applicator

of the UAN applicator were shovel type furrow opener (20 mm width, 150 mm height and 5 mm thickness), fluted roller seed metering mechanism, common rail UAN metering mechanism operated by diaphragm type pump (18.9 LPM capacity at 3.1 bar and 12V battery operated), fertilizer delivery tubes. A common rail UAN metering mechanism with plain orifice nozzles was used for uniform application which delivers required dose of UAN diluted with water (1:30) to nine furrow openers. There are nine furrow openers for seeds and separate nine furrow openers for fertilizer fitted on the frame in such a way there is no direct contact between seed and fertilizer after delivery of seed and fertilizer. The UAN applicator was designed to place the fertilizer 2.5 cm beside the seed at a depth of 5 and 10 cm.

4.6.5 Performance Evaluation of Pneumatic Precision Planter in Farmers' Fields

The developed Pneumatic precision planter for small vegetable seeds in collaboration with CSIR-

Testing of pneumatic precision planter on raised bed

CMERI-CoCPM was evaluated in farmers' fields of Hapur district, Uttar Pradesh. The machine was modifies to suit the sowing pattern of cabbage seed in raised beds. The raised beds were made by tractor operated bed former. Three planting modules were so arranged that sowing two rows in one bed and one row in adjacent bed. The field capacity of the machine was 0.17-0.22 ha/h with a field efficiency of 66.54 to 73.28%. About 17-24% of seed saving was recorded when compared with conventional planting. The saving in time and cost of operation by use of this planter was well appreciated by the farmers, and is greater scope of custom hiring of this planter in the study area.

4.6.6 Design and Development of Battery Assisted Four-Wheel Weeder

The components of the developed battery assisted weeder are frame, 250w dc brushed motor, pulse-width-modulation motor controller and throttle, two lead-acid batteries, each 12V, 14AH, t-type swinging handle, 250mm cutting blade with depth adjustment mechanism, two rear traction wheels and two depth control rolling wheels. Power consumption assessment was made through micro-controller (ATmega328) based energy meter which comprises of 25A current and 25V voltage sensor. A micro-controller was programmed in 'C' language to display power consumption and battery charging levels. Sweep type cutting blade was found more suitable as compared to arc type cutting blade. Based on trial in a grassy field, the field capacity observed was 0.0541 ha/h with weeding effi ciency of 98%. The power consumption in idle and weeding condition were 50-60W and 100-120W, respectively. This machine can be operated with fully charged batteries for about 3h.

Battery assisted four-wheel weeder

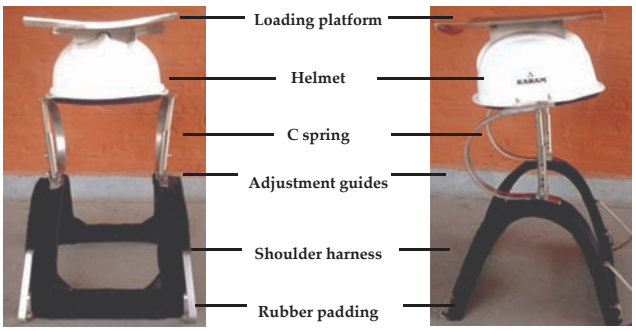
4.6.7 Design and Development of Mobile GPS based Seed Drill Monitoring System Suitable to Custom Hiring

This unit can be fitted on cultivator or seed drill. The implement size can be fixed by selecting the button on display unit. The system consist of ground wheel, flexible meter cable, rotary encoder, microcontroller and display unit. The rotary motion of ground wheel is transmitted to rotary encoder through flexible meter wire. A microcontroller receives the signal from the rotary encoder and calibrate the area by multiplying the implement size and covered distance. The ground wheel is made of plastic material having spikes on its periphery. The spikes are provided to avoid the skidding on the soil surface. The covered area can be displayed in local units like Bigha, Katta, acre, etc. The microcontroller is also programmed to display time in hour and speed in kilometer per hour. The system is useful for custom hiring purpose. The system is able to measure the distance with accuracy of 96.2-97%.

Prototype of area measurement unit

4.6.8 Development of Harness with Integrated Loading Platform

A harness was developed with integrated loading platform. It consists of shoulder harness, rubber padding, adjustment guides, U spring, helmet and loading platform. There are three paths for transmission of load, through C spring, head and adjustable guides. The load on head is limited with C spring and adjustable guides. As there is no eccentricity introduced with this harness, it was observed that there was no significant difference in energy expenditure between head loading and with this integrated platform harness.



4.6.9 Design and Development of Walking Type Battery Operated Boom Sprayer

Walking type battery operated boom sprayer mainly consist of 6 nozzles (flow rate 0.8 l/min each),

Testing of walking type battery operated boom sprayer

two battery (12V, 7AH each), two diaphragm pump (flow rate 4 L/min, 35 PSI) and two plastic tank of 20 L capacity each. The movement of designed sprayer is manually. Both the diaphragm pump are powered with 12V battery individually. Field capacity of designed sprayer is 150 m^2/min. Battery operated knapsack sprayer has to be carried on human body which is not ergonomically suitable for long time whereas designed sprayer is ergonomically suitable for operator. This sprayer is compact (width 20 cm), due to compactness of this sprayer it can be operated in between rows of field crop. This sprayer has 6 nozzles with 40 L tank. Boom height of design sprayer is adjustable like tractor mounted boom sprayer and swath of nozzle is also changeable. It is low cost and can be easily fabricated by village artisans.

4.6.10 Development of Solar Powered Fruit and Vegetable Grader

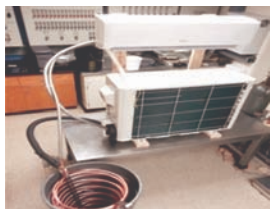
The machine consists of canvas belt, DC motor 150 W, reduction gear and a hopper for feeding the material to the belt of the grader. The machine runs

Solar powered fruit and vegetable grader with solar power pack

with the help of DC motor which has 1036 rpm. This motor is connected to a reduction gear which reduces the rpm to 37 thus having a reduction ratio of about 1:28.5. This power is then given to a flat belt length 2.8 m, width 0.295 m. The rpm of the belt is 11. The material to be graded is fed on to the belt through the hopper. On this belt four compartments are made which have different spacing. The material is passed through these spacing in order of small, medium and big. Thus the grading of the material is done in four sizes. Depending upon the requirement of size of the material to be graded the spacing of the compartment can be changed. This machine can be operated with the help of solar power. Four solar modules (60 Wp/18 V open circuit voltage each) were used to operate the system. The direct current (DC) power of the solar panel was supplied to the 12 V/150 W DC motor through a 12 V/ 75 Ah battery. This machine is best suited for effi cient grading of round shaped potato, onion and other fruits.

4.6.11 Low Cost Storage Structure

Four 1/10 scale prototype evaporative cooled (EC) structures have been constructed with differing walls materials including pervious concrete (PC), traditional brick-sand-brick (BSB) and mesh fabric (MF) on the IARI campus. The designs are currently being tested to validate mathematical models to predict their performance. The mesh fabric EC structure (MFEC) with low thermal mass and high thermal transmittance outperforms other designs, cooling faster and obtaining lower temperatures. The fabric-mesh structure also cost significantly less to build and is easier and faster to construct than BSB or PC designs. The walls of the structure are wetted at a controlled rate to achieve maximum evaporative cooling. The design and material for the roof and floor have also been finalized for lowest heat transfer.

Mesh fabric EC structure (MFEC) Wall: mesh and fabric Size: 100 kg Cost of construction: ₹ 6000/- Low thermal mass Cools quickly 10°C in 10 hours Most effective	
Pervious concrete EC structure (PCEC) Wall: Pervious Concrete Size: 100 kg Cost of construction: ₹ 10000/- Medium thermal mass Cools quickly 10°C reduction in 15 hours	
Brick sand brick EC structure (BSBEC) Wall: Brick-Sand-Brick Size: 100 kg Cost of construction: ₹ 20000/- High thermal mass Cools slowly 10°C reduction in 30 hours	
Full scale mesh fabric EC structure (FMFEC) Wall: Mesh fabric Size: 2000 kg Cost of construction: ₹ 2.5 Lakhs Low thermal mass Cools fast 10°C reduction in 10 hours (under testing). To be fitted with solar refrigeration system	
Solar refrigeration system No Battery BLDC system To be fitted to full scale mesh fabric EC structure	

4.6.12 Farm, Horticulture and Landscape Operation Services

The Farm, Horticulture and Landscape Operation Service Unit (FHLOSU) has five basic/major component i.e., i). Farm operation management, ii). Irrigation system management, iii). Biomass /crop residue management, vi). Weed management in non-cropped area, and v) Ornamental horticulture and landscaping unit (OHLU).

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. In addition to this other operational and routine farm

operations activities, transportation of farm produce from different divisional field to Pusa produce sale Centre. Sowing and harvesting operations of crops at experimental fields were accomplished in time during *rabi* and *kharif* seasons.

For effi cient distribution of irrigation water and to improve the conveyance effi ciency of irrigation system at IARI farm, an additional 1000 m of pucca channel was constructed. These channels would save 20-30 % of irrigation water which was wasted due to seepage/ conveyance of water in unlined field channels.

FOSU with close collaborative efforts of Divisions of Agronomy and Agricultural Engineering, is working on collections and transportation of crop residues and other biomass produced at IARI experimental farms for preparing compost. FOSU has lifted approximately 1500 trolley per year load of crop residue/biomass from various corners of IARI farm and transported them to the site of "Biomass Utilization Unit", for value addition. FOSU has acquired one biomass grabber and two hydraulic trolleys for effi cient biomass collection and disposal.

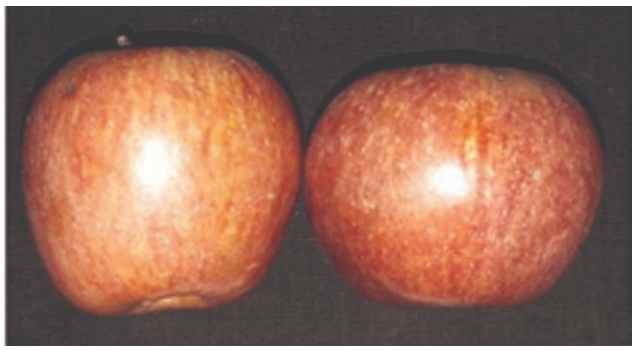
Weed control work was carried out at IARI farm in non–cropped area i.e., farm road sides, bund and channels, *Nala* sides and security road. In addition to above work FOSU has distributed and managed all the DPL's and contractual labours to different divisions and projects of IARI including salary distribution, EPF and ESIC management of daily paid labours.

Ornamental Horticulture and Landscaping unit (OHLU) was merged in the FOSU for creating synergies of work for effi cient operations of the Unit. The merged unit was named as Farm, Horticulture and Landscape Operation Service Unit (FHLOSU). The unit supervised all the landscaping work, maintenance of gardens/lawns of the Institute. Due support of machinery and maintenance of machinery was carried out by FOSU and its workshop staff.

4.7 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.7.1 Effect of Indigenously Developed Particle Films on Royal Delicious Apple

Four different particle films were developed by using different combinations of clay, kaolinite, gum arabic, and eucalyptus oil, which were named as PCS-I, PCS-II, PCS-III and PCS-IV. These were tested on apple to observe their effects on colour, diseases, quality and storage disorders. Three sprays of each clay film were given at 15 days interval, starting from 15th June, 2016 on Royal Delicious plants at Bajaura (H.P.). After harvesting the fruits, observations were



Indigenously developed particle films

Intensive colour development in PCS-IV sprayed particle film

recorded on colour, quality and storage disorders. Results revealed that all the particle films were effective in improving the fruit colour and fruit quality. However, PCS-IV film was most effective as it produced best coloured fruits (Hunter 'a' = 56.2±0.2) with high concentrations of total phenolics (116.2±3) and total soluble solids (15.5±0.1%).

4.7.2 Impact of Pre-Harvest Fruit Bagging on Quality of Rainy- Season Guava

Farmers usually discard rainy-season guava primarily because of very high incidence of fruit fly and insipid fruit quality. Hence, an attempt was made to study the impact of pre-harvest fruit bagging in Allahabad Safeda variety of guava using four different bags (PP-woven, PP Non-woven, Butter paper & Brown paper bags) at three different stages of fruit development (Pea, marble, half grown). It was observed that from all points of view, bagging at marble stage of fruit development with PP woven bags was the best. It helped to produce large sized fruits and free of fruit fly.

Fruit bagging in guava

Marble stage of fruit development in guava

4.7.3 Development of Shelf Stable Apple Wedges

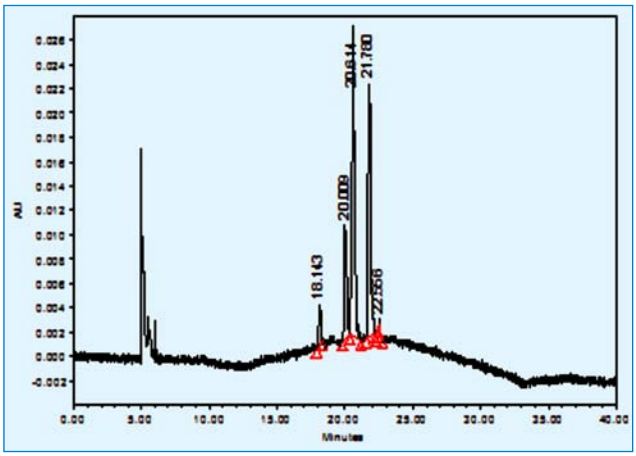
Hexylresorcinol (0.01%) + ascorbic acid (0.5%) + calcium chloride (0.2%) was found to be the best treatment for controlling browning in cut apple wedges. The samples could be stored under low temperature conditions for a period of seven days. Edible coatings such as carboxy methylcellulose and aloe vera worked synergistically with the antibrowning agents to curb the browning and retain the firmness and other quality attributes throughout the storage period.

Shelf stable apple wedges

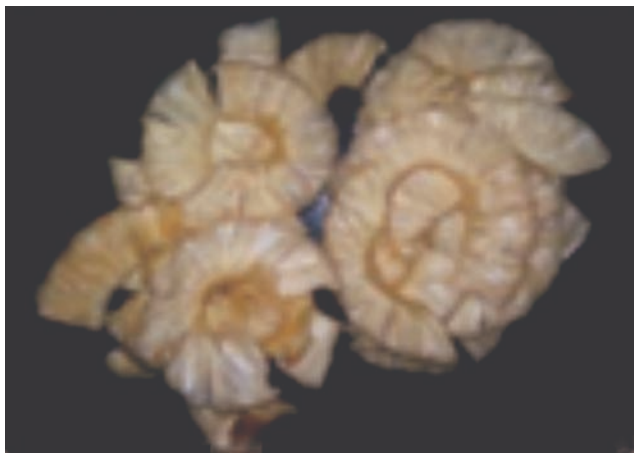
4.7.4 Storage Stability of Dehydrated Pine Apple Slices

The storage life of osmotically dehydrated pine apple slices could be extended for 4 months at ambient condition after packing the slices in low density polyethylene (LDPE) and for 6 months after packing in Aluminium laminated polyethylene (ALPE 260g) pouches with vacuum technology followed by storage at low temperature (7±2°C) with higher retention of ascorbic acid, total phenolic as well as sensory score and less total color changes of dehydrated pine apple slices. Moisture content, water activity total sugar, color changes increase with the increase in storage period, while ascorbic acid, total phenols and sensory score decreased with increase in storage period. However, these changes were affected

Fresh pineapple



HPLC chromatogram of black carrot anthocyanins



Dehydrated pineapple slices

by mode of pack and, storage temp. During 4 months of storage of dehydrated pine apple slices, product remained free from any microbial load in respect of yeast, mould and bacteria.

4.7.5 Characterization of Black Carrot Anthocyanins and Co-Pigmentation Studies

Black carrot anthocyanins of variety Pusa Asita have been characterized. The major anthocyanins detected were cyanidin-based containing different sugar moieties non-acylated, or acylated with sinapic acid, ferulic acid or coumaric acid. Optimized black carrot juice was found to contain a mixture of five anthocyanins which were characterized as (1) cyanidin 3-xylosylglucosylgalactoside, (2) Cyanidin 3-xylosylgalactoside, (3) cyanidin3-si napoylxylosylglucosylgalactoside, (4) cyanidin 3-feruloylxylosylglucosylgalactoside and (5)cyanidin 3-coumarylxylosylglucosylgalactoside. Based on their UV spectra and other characteristics. Black carrot juices exhibited the highest half-life values (27.18, 18.14, and 8.99 hr) at 70, 80 and 90°C, respectively. The potential role of black carrot anthocyanin as colour enhancers in promoting co-pigmentation, improving the colour and anthocyanin stability of plum was established by measuring colour density, thermal stability, chromaticity parameters, hyper chromic effect and bathochromic shifts. Addition of black carrot anthocyanin (BCA) had significant effect on lowering the anthocyanin degradation (k), which is clearly in high $t_{1/2}$ and low k values of co-pigmented juice. Addition of BCA resulted in lowering of k value and concomitant increase in $t_{1/2}$. Color attributes showed favorable response and there was decrease in L value and hue angle and increase in a* and b* and chromaticity parameters.

4.7.6 Enzymatic Treatment of *Kale* Powder

Kale powder was treated with enzymes (cellulase, pectinase and xylanase) individually in 10% substrate solution at 25 °C for 24 hr. The treated solution was analyzed for viscosity using RVA to evaluate the liquefaction by enzyme treatment. Pectinase enzyme demonstrated maximum liquefaction (least viscosity)

at all shear rates (25, 50 and 100 Pa) at 1 mm gap of PP50 measuring system. Beta-carotene content of filtrate and retentate was analyzed and was found to be higher in samples treated with pectinase followed by cellulase and xylanase. Optimization of time and temperature conditions of pectinase was done using CRD (5×5) for time (6, 12, 18, 24, 30 hr) at temperature (25, 30, 35, 40, 45 °C) with beta-carotene content as the prime indicator.

4.7.7 Colour Quantification through RGB Colour Cube Concept

On the basis of the fact that all the existing colours in nature are secondary and are made up of three primary colours i.e., Red (R), Green (G) and Blue (B) in different ratio of intensities, ranging from 0 to 255, a methodology was standardized using RGB colour cube concept. For protocol standardization, 13 cultivars of apple (*Malus x domestica* L.) were procured from Regional Research Station, Seobagh, Kullu, Dr. Y. S. Parmar University of Horticulture and Forestry, Himachal Pradesh having vast variability in peel colour. This is a non-destructive method for colour evaluation upto single picture element (pixel) of desirability quantification. Immediate validation can be done at researchers' end to ensure whether the quantified colour is a true representative of the whole lot or not, unlike other established protocols. RGB values can be converted into Hunters L*, a*, b*; CIE L, a, b; HSI; HSL; HSV terms, which are also universally accepted colour quantification formats.

4.7.8 Establishing Anti-Diabetic Potential of Ragi-based Extruded Snack

The anti-diabetic potential of the ragi based extruded snack was established through glucose adsorption capacity (GAC) assay and compared with commercial sample. Results show that ragi based snack could adsorb significantly ($p < 0.05$) higher levels of glucose (1.53–12.54 mmol/g) than commercial sample (0.12–3.19 mmol/g) at different glucose concentration (5–50 mmol/L). At 5 mmol/L glucose concentration, GAC of RFH was 1.53 mmol/g; however, that of CS was as low as 0.12 mmol/g. The results clearly imply that irrespective of the concentration of glucose; RFH has ability to adsorb considerably higher amount of glucose than CS thus would be beneficial in reducing amount of glucose available for transport across the intestinal lumen, consequently blunting the postprandial hyperglycemia.The higher GAC of the RFH may be attributed to its high dietary fiber content (17.65 g/100g), as both insoluble and soluble fiber.

4.7.9 Development of Reconstituted Rice

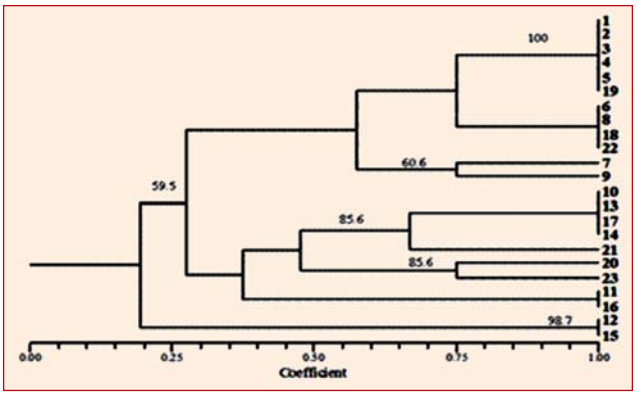
Reconstituted rice was developed through extrusion processing using flours of by-product of rice milling i.e, fine broken rice. The prepared rice is convenient product with very less cooking time. The production technique can be exploited to produce rice with different natural colours and at the same time its nutritional quality could also be enhanced many fold.

Reconstituted rice

4.7.10 Formulation of Pulse-Moringa Spaghetti

Formulation of spaghetti with high protein and micronutrients was standardized by incorporation of whole mung pulse and moringa leaves. The developed spaghetti was profiled for nutrients as well as textural attributes before and after cooking. Besides having good protein content of 15.2%, the spaghetti provides 2.6%dietary fibre and 7.2 mg/100g ascorbic acid. The developed spaghetti showed good cooking characteristics in terms of extensibility and stickiness. The overall acceptability of noodles was also good.

Pulse-moringa spaghetti



UPGMA clustering analysis from RFLP profile of 16S rRNA amplified product with restriction enzyme *Hinf*

4.8 MICROBIOLOGY

4.8.1 BGA based Composite Liquid Inoculant for Sustaining Crop Productivity and Soil Health Improvement

Studies on selected four formulations viz., 3, 4, 10 and 11 were carried out for effi cacy and shelf life. Compared to initial cell population of 2.2 X 10^4, the formulations were able to maintain cell population of 1.8 -1.9 X 10^4 and ARA of 37- 42 µmol C_2H_4/mg chl/hr against a control value of 45 µmol C_2H_4/mg chl/hr after one year of incubation.

4.8.2 Bioprospecting Rhizospheric and Endophytic Cyanobacterial Diversity amongst Selected Genotypes of Rice for N Uptake and Crop Yield

16S - RFLP profiles of 23 selected cyanobacteria from different rice varieties were generated using three restriction enzymes *Dpn* II, *Mse* I and *Hinf*. The percent polymorphism of 100, 80 and 88 was scored with *Dpn* II, *Mse* I and *Hinf* and a unique band of 354bp was recorded with *Mse*I in one isolate.

4.8.3 Encapsulated Microbial Inoculants for Phosphorus Nutrition and Crop Productivity

Multi functional phosphate dissolving fungus (*A. niger*) spores were encapsulated in different blends of alginate, agar, acacia gum and agro-residue matrices. These were tested for phosphorus related parameters Application of alginate encapsulated beads resulted in maximum alkaline phosphatase activity of 1.3 mg pNP/g soil and available P content of 72.37 µg P/g soil; an increase of 20-30 % over agar, acacia gum and agro-residue encapsulated formulations. However, acid phosphatase activity in intact root extract was highest (13.52 mg pNP/g fresh wt.) in agar and alginate based formulation phytase activity in intact

Viable cell count and Nitrogen fixation* of BGA in selected composite formulations at different time intervals

Formulation no.	Viable cell count (X 10^4.mL^{-1}) after incubation (months)			µmol C_2H_4/mg chl/hr after incubation (months)		
	1	6	12	1	6	12
3	2.1	2.0	1.9	45.2	42.2	39.2
4	1.9	1.8	1.8	44.4	40.8	37.1
10	2.0	2.0	1.8	47.8	42.0	41.8
11	2.2	2.1	1.9	45.5	42.1	41.9
Sem±	**0.42**	**0.54**	**0.44**	**0.68**	**0.27**	**0.37**
CD (P=0.05)	**1.16**	**1.50**	**1.51**	**1.88**	**0.75**	**1.03**

* Acetylene Reducing Activity

root extract showed an average increase of 33 % over other encapsulated counterparts.

4.8.4 Effect of Bio-Control Agents and their Impact on Rhizospheric Microbial Communities under Soybean-Wheat Cropping System

Impact of BCA and AM fungi on the soybean rhizospheric community composition in terms of PLFA analysis at two stages of the crop growth were evaluated. Increase in microbial biomass content was observed in inoculated treatments at 65 days of crop growth. No such increase was observed at 35 days of crop growth. The increase was 7X and 13.7X in case of *P. polymyxa* HKA15 and Wi-9 treated plant rhizosphere. Gram positive bacterial populations were 16X and 4.7X more than Gm-ve in uninoculated at 35 and 65 DAS, respectively. All inoculated plots had 2-8X Gm+ve bacterial populations compared to Gram negative ones. Distribution of PLFA was found to be influenced by the crop growth stages. Sum of C15 and C17 PLFA was found to be more at later growth stage as compared to 35 DAS crop rhizosphere. The branched vs. straight chain FA types did not vary much in individual plots during the crop growth. However, MUFA:PUFA ratios increased in the later stage of the crop growth. AM colonization was also estimated in the roots of these plants. It was found that percentage of root colonisation (61.1%) and spore counts (62.3 per gram of soil) were maximum in the Wi-2 inoculated plants which show that this organism supports the AMF colonisation to the maximum extent as compared to others.

4.8.5 Enhancing Microbe Mediated Nutrient Cycling under Non-Flooded (Aerobic) and Flooded (Anaerobic) Conditions for Improved Productivity in Rice-Wheat and Rice-Chickpea Cropping System

Seven chickpea genotypes viz., BGD 72, GNG 1581, Pusa 256, Pusa 362, Pusa 372, Pusa 547 and Pusa 1103 were inoculated with *Mesorhizobium* + arbuscular mycorrhiza and evaluated for symbiotic potential, plant growth and yield. It was observed that rhizobial population in maize field soil was 40.9 $X10^2$ cells /g where as rice field soil showed no counts. Nodulation and plant growth improved upon inoculation when chickpea genotypes were grown after maize in comparison to rice. Soil microbial enzyme activities such as β glucosidase (25.59 µg PNP /g dwt soil/hr) urease (10.7 µg NH_4-N/g dwt soil/hr) and phosphatase (234.19 µg PNP /g dwt soil/hr) were higher in soil collected from maize field in comparison to rice.

4.8.6 Microbes Mediated Water Stress Alleviation in Mustard

A pot experiment was conducted to evaluate the effect of seed inoculation of mustard with the selected rhizobacterial isolates (NAD 7 and MRD 17) on plant physiological, biochemical and photosynthetic parameters under water stress conditions. Inoculated plants showed improved membrane stability, relative water content and chlorophyll content under stress conditions. Similar trend was observed for proline, amino acids and sugars. The changes were more apparent in drought susceptible cultivar as compared to tolerant cultivar. No effect of inoculation on starch content was observed in both the cultivars under normal water conditions; however, inoculation significantly improved starch content under water stress conditions.

4.8.7 Bacterial Endophytes for Plant Growth Promotion

Fourteen bacterial isolates (9 *Enterobacter* sp. and *5 Pseudomonas* sp.) tolerant to heat stress (50^0C) and drought stress (40% PEG) producing growth hormone in the range of 120 to 2480 µg IAA /mg protein, P solubilisation 2.02 to 90.61µgP/ mg protein, K solubilisation 1.07 to 38.5µg K /mg protein were tested for their PGP effect on mustard plant growth in a pot house study. *Enterobacter asburiae* (M23), isolated from *Brasicca carinata*, being a multiPGP bacteria having capacity to solubilise P, K and Zn, produced maximum plant biomass at half NPK than the control. This isolate was tested on maize under 5 variable NPK treatments in pot house experiment for the interactive effect on plant growth parameters. Bacterial inoculations

improved maize plant biometric parameters and SPAD value when applied in combination with different fertilizers. Shoot length and fresh wt. was 57% more with half NPK and maximum average SPAD value of 34.5 at 30 days (30.5–36.5) as compared to recommended NPK level with 24.5 SPAD value (18.5–26.8).

4.8.8 Agri-Residue and Biomass Management

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

High rate of biomass production is important in the mass multiplication of *Azolla* under any environmental conditions. Elevated carbon dioxide and salinity decreased biomass production but the crude protein content increased by 6%. However, other nutritional parameters such as crude fat, crude fibre and moisture content did not show significant variation. An increase in vitamin C content and secondary metabolites such as anthocyanin, phenolics and flavanoid were also observed in *A. microphylla* in response to elevated carbon dioxide and salinity indicating its suitability as feed supplement. Twelve PHB producing isolates were found to possess cellulase and xylanase activity. Of these, two isolates LB7 and 2S4R1, could accumulate significant amount of PHB ranging from 24.3 (±3.4) to 27.3 (±2.7) % on cell dry weight basis. The C: N ratio was optimized for LB7 and 2S4R1 for maximum PHB recovery in minimal medium and was found to be 35:1 and 38:1, respectively. These cultures are being used to produce PHB by utilizing reducing sugars produced through pre-treatment followed by saccharification of paddy and wheat straw.

4.8.8.2 Developing efficient low-cost technologies for utilization of biomass as fuel

Paddy straw was pre-treated with 1% NaOH by autoclaving for 30 min at 121ºC and 10% solid loading, and extracted twice with water at same loading. This led to 63% glucan enrichment with concomitant high lignin and 50% dry matter loss. Enzymatic saccharification of the pre-treated solids carried out at higher glucan loading of 2 and 4% with Accellerase® enzyme for 24 h at 50 ºC gave saccharification efficiency 76% and ~50%, respectively. Hydrolysates containing 18 and 23 mg/mL sugars and supplemented with minimal salts and yeast extract and fermentated with *S. cerevisiae* LN for 24 h yielded ~2 and 4 mg/mL ethanol. Fermentation efficiency of 55 to 66% was obtained against 81% for synthetic controls with glucose. Protoplast fusion of *S. cerevisiae* and *P. stipitis* was attempted for obtaining efficient glucose and pentose fermenting strain. After 72 h of incubation, % of protoplasts was higher and most of the cells turned into protoplasts. To improve the temperature tolerance and activity besides creating an opportunity for recycling for future use, five nanoparticles were screened for their efficiency to immobilize one promising indigenous enzyme cocktail produced from *Aspergillus niger* strain SH3 *via* physical adsorption and covalent coupling methods. The enzyme-nanoparticle complexes (ENC) were screened for protein binding, enzymatic activities and immobilization efficiency. Magnetic enzyme-nanoparticle complexes (MENC) formulation showed higher immobilization efficiency (60–80%) for most of the enzymes. MENC showed better catalytic efficiencies in term of higher V_{max} and lower K_m than free enzyme. Saccharification yields from alkali treated paddy straw were higher (375.4 mg/gds) for covalently immobilized MENC than free enzyme (339.9 mg/gds). The immobilized enzyme was used for two cycles of saccharification with 55% enzyme recovery.

4.8.8.3 Lignocellulolytic fungi for *in situ* degradation of crop

Good colonizers *C. cinerea* LA2 and *C. stercoreus* ITCC 3745 showed a 27.6-28.16% dry matter loss within 15 days incubation in the soil. Spatial and temporal changes in FDA hydrolase, dehydrogenase, acid and alkaline phosphatise were observed. In case of soil hydrolytic enzymes, activity of xylanase and â glucosidase was stimulated by inoculation of *C. cinerea* LA2 and *Cyathus stercoreus* ITCC 3745. Highest activity of Xylanase (0.56IU/g) was recorded after 60 days in soil where mixed cultures of both the fungi

were inoculated. Similarly, β glucosidase activity was observed to be maximum (900 µg pNP/g soil) in the same treatment. These inoculants will be tested further in the same field with rice-wheat cropping sequence.

4.8.8.4 Development of formulation of potential microbial consortium for *ex-situ* degradation

The viability of efficient fungal spores selected for the rapid degradation of various substrates like fruit waste, kitchen green waste, flower waste were evaluated for their shelf life in various additives. All the additives were sterilized before studying for shelf life, and later spores were added and stored. The stored fungal spores in different additives and their CFU count were taken up to 6 to 12 months for shelf life. Spores stored at ambient temperature and in refrigeration gave a shelf life of one year and the count remained viable as 5.9×10^7.

4.8.8.5 On-farm evaluation of microbial inoculants in different crops and agro-ecosystems of India

Results of OFT/FLD conducted at KVK, Kathua (J & K) showed that the combined inoculation of BGA @1.25 kg/ha and liquid ZnSB replaced 25% of chemical fertilizer and gave 0.27 and 0.19 t/ha additional yield over 100% RDF and farmers' practice (FP), respectively. Treatments with 75% RDF + BGA and 75% RDF + liquid *Azotobacter* + liquid ZnSB gave net returns of Rs 67,500 and Rs 75,350/ha; whereas 100% RDF and FP gave net returns of Rs 58,750 and Rs 54,380/ha, respectively. Similar response of BGA was reported from KVK, Durg and Rajnandgaon (CG), KVK, Kheda (Guj), KVK, Saharanpur (UP), KVK, Haridwar (Uttrakhand), KVK, Raisen (MP), KVK, Ludhiana and Jalandhar (Punjab), KVK Burdhwan (WB), KVK, Rohtas (Bihar), KVK, Gumla and Sahibganj (Jharkhand). The average increase in rice grain yield across the locations owing to BGA and PSB application ranged between 5–12% over FP. Inoculation of liquid formulations of *Azotobacter,* ZnSB and KSB increased the rice grain yield by 4–11, 3–9 and 2.5–4.5%, respectively over FP across the locations. Many KVKs have started *Azolla* production units at their farm as well as farmers fields when the inoculums were provided to them by IARI. A large number of farmers (>650) were also trained on biofertilizer use.

4.8.9 Bio-resources

Draft Genome Sequence of *Halolamina pelagic* CDK2; a halophilic archaeon isolated from Rann of Kutch, containing 2,972,542 bp and 3,485 coding sequences, has been published. This whole-genome project has been deposited at DDBJ/EMBL/Gene Bank under the accession number SUBID SUB1035521, BioProjectID PRJNA272888, BioSampleID SAMN03287580, and accession number LGUC00000000. Many important annotated coding genes which could impart tolerance to high salinity were found. Another draft genome sequence of a plant growth promoting and cold active enzyme producing psychrotrophic *Arthrobacter agilis* strain L77 consisting of 3,608,439 bp (3.60 Mb) has been published. The genome comprises of 3316 protein coding genes and 74 RNA genes, 725 hypothetical proteins, 25 pseudo-genes and 1404 unique genes. WGS of two diazotrophs KMS55 and KMS 80 has been carried out. A total of 5,006 and 8,692 promoters were predicted for KMS55 and KMS80, respectively. An osmotolerant *Nostoc* has been isolated (KY623713). A hybrid vector pMICRO12 with promoter less reporter gene (β galactosidase gene), has been developed for successful promoter mining.

4.9 ENVIRONMENTAL SCIENCE AND CLIMATE RESILIENT AGRICULTURE

4.9.1 Development of Infocrop-Green Gram Model

The InfoCrop-generic model was calibrated and validated for simulating the growth and yield of green gram. Validation was also done for total dry matter and seed yield of various treatments in experiments conducted at different locations of India viz., Ludhiana, Akola, Sambalpur, Navsari, and Hyderabad. Statistical indicators such as mean bias error (MBE), root mean square error (RMSE) and agreement index (AI) were used to evaluate InfoCrop-Green Gram model

performance in simulating various crop parameters. The RMSE for phenological events (4-5 days), dry matter of different plant parts and TDM (347–453 kg/ha) and seed yield (306 kg/ha). The AI, which indicates the degree of match in trend between simulated and observed values across treatments, was in the range of 0.84 to 0.98 for these parameters indicating high simulation efficiency of the model. The model can be applied for further analytical studies such as climate change impacts.

4.9.2 Development of Spinach Model

A simulation model was developed for Indian spinach. The model could capture the phenology of crop with a deviation of 1 day and the trend of change in duration for phenological events due to nitrogen and irrigation levels. The model also could simulate the total dry biomass, harvested leaf yield, seed yield, total nitrogen in crop and seed nitrogen. The model performance indicators (MBE, RMSE and AI) indicated a good performance of the model in simulating harvested leaf yield and seed yield with an RMSE of 3.85 Mg/ha and 286 kg/ ha, respectively. The high AI for all these parameters indicated that model could capture the treatment effect on dry matter partitioning as well as nitrogen percentage satisfactorily. Comparison of both observed and simulated results showed that model is efficient in simulating the phenology, leaf area index, leaf yield and seed yield of Indian spinach. This model has a potential for use in crop management decisions.

4.9.3 Studies on N_2O and CH_4 Emissions

Fluxes of nitrous oxide and methane were measured using the closed chamber technique followed by chromatographic analysis (once a week and intensive measurement after each fertilizer event). The highest N_2O emissions were obtained from prilled urea. Application of NCU reduced N_2O emission by 14.8% under continuous irrigation whereas the reduction was non-significant under intermittent irrigation. The application of LCC based N (125% N) significantly decreased N_2O under continuous flooding. Highest methane emissions were obtained on application of FYM both under intermittent and continuous flooded water regimes. The total N loss in rice due to different N loss pathways ranged from 12 to 32 kg/ha in the different treatments. The % N loss of applied N was lowest at 24% in LCC based N application.

4.9.4 Methane Enrichment in Biogas using Selective Chemical Scavengers

In a study, it has been found that the treated biogas showed a significant reduction in CO_2 and increase in CH_4 content. The chemicals removed CO_2 upto 94%, amongst different chemicals used (KOH, $Ca(OH)_2$, NaOH, MEA, PEG, NH_4OH, EDTA). The MEA performed best regarding CO_2 reduction capacity, regeneration capacity, and price. The cost of chemical treatment of biogas was evaluated around ₹7.2/dm. The calorific value was also found to be increased to 8.15–9.79 kWh/Nm^3 from 6.55 kWh/Nm^3. Inferring from the study, it could be safely said that the use of chemicals for treatment of biogas can help in reducing the emission of CO_2.

4.9.5 N_2O Emission and Responses of Soil Microbial Community to Biogas Slurry Application in Wheat Crop

The application of biogas slurry stimulated the growth and yield of wheat. N_2O flux from the treatments showed more or less similar temporal trends with the appearance of a peak of N_2O emission three days after urea applications, however, the magnitude of flux differed. Highest N_2O emission reduction was found in control (54%) which was devoid of both urea and BGS application, but N_2O emission was significantly reduced with the application of BGS. After control, 100% BGS treatment showed maximum N_2O emission reduction (25%) of the recommended dose of fertilizer treatment. Total microbial densities were determined by classical plate count methods. The amendment incorporation resulted in significant increases ($p < 0.05$) in AWCD, R, and H compared to the un-amended and recommended doses of inorganic fertilizer amended plots. The regression functions showed linear relationships when H and AWCD were related to soil organic carbon (R^2 = 0.85 and 0.76, respectively).

4.9.6 Effect of Elevated CO_2 and Temperature on Biomass Partitioning Between Root and Shoot of Rice

Rice crop was grown inside OTC under varying CO_2 conc. and temperature conditions. Two CO_2 levels i.e., ambient (400 ppm) and elevated (500±50 ppm) and two temperature treatment i.e., ambient and elevated (+1.5º - 2°C) were maintained. Rice crop (var. Pusa Basmati 1509) was grown inside the OTCs. Growth and biomass of rice crop increased under elevated CO_2 treatment. Relative gain in dry weight was more in roots as compared to shoots under high CO_2 condition. Nitrogen concentration in rice grains decreased under high CO_2 condition but N uptake increased due to higher grain yield of the crop.

4.9.7 Isolation of Heavy Metal Resistant Microbes

With the aim to isolate metal resistant bacteria, heavy metal contaminated water was sampled from microcosms systems (managed by WTC) which are artificially spiked with different levels of Nickel (Ni), Chromium (Cr) and Lead (Pb) and planted with different aquatic hyperaccumulator plants. Four Chromium resistant bacterial strains were isolated by minimum inhibitory concentration (MIC) method. Chromium removal capacity by those microbes was assessed through using an immobilization technique. We immobilized the microbial cells in different percentage of Ca-Alginate beads and used for biosorption based removal capacity. Other two critical factors (in different combinations) viz., solution pH and bacterial dose were also checked. Using Box Bhenken design (Software used: Design Expert (version. 7) responses in each combination of BBD were analyzed through the fitting into a second order quadratic model. Out of four resistant microbial strains, the optimum condition for best performance/ maximum removal of $Chromium^{6+}$ by strain-3 was assessed. At a combination of bacterial dose: 0.1 g/100 ml beads, Ca-Alginate: 4.72 % and pH: 1.36, the model generated maximum predicted removal was 97.14%. This was validated in laboratory condition, and could obtain removal of 95%. The isolate was sequenced and identified as *Lysinibacillus spherical* which reportedly possesses *chrA* gene (Chromate resistance gene) and *nitR* and *yieF* gene (involved in Cr^{6+} reduction).

4.9.8 Lead Immobilization in Contaminated Soil Using Organic and Inorganic Amendments

Dry matter yield of spinach is significantly increased in amended soil as compared un-amended Pb contaminated soil. Lead concentration in shoot and root of spinach was significantly reduced in amended soil as compare to un-amended Pb contaminated soil. Sequential extraction of Pb in soil indicates that lead concentration in labile pool significantly reduced in amended soil as compare to the un-amended soil. Lead content in the labile pool found in the order of contaminated soil>RP>RP+BGM>SSP>VC+RP. Therefore, single super phosphate and rockphosphate in combination with vermicompost were found the most effective amendments in stabilizing the Pb in contaminated soil. This technology will not only help in the stabilization of lead in contaminated soil but also utilize low-grade rock phosphate which is otherwise treated as a waste.

4.9.9 Isolation of Strain Using Ammonium as Sole Nitrogen Source

Farming (manure from livestock and fertilizer) is the primary source of atmospheric ammonia. In the air, ammonia mixes with other emissions to form particulates. Under certain conditions, the heterotrophic microorganisms oxidize ammonia to N_2O and N_2. It is one of the most economical and attractive methods for environmental remediation. Strain C 2 which has 99% similarity with *B. amyl liquefacients* has been isolated which can use ammonium as a sole nitrogen source.

4.9.10 Physiological and Biochemical basis of Effect of Air Pollutants on Crop Growth and Productivity

Effect of short-term exposure to SO_2 and NO_2 of 2 hour duration daily for 7 days, in a concentration range of 5 and 20 µg m^{-3}, over and above the ambient concentration, with ambient level of natural control, was studied on field grown tomato, spinach, mustard,

carrot and wheat at 30 DAS. Effects were measured in terms of ROS production and differential induction of antioxidative defense system across crops. Lipid peroxidation, ascorbic acid content, superoxide radical, peroxidase activity, H_2O_2 production, SOD activity, catalase, glutathione reductase activity, leaf chlorophyll, membrane stability index, S content, ^{14}C partitioning, ^{14}C exudation capacity and gas exchange attributes such as Pn, Gs, and Tr. Visual symptoms of aerial exposures of SOX and NOX were visualized in all crops. Tomato showed least growth inhibition even at the highest level of SOx and NOx determined from the ratio of leaf necrotic area when compared to total green leaf area. Among the crop species tested, spinach showed greater growth recovery following withdrawal/removal of gaseous pollutants exposure.

4.9.11 Air Pollution Load and APTI Index

Ten different farmers' field situated in different villages located at varying distance within 1-10 km radius near Dadri, Uttar Pradesh were selected on the basis of windrose map for study. The results indicated that average annual concentration of NO_2 and O_3 were maximum at Jarcha and Sultanpur villages. The average annual concentration of SO_2 was maximum at Jarcha and Upralsi villages. Total suspended particulate (TSP) concentration was also high in these three villages. These villages are in the periphery of 4 km from NTPC, Dadri.

Air pollution tolerance index (APTI) value was found between 7 (Payawali Tezpur) to 9 (Sultanpur) in wheat crop and 6 (Payawali Tezpur) to 10 (Jarcha) in rice crop. The APTI lies below 16 (Sensitive < 16,; Moderate 16-29 & Tolerant > 30) in all the samples. It has been found that rice and wheat come under the sensitive category. Hence, it will differently affect the crop productivity, but we could conclude it after the study of 2-3 years.

In another study conducted at NTPC, Anta, Rajasthan, indicated that *Sesamum indicum,* and *Abelmoschus esculentus* having APTI value of 13.1 and 10.3 were identified as intermediate species tolerant to pollution. Whereas, *Glycine max, Zea mays, Arachis hypogaea* and *Vigna mango* were identified as a sensitive crop species. The crop species having higher APTI value can be given priority for cultivation in urban agriculture and industrial areas; so as to reduce the effects of air pollutants and to make ambient atmosphere clean and healthy. Sensitive species are more useful as bioindicators, and tolerant crop plant species are more appropriate as phyto-remediating agents in polluted environments.

4.9.12 Impacts of Air Pollutants on Physico-Chemical and Biological Properties of Soil

Soil and plant samples were collected from the villages in the vicinity of NTPC, Dadri (in 10 km periphery) for the study of the impacts of particulate deposition on soil properties. The deposition of particulate matter had shown the variable deposition trend on the soil as well as on plant surfaces. On soil surface, maximum deposition was found in Kangra (26.3 g/m^2/month) followed by Upralsi village (21.9 g/m^2/month) and on control site (Akilpur Jagir) was 10.3 g/m^2/month. On plant sample during the flowering stage, deposition ranged from 1.2 to 2.3 mg/cm^{2-}. The pH of soil ranged from 7.4 (Nidhauli) to 8.8 (Piyawali), and EC of soil was varied from 0.23 mmhos/cm (Upralsi) to 0.77 mmhos/cm (Piyawali) at selected sites. The results shows that maximum deposition was found from 1 to 5 km distance from power plant and continuously decrease after 5 km in leeward side.

5. CROP PROTECTION

Crop losses due to pests and diseases can be managed by applying effective crop protection strategies. In the recent climate change scenario, many pests and pathogens are remerging, besides new ones being reported. Hence, there is a need to study the etiology of the diseases, population dynamics of pests & pathogens; and further to plan newer crop protection strategies. The management strategies may include developing new chemical molecules, identifying novel bio-control agents having broad spectrum activities and newer formulations with slow release abilities. During the year under report, diversity studies, resistance in hosts against major pests and pathogens, identification of some new diseases and development of diagnostic protocols were undertaken.

5.1 PLANT PATHOLOGY

5.1.1 Genetic Variability, Pathogen Characterization and New Records

Genetic variability in Tilletia indica. A total of twenty one *Tilletia indica* isolates were characterized based on partial *Gapdh* gene sequences, clustering seventeen isolates in clade I and four isolates in clade II. All isolates of *T. indica* did not cluster region wise and showed high genetic variability.

Virulence spectrum of rice blast (Magnaporthe oryzae) isolates from Kashmir region. Twenty two isolates from rice growing regions of Kashmir analyzed on 24 monogenic blast differentials, showed virulence frequency varying from 33 to 89%. *Pi-9, Pi-54, Pita, Pita2, Pi-z5, Pi-z* and *Pi-zt* were identified as effective genes.

Characterization of Fusarium oxysporum* f. sp. *lentis isolates. Seventeen representative isolates were confirmed as *Fusarium oxysporum* f. sp. *lentis* with 99-100% similarity based on ITS region amplification (KY319342 to KY319358). Phylogenetic analysis of RAPD and SSR data grouped the isolates in 5 major clusters.

Taxonomy of Curvularia and its phylogenetic relationship with Bipolaris and Cochliobolus complex. The phylogenetic relationship based on morphology and molecular analysis of *Curvularia* with *Bipolaris* (imperfect stages) and *Cochliobolus* (perfect stage of both the genera) showed clear formation of *Curvularia* and *Bipolaris* clusters; and the species of *Cochliobolus* were clustered along with the respective anamorphic (*Curvularia* and *Bipolaris*) species. Therefore, *Cochliobolus* is considered as the perfect state of both the genera. *B. australiensis, B. hawaiiensis* and *B. spicifera* clustered with *Cuvularia* and not with *Bipolaris*, therefore, these species may be transferred to *C. australiensis, C. hawaiiensis* and *C. spicifera.*

Characterization of Indian peanut clump virus. Indian peanut clump virus was identified on groundnut in Bikaner district of Rajasthan. Complete genome of Indian peanut clump virus was characterized from the *N. benthamiana,* which shared 87% and 97% sequence identity in RNA1 and RNA2, respectively with that of Ludhiana isolate of IPCV. Serological diagnostic was developed by using polyclonal antiserum effective at 1:5000 dilution.

Characterization of Grapevine leaf roll-associated virus 4. *Grapevine leaf roll -associated virus* 4 (GLRaV-4) was identified infecting 12 grapevine cultivars by ELISA, RT-PCR and sequence comparison of coat protein (CP), heat shock protein 70 homologue (HSP70h) and p23 genes. A phylogenetic analysis of the CP gene showed that the Indian isolates clustered with GLRaV-4 isolates Y252-IL (AM162279) from Israel, Y253-TK (AM176759) from Turkey, and LR106

(FJ467503) from USA with a maximum identity of 98% at the amino acid level.

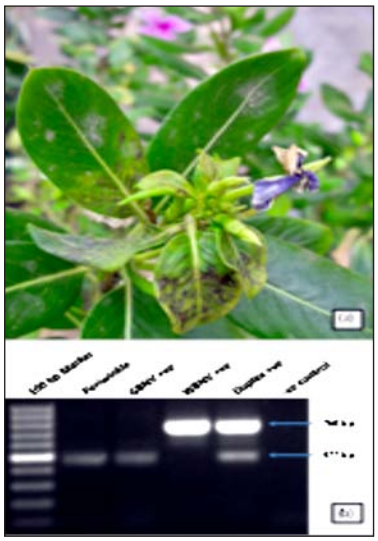
Molecular characterization of phytoplasmas. Clover proliferation phytoplasma belonging to subgroup D were identified on *Hibiscus rosa-sinensis* (Pune isolate), *Saponaria officinalis* (Pune isolate) and *Allamanda cathartica* (Delhi isolate) on the basis of 16Sr DNA sequences. This is the first record of the phytoplasma association of *'clover proliferation'* subgroup D. On the basis of 16 SrDNA sequences Phytoplasma strains of 'clover proliferation' (16SrVI) group were identified on four vegetable crops, viz. *Apium graveolens*, *Brassica oleracea* var. *capitata*, *Solanum melongena* and *Lactuca sativa*. *Hishimonas phycitis* also tested positive for the 16SrVI phytoplasma group. Detection and occurrence of 16SrI-B subgroup of phytoplasma causing witches' broom disease of summer squash plants (*Cucurbita pepo* cv. Pusa Pasand) at IARI, New Delhi was also confirmed which is a new report. The 16S rRNA gene of 16SrXI-B subgroup phytoplasma was detected in durum and bread wheat genotypes at ICAR- Indian Agricultural Research Institute Region Station, Indore. The disease incidence was greater in durum (1.7 – 20 %) as compared to bread wheat (1.3 – 10.4 %). Two phytoplasma subgroups (16Sr XI-D and 16Sr XIV-A) associated with leaf rolling, necrosis and apical bud proliferation symptoms in Lychee (*Litchi chinensis*) were identified and characterized. Phytoplasma on three legume species, cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*) and mung bean (*Vigna radiata*) were identified as 'Ca. P. cynodontis' (16 SrXIV-A), 16 Sr IX-C and 'Ca. P. australasia' (16Sr II-D), respectively.

Citrus tristeza virus (CTV) in NE India. Twelve CTV isolates were collected from Mandarin (*Citrus reticulata*) growing areas of the Darjeeling hills, Sikkim and Manipur of NE India. Sequence analysis of CP genes of CTV isolates showed 91-100% nt identity which revealed that CTV in NE India is diverse.

***New host record of Pleurotus cystidiosus* sub sp. *abalonus* from India.** A delicious edible mushroom was collected from partially rotted stems of living trees of Maxican silk cotton (*Salamalia malabarica*). It is a delicious edible mushroom. This is a new record of *Pleurotus cystidisus* sub sp. *abalones* from India.

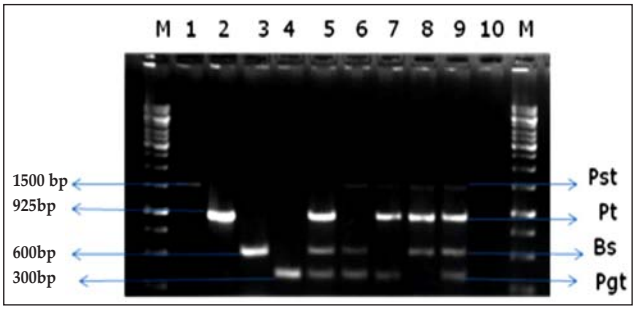
Witches' broom, little leaf, stunting symptoms on pigeon pea (a-c U.P.); flat stem symptoms on cowpea (d-e Kerala); and little leaf, yellowing and extensive proliferation of branches in mung bean (f-g Delhi)

New record of Groundnut bud necrosis virus (GBNV) on periwinkle and Phalaenopsis hybrids. GBNV was identified on *Catharanthus roseus* through serology, duplex RT-PCR amplification and sequencing of N gene. GBNV was also identified in *Phalaenopsis* hybrids, obtained from germplasm collection of NRC for Orchids, Pakyong, Sikkim.



5.1.2 Molecular Diagnostics

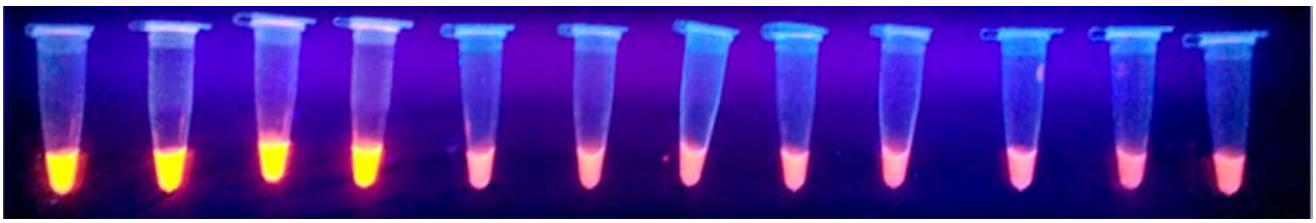
Multiplex PCR for detection of major wheat pathogens. A multiplex polymerase chain reaction (PCR) assay was developed to detect and quantify foliar pathogens, *Puccinia triticina, P. graminis tritici, P. striiformis* and *Bipolaris sorokiniana,* in wheat. Specific amplicans of 1.5 kb, 925bp, 600bp and 300bp were obtained for *P. striiformis*, *P. triticina*, *B. sorokiniana* and *P. graminis tritici* when used simultaneously in multiplex PCR. With this multiplex PCR, the presence of different pathogens at pre-symptomatic infection levels is possible.



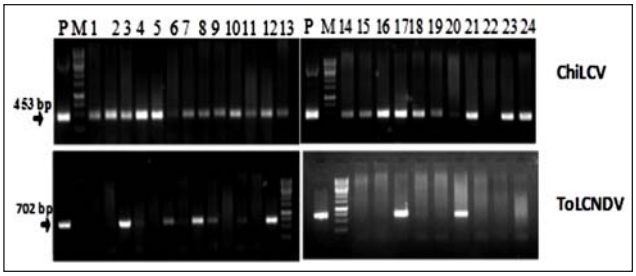
Multiplex PCR for the detection of foliar pathogens of wheat [1: *P. striiformis* (46S119); 2: *P. triticina*(77-5); 3: *B. sorokinina* (Bs-75); 4: *P. graministritici* (40A); 5: Pt + Bs + Pgt; 6: Pst+ Bs+ Pgt; 7: Pst+ Pt+ Pgt; 8: Pst+ Pt+ Bs; 9: Pst+ Pt+ Bs+ Pgt; 10: Healthy wheat leaf DNA]

LAMP based detection of Puccinia triticina. A quick and reliable LAMP protocol was developed for speedy detection of *P. triticina* causing leaf rust of wheat using a set of six primers designed from specific region (PTS68) of *Puccinia triticina* and conditions were optimised to complete in 60 minutes at 65°C. No cross reaction with other related pathogens was observed and sensitivity increased to 100 fg from 25pg by conventional PCR.

Species specific diagnosis of Chilli leaf curl virus .A pair of primer for *Chilli leaf curl virus* (ChiLCV) with the 3¢polymorphism was designed based on the comparison of sequences of all the known begomoviruses in India, showing specific band of 453 bp. Previously, similar specific diagnosis was developed for tomato leaf curl New Delhi virus (ToLCNDV). The specific diagnostic method for both ChiLCV and ToLCNDV showed that ChiLCV (60%) was more predominantly associated with the chilli leaf curl disease compared to ToLCNDV (11%).



LAMP assay detection of *Puccinia triticina* using ethidium bromide. Tubes from left to right; DNA template of *P. triticina* (1: 77-5; 2: 12-3; 3: 104-2; 4: 162-1); 5: *P. striiformis tritici* (46S119); 6: *P. graminis tritici* (40-1); 7: *Bipolaris sorokiniana*; 8: *B. oryzae*; 9: *Fusarium graminearum*; 10: *Alternaria triticina*; 11: Healthy wheat leaf DNA; 12: sterile water



Species specific PCR analysis showed that ChiLCV is more prevalent in chilli than ToLCNDV in samples tested from IARI experimental fields

Simplified isothermal polymerase amplification based assay for diagnosis of Banana bunchy top virus. A highly simplified isothermal polymerase amplification based assay for diagnosis of *Banana bunchy top virus* was developed which was found comparable with conventional PCR.

Production and validation of antibody against Rice tungro bacilliform virus. Using coat protein gene of *Rice tungro bacilliform virus*, polyclonal antibody was produced, which was validated with rice tungro infected samples from Uttar Pradesh, Uttarakhand, Tamil Nadu and Andhra Pradesh; and also in leafhoppers.

Identification and diagnostics of viruses infecting orchids. A duplex reverse transcription polymerase chain reaction (RT-PCR) assay was developed for simultaneous detection of two orchid viruses: CymMV and ORSV, using coat protein gene fragments of 672bp and 477bp, respectively.

Antibody to the recombinant coat protein for diagnosis of CGMMV. A coat protein (CP) gene construct of CGMMV was developed in pET-29a(+) expression vector and the expressed purified coat protein (~24 kDa) was utilized to produce polyclonal antibody, which efficiently detected CGMMV in ELISA and dot blot immunoassay.

5.1.3 Whole Genome Sequencing, Assembly, Prediction and Annotation of Different Pathogens of Cereals

Tilletia indica. The monoteliosporic culture of *T. indica* isolate (RAKB_UP_1) was sequenced using HiSeq 2500 and PacBio RSII platform, showing genome assembly size of 33.7 MB with 55.0 per cent G+C content. A total of 1,737 scaffolds were generated with the N_{50} scaffolds of 58,667 bp and an average scaffold of 19,443 bp. The whole genome shotgun project has been deposited at DDBJ/ENA/GenBank under the accession number MBSW00000000. A total number of 1,877 TEs were identified out of which gypsys having the highest count of 573 followed by cacti with 309 times occurrence. The most abundant SSRs type were trinucleotide in genome with 2456 in number (42 % of all SSRs).

Puccinia striiformis tritici. Whole genome sequence of *Puccinia striiformis tritici* (pathotype 38S102) using Illumina NextSeq 500 platform revealed draft genome of 75.59 Mb, with 43.47% G+C content. The assembly comprises of 997 scaffolds with a scaffold N_{50} value of 145.23 kb. Gene prediction using the FGENESH trained on *Puccinia* group models predicted a total of 19,677 genes. This whole genome shotgun project has been deposited in DDBJ/ENA/GenBank under the accession number MKXH02000000.

Magnaporthe oryzae. Isolate RMg-Dl was genome sequenced using dual sequencing platform such as Illumina-HiSeq2500 and PacBio RSII. In total, the assembly of 996 scaffolds resulted in genome size of 34.82 Mb. A total of 12,747 genes in the range of 201-14,916 bp were predicted with average size of 1007 bp. Besides, a total of 300 transposons were identified using Transposons PSI in *Magnaporthe oryzae* (NCBIAccession no. MBSD00000000).

Fusarium fujikuroi. *Fusarium fujikuroi* isolate "F250" was sequenced with an assembly size of 42.47 Mb providing coverage of 96.89% on reference genome. A total of 13603 protein-coding genes were predicted from genome assembly. The average gene density in the *F. fujikuroi* genome was 315.10 genes per Mb with an average gene length of 1.67 kb. Additionally, 134374 SNPs identified against IMI58289 isolate, with an average SNP density of 3.11 per kb of genome, out of which 130205 are homozygous in nature. Repetitive elements represent approximately 270550 bp, which is 0.63% of the total genome. In total, 3109 SSRs,

including 302 compound SSRs are identified (NCBI accession no. MBPO00000000).

5.1.4 Host-Pathogen Interaction

Cloning and functional characterization of SCD1 gene involved in melanin biosynthesis in Bipolaris soroliniana. Scytalone dehydratase (*SCD1*) is a gene encoding scytalone dehydratase in phytopathogenic fungus *B. sorokiniana* involved in the production of dihydroxynaphthalene melanin. Knockout mutants of *B. sorokiniana* displayed an albino phenotype showing no melanin production. Pathogenicity assay on wheat plants with wild type (WT) and *SCD1* knockout strains of *B. sorokiniana* clearly showed that *SCD1* is indispensable for causing the disease.

Response of putative pathogenicity-related genes in Tilletia indica. Putative pathogenicity-related genes analysed in *Tilletia indica* at different time intervals revealed that MAP kinase genes, viz., *TiPmk1, TiHog1, TiKss1* were highly up regulated in the presence of susceptible host factor.

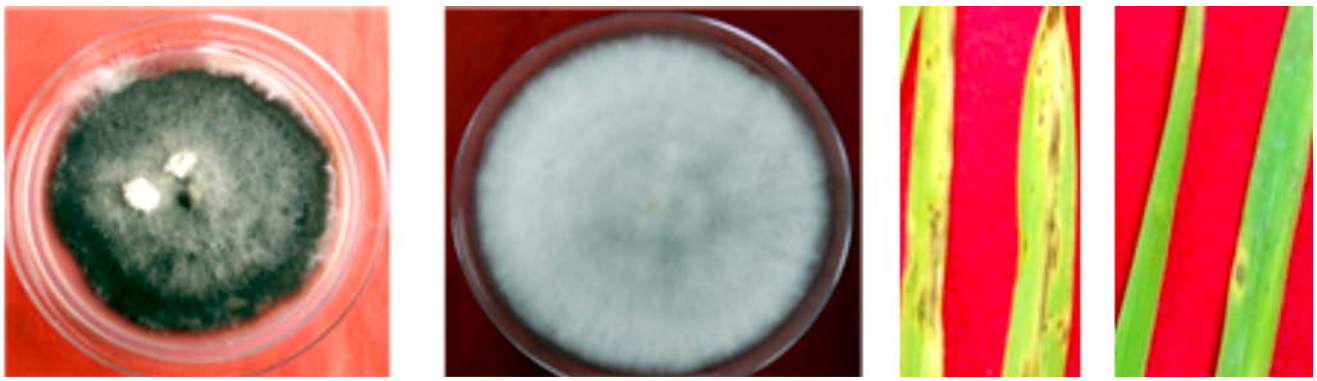
Histopathological studies of Fusarium fujikuroi infected rice seed and seedlings. Localisation of *F. fujikuroi* in different parts of seed was studied under scanning electron microscope and light microscope, which showed presence of pathogen in glumes, embryo and husk of rice seeds. Penetration by swollen tip hyphae to host tissue was also visible at 12 h after inoculation. Fully colonized root tissue of rice was observed at 72 h after inoculation.

Identification and validation of potential molecular targets in Colletotrichum orbiculare-cucumber. Hypothetical pathogenicity genes of *C. orbiculare* inciting anthracnose of cucumber studied in response to reactive oxygen species revealed a less significant expression of superoxide dismutase coupled with a strong expression of catalase in ferulic acid than that in menodione and hydrogen peroxide indicating its oxidative effect through generation of radicles similar to that of hydrogen peroxide.

XopR TTSS effector of Xanthomonas oryzae* pv. *oryzae (Xoo) regulates ROS accumulation to defeat rice innate immunity during bacterial blight development. XopR, a core TTSS effector secreted by Xoo play crucial role during blight development in rice by suppressing the ROS-mediated immune responses in rice. Rice leaf infiltrated with Xoo*ÄxopR*

	N. benthamiana expressing XopR	*N. benthamiana* (Control)
O_2^- accumulation by Xoo ΔxopR	+++	+

XopR expressing tobacco complemented the ROS suppression activity by Xoo*"xopR*



Colony of *Bipoilaris sorokiniana* on PDA (a) WT strain; (b) *ÄSCD1* knockout strain; pathogenicity on susceptible genotype with (c) WT strain and (d) *ÄSCD1*

showed higher ROS accumulation compared to that of Xoo (wild) used as control. Further, suppressed O_2^- accumulation in *N. benthamiana* leaf by Xoo "*xopR* was compromised in tobacco expressing XopR. This clearly suggested the role of XopR in suppressing the ROS accumulation.

Citrus tristeza virus (CTV)-citrus. Studies on interaction between CTV and its citrus hosts and the evolutionary history of CTV, divided CTV isolates into three subgroups, Ca-CTV (29 isolates) originated from *C. aurantifolia*, Cr-CTV (38 isolates) from *C. reticulata* and Cs-CTV (55 isolates) for *C. sinensis*. The present study showed that CTV displays low codon usage bias and higher genomic stability.

5.1.5 Biological Control

Talaromyces flavus-a potential biocontrol agent against bakanae. Flourescein diacetate (FDA) dye was used to detect the cell viability of the roots of rice plant. Roots were inoculated with *Fusarium fujikuroi* followed by *T. flavus* isolates (*Tf1, Tf2* and *Tf3*). Roots treated with *T. flavus* were more viable as observed by Flourescein diacetate (FDA) staining compared to the control indicating that *T. flavus* keeps rice root alive. Similarly, nuclear DNA content of the root tips of rice plant by DAPI (4,6-diamidino-2-phenylindole) revealed more nuclear DNA in *T. flavus* treated plants compared to the untreated control.

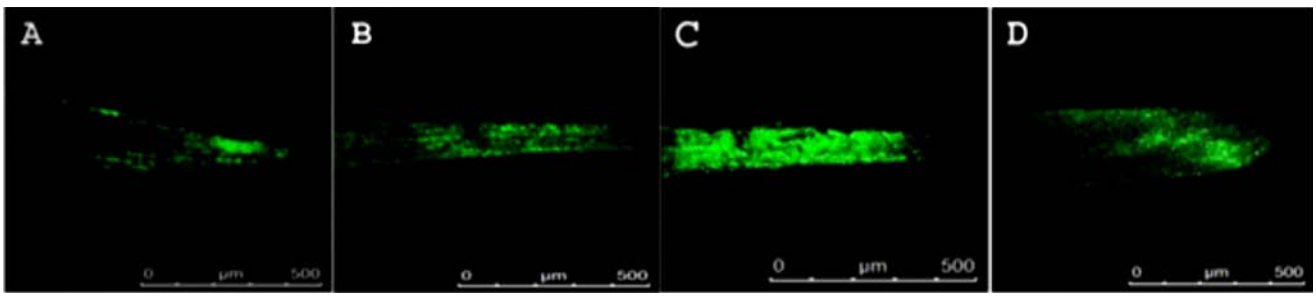
Understanding Fusarium wilt resistance of tomato induced by a biocontrol consortium. Potential biocontrol consortia comprising of the plant growth promoting rhizobacteria, *Bacillus subtilis*, *Pseudomonas* sp., and species of *Trichoderma* and *Chaetomium* effective against *Fusarium oxysporum* f.sp. *lycopersici* (FOL) inciting vascular wilt of tomato have earlier been identified *in vitro*. Seed treatment and soil application of a biocontrol consortium comprising of TEPF+CGA+S17TH challenge inoculated with FOL resulted in significantly lower incidence (63.5% reduction) of Fusarium wilt relative to the pathogen control. This lower incidence was associated with increase in the height of root and shoot length of 145.2%, relative to the pathogen control.

Phyllosphere microbiome. The bacterial flora on healthy pomegranate phyllosphere was dominated by *Bacillus* species, viz., *B. subtilis, B. megaterium, B. cereus.* These bacteria displayed strong antagonistic activity against *X. axonopodis* pv. *punicae* and *Ceratocystis fimbriata.* The blast susceptible rice genotype PRR78, showed rich diversity of bacteria compared to monogenic resistant counterpart Pusa 1602. *Pantoea ananatis* dominated the bacterial flora on phyllosphere.

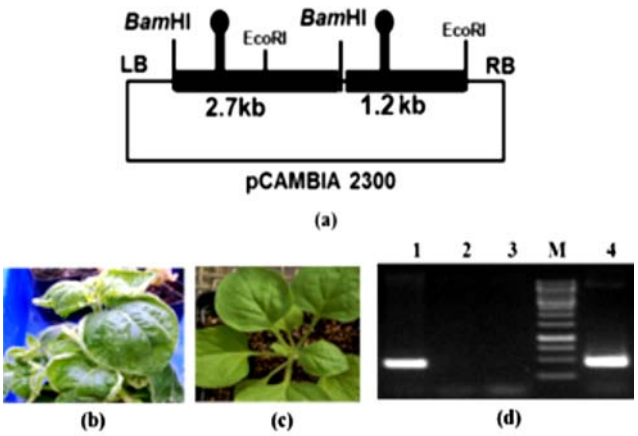
***Screening of phenazine-1-carboxylic acid (PCA) gene in Pseudomonas* spp.** *Pseudomonas* spp. is effective against a variety of fungal and bacterial root pathogens. Out of 17 strains of *Pseudomonas* spp. from rhizosphere and endophytic population of tomato screened for Phenazine-1-carboxylic acid (PCA), a secondary antimicrobial metabolite, 12 strains showed an amplicon of 767bp.

5.1.6 Development of Infectious clones of viruses

Development of infectious clone of Chilli leaf curl virus. A partial tandem repeat construct (1.4 mer,



Cell viability of rice plant roots under confocal microscopy (A) *Fusarium fujikuroi* (F304) inoculated root: (B) F304 + *Tf1;* (C) F304 + *Tf2* and(D) F304 + *Tf3*



Designing of partial tandem repeat construct against *Chilli leaf curl virus* and its infectivity study: (a) Map of partial tandem repeat of *Chilli leaf curl virus*, (b) Development of leaf curl symptom in *N. benthamiana* upon agroinoculation, (c) Healthy *N. benthamiana* plant, and (d) Detection of *Chilli leaf curl virus* from agro inoculated plants of *N. benthamiana*

*Eco*RI- *BamH*I-*BamH*I) of chilli leaf curl virus was made and agro-inoculation of this construct in *Nicotiana benthamiana* yielded typical leaf curl symptoms within 10 dpi, which was also confirmed by PCR.

Infectivity of cloned DNA of CGMMV in cucurbits. The full-length genome clone (BP4) of *Cucumber green mottle mosaic virus* (CGMMV) successfully caused infection after agro inoculation to different cucurbits which was confirmed by electron microscopy, ELISA and RT-PCR.

Development of infectious clones of CLCuD-begomovirus and its associated betasatellite molecule. An infectious clone (designated as pCAMBIA+S-11-1.4 mer), 1.4 mer tandem repeat (partial dimer) of the DNA-A of CLCuKoV-Burewala isolate S-11 was constructed in binary vector pCAMBIA-2301. An infectious clone (designated as pCAMBIA+S-11B-2mer), a dimer of S-11B betasatellite molecule associated with CLCuMuV-Faislabad isolate S-11 was constructed in binary vector pCAMBIA-2301. The infectious clones were transformed to *A. tumefaciens* strain EHA105. The infectivity of infectious clones was tested in two cotton varieties, HS 6 and F 846 and tobacco (*N. benthamiana* and *N. tabaccum*).

5.1.7 Evaluation of Crop Genotypes for Disease Resistance and Mechanism of Resistance

Rice. Among the 373 rice genotypes evaluated for blast resistance, 6 entries (1615, 1303, 2330, 3323, 4201 and 4204) showed resistance. Out of 26 entries evaluated for monitoring of virulence against *Magnaporthe oryzae,* entries like Raminad STR-3, *O. minuta,* Zenith, Tadukan and Tetep were found to be resistant. Out of 667 genotypes evaluated against sheath blight, 9 entries, viz., VL-31817, 1327, 1516, 3511, 11/123, 34/159, Tetep, CH-45, VL-892 were moderately resistant.

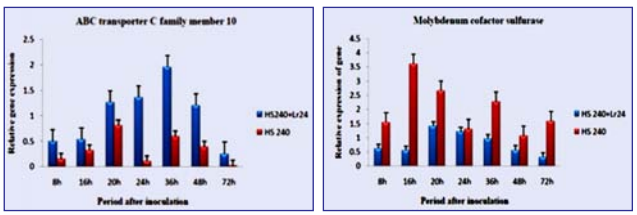
Wheat. Among the 576 PDSN wheat entries evaluated for rusts and leaf blight resistance at different hot spot locations, forty five entries were found to be highly resistant against all the three rusts and leaf blight at adult plant stage across the test locations. Some promising entries are: CL 3829, PS 14, PS 70, CLY 1547, CLY 1553, HAS 2000, HG 6, HG 116, and HG 164. Out of 319 CVT wheat genotypes evaluated for rusts at seedling stage (SRT), twenty six entries, viz., IND 425, IND 444, ID 1508, ID 1516, ID 1518, ID 1519, ID 1520, SBP 15-39, SBP 15-42, DL 2499, ID 1524, ID 1526, ID 1528, ID 1532, ID 1534, ID 1539, WBM 3562, WBM 3628, WBM 3629, WBM 3602, WBM 3632, WBM 3635, WBM 3599, WR 3039,WR 3040 and WR 3054 have been found to be resistant to all three rusts. With regard to stripe rust resistance of CVT genotypes, thirty five entries were identified to be highly resistant. Race specific (78S84 and 46S119) APR response of AVT IInd and AVT Ist year wheat entries (173) revealed that some of the wheat genotypes, viz., HD 3086, WH 1124, HD 4728, HI 8498, MACS 3949, NIDW 295, TL 2942, HPW 423, HPW 432, HS 622, HS 626, HS 627, HS 628, VL 1008, VL 1009, DBW 179, PBW 725, PBW 737, WH 1184, HI 1612, RKD 283, TL 3006, TL 3007, TL 3008, TL 3009, TL 2010, HPPAU 05, PBW 760, DBW 220, PBW 757 and HS 580 possess high degree of resistance to both the pathotypes of stripe rust. Evaluation of wheat genotypes of IPPSN (1619), PPSN (526), EPPSN (77) and MDSN (41) revealed that 695, 228, 26 and 18 entries, respectively were found to

be resistant against stripe and leaf rust. Out of twenty CIMMYT lines with different *Sr* genes evaluated for adult plant resistance at Wellington station, line with *Sr24* gene (BTSR 24 AG) was resistant to the prevailing pathotypes of stem rust at wellington and the line with *Sr25* gene expressed the susceptible reaction. Based on field reactions and SRT, the breakdown of resistance against *P. triticina* was recorded in var. Amrita (40-80S), MP 4010 (20S), HW 2001A (20S), HW 2004 (40S), HW 2005 (60S), HW 2006 (60S), HW 2007 (5S), HW 2019 (5S), HW 2020 (20S), HW 2008 (5S), HW 2022 (20S) and RL 6064 (40S) during the months of September and October 2016 at Wellington. Out of 576 entries, entries like HI 8759, HD 3171, HI 1605, HD 3209, HD 3184, HI 8774, HI 8777, etc., possess high degree of resistance to stem rust pathotypes at Indore conditions. Out of 179 entries (79 KBSN and 100 AVT) of wheat screened for resistance to Karnal bunt, 6 entries remained free from KB infection.

Maize. Out of 334 maize genotypes evaluated against maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*), 188 entries were found resistant to MLB disease, 22 entries were resistant to BLSB and 20 entries were resistant against both the diseases.

Pearl Millet. Out of 65 Pearl Millet genotypes evaluated against blast pathogen (*Magnaporthe grisea*), 12 entries (IP 11036, IARI B3, IARI R1, BHLB 23 B, DHLB 1-1103, R1-25003, R2-25005, R3-35006, BRBL5, ICPH-1, BKN-186-195) showed resistant reaction.

Validation of selected differentially expressed genes in wheat (Lr24 NIL) using real time PCR. Out of 349 up regulated genes identified through transcriptomics, highest expression of ABC transporter C family gene was observed in resistant genotype having *Lr24* at 24 hpi, while Coatomer alpha subunit reached its peak at 16 hpi. Of the 310 down regulated genes, expression of cell division cycle 5 like protein and molybdenum cofactor sulfurase was highest at 16hpi.



Expression pattern of (a) ABC transporter C family member 10; (b) Molybdenum cofactor sulfurase in HS240+*Lr*24 and HS240 at different time periods by qRT-PCR

Locally adapted host differentials for Indian pathotypes of wheat leaf rust. Differential sets (near isogenic lines) were developed in the background of NP4, viz., HI KK1 (NP4+*Lr1*) (INGR16024), HI KK2 (NP4+*Lr2a*) (INGR16025), HI KK3 (NP4+*Lr2c*) (INGR16026), HI KK4 (NP4+*Lr3a*) (INGR16027), HI KK5 (NP4+*Lr9*) (INGR16028), HI KK6 (NP4+*Lr10*) (INGR16029), HI KK7 (NP4+*Lr15*) (INGR16030), HI KK8 (NP4+*Lr17a*) (INGR16031), and HI KK9 (NP4+*Lr20*) (INGR16032) for characterizing pathotypes of leaf rust.

Development of culturing protocols for thrips. A primary cell culture of *Frankliniella occidentalis* (Western flower thrips) was developed to study the multiplication of tospoviruses in vector system. One egg laying apparatus has been designed to harvest the eggs without any mechanical damage. One improved media has been formulated which is efficient to support the growth, survival and multiplication of thrips cells.

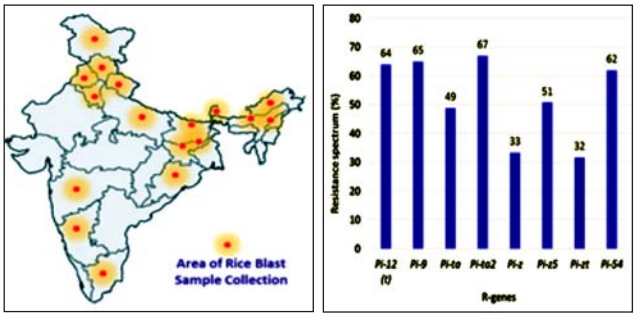
Evaluation of germplasm for viral resistance. Out of 93 watermelon genotypes evaluated against *Watermelon bud necrosis virus (GBNV)* through DAC-ELISA assay, only one wild genotype (*Citrullus colosynthis*) showed immune while two genotypes, P-30 and P-55 were highly resistant. Out of 53 entries of soybean evaluated under AICRP against yellow mosaic and bud necrosis diseases, 8 entries were found resistant against both the diseases. Field screening of 101 chilli lines from IIHR Bangalore, when screened against leaf curl disease, LCNV 1, 2, 8, 15, 22, 24, 33, 36, 51, 55, 66, 90, 97, 98 showed profuse fruiting and symptoms of leaf curl disease. Testing of the leaf samples of these lines with species specific PCR showed absence of ChiLCV and ToLCNDV.

5.1.8 Epidemiology and Disease Management

Temperature influence on R gene-mediated resistance against rice blast. Relative resistance against leaf blast in rice (in terms of infection efficiency and sporulation) is significantly higher at suboptimal (22°C) and supra-optimal (32°C) as compared to optimal (27°C) temperature. Higher level of resistance at suboptimal temperature is supported by activation of defence process regulated by transcription factor (WRKY45) and R gene associated with higher phosphorylated protein in rice genotype (Pusa 1603). Active defence process is appeared to be sustained by the expression of *WRKY45* and *Pi54* gene along with protein phosphorylation at 22°C.

Effect of temperature on pathogenicity related gene expression in mungbean. Expression of *ABC transporter* gene was observed at 30 ^{0}C at 72 h after inoculation with *Rhizoctonia solani* in mungbean. However, genes like *â-1,3,glucan-hydrolase* have shown maximum expression at 25 ^{0}C, although isolates belonging to the group AG2-3 were pathogenic at 20 ^{0}C also.

Gene deployment strategy for blast resistance in rice growing regions of India. Pathotyping of *Magnaporthe oryzae* isolates from different rice growing areas of India revealed effective blast resistance genes for deployment strategy. The highest degree of resistance was demonstrated by *Pi-ta2 (Pi-4b).* Other effective *R*- genes, viz. *Pi9, Pi12(t), Pi54, Piz5, Pita, Piz* and *Pi-zt* have the potential to exclude the virulent pathotypes of *M. oryzae* prevalent in different rice growing regions. These resistance genes, individually or in combination can be utilized in gene deployment strategy for the management of blast disease.



Effective blast resistance genes identified for deployment in different rice growing regions of India

Management of stripe rust of wheat using fungicides. Out of eight fungicides and two bioagents evaluated against stripe rust disease of wheat, minimum mean disease severity of 1.22 per cent was recorded with azoxystrobin 25SC (Amistar @ 0.1%). Bioagents *Pseudomonas fluorescence* and *Bacillus subtilis* were moderately effective in controlling stripe rust by reducing disease to 41.83 and 39.92 per cent, respectively.

Impact of yellow rust infection in promising wheat varieties with regards to yield loss. The losses in yield due to stripe rust varied 1.2-69.2% depending on the degree of resistance of variety. Maximum yield reduction (69.2%) was observed in old cultivars, A-30-9-1 and Kathia red which are highly susceptible to stripe rust followed by HD 2733 (14.1%), PBW 590 (32.6%) and PBW 343 (36.35%).

Assessment of slow rusting resistance components to stripe rust in exotic wheat germplasm. Promising slow rusting resistance was observed on exotic wheat germplasm, viz., CIMCOG 1, 2, 3, 5, 6, 7, 12, 14, 15, 17, 18, 20, 21, 22, 26, 27, 28, 29, 32, 33, 34, 35, 36, 38, 40, 43, 46, 47, 49, 52, 53, 58, 59 and 60. A positive relation of CI was found with FRS, rAURPC and *r* among the wheat germplasm with a strong R^2 value of 0.98, 0.97 and 0.95, respectively.

Management of maize diseases. Out of eight fungicides evaluated in the management of BLSB disease, Validamycin (0.1%) was found superior. Four new molecules of Micro Chemicals (India), namely, Carbandazin-20, Carbandazin-10 (+ Phytolaxin), ALK Phosphoric Acid and Prevent 107 when tested *in vivo* for the management of post flowering stalk rot (PFSR) disease, all were found superior to Carbendazim. Of these, Prevent 107 @ 0.5 ml/l was the best in controlling charcoal rot followed by Carbendazim 20 @ 0.05 ml/l.

Management of viral diseases in vegetable crops under field conditions. Field experiments were conducted at IARI Regional Station, Pune for viral disease management in tomato, capsicum, chilli,

muskmelon, cucumber and okra using various organic and plastic mulches in combination with insecticide/ biopesticides. Viral disease incidence was lowest and the yield was highest in silver colour plastic mulch along with insecticide and biopesticides followed by the rice straw mulch in tomato, capsicum, muskmelon and okra. Lowest vector (aphid, thrips and whitefly) population was recorded in treatment with silver colour mulch in all trials.

Management of spot blotch (Bipolaris sorokiniana) of wheat. Out of five fungicides tested, namely, Propiconazole 25%EC, Tebuconazole 25%EC, Azoxystrobin 11% + Tebuconazole 18.3% WG, Trifloxystrobin 25% + Tebuconazole 50% WG, and Mancozeb 75%WP, foliar spray of Propiconazole 25%EC or Tebuconazole 50% + Trifloxystrobin 25% WG were found significantly superior along with 99% reduction in disease severity.

Management of brown spot (Bipolaris oryzae) disease of rice. Fungicide, Trifloxystrobin 25% + tebuconazole 50% 75WG (@ 0.1%) fungicide was found significantly effective against brown leaf spot disease with least mean disease severity (3.92%) along with highest grain yield (4.823 t/ha).

Integrated management of bakanae disease of rice. The combined effect of seed treatment with *Talaromyces flavus* + carbendazim and seedling drenching with carbendazim @ 0.20% resulted 0-1.29% bakanae disease incidence along with higher number of effective tiller/m^2 (433.34), plant height (138.58 cm) and panicle length (28.40 cm) in paddy cv. Pusa 1176.

Integrated disease management of diseases of papaya. Seed treatment with copper oxychloride or metalaxyl (35% WS) @ 2.5 g/kg seed provided highest seed germination along with the 96% control of seedling damping off. Integration of various management practices; organic mulch plus 0.75 m soil mounding + soil drenching with metalaxyl + mancozeb @ 0.25% revealed significantly high control of root rot disease (97%) along with the highest increase in fruit yield (36%) and its contributing traits. Basal application of borax @ 5.0 g/plant was found most effective for the management of fruit (bumpiness) deformity in papaya.

5.2 ENTOMOLOGY

5.2.1 Integrated Pest Management

5.2.1.1 Cereals

Evaluation of rice germplasm against brown planthopper (BPH). Out of nineteen rice germplasms, evaluated against brown planthopper (BPH) under greenhouse conditions, one line, RP 2068-18-3-5 was found to be moderately resistant (3-5 damage score), while Ptb33 and T-12 (ACC56988) were rated as moderately susceptible (5-7 damage score).

Evaluation of biopesticides against rice insect pests. Biopesticides, viz., neemazal 1EC@ 1000 ml/ha, nimbecidine 0.03EC @ 2500 ml/ha and multineem 0.03 EC @ 2500 ml/ha along with insecticidal checks, viz., dinotefuran 20 SG@ 200 g/ ha and coragen 20SC @ 150 ml/ha, evaluated against rice insect pests showed lowest BPH population in dinotefuran treated plots but none of biopesticides treatments were effective.

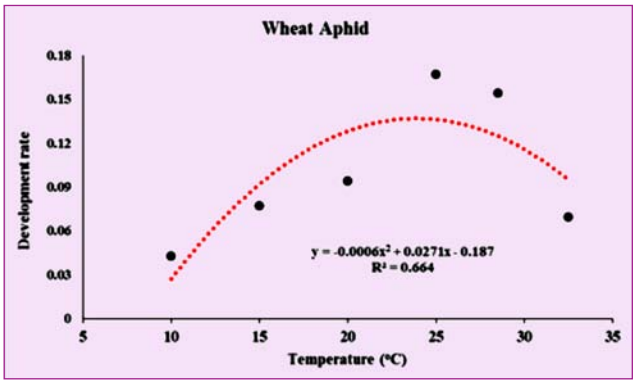
Impact of elevated carbon dioxide on the protective enzymes in Brown Planthopper (BPH). Protein level in un infested plants was significantly reduced at elevated CO_2(570±25 ìl/l) compared to ambient CO_2(400±25 ìl/l) but the activity of protective enzymes, such as catalase and peroxidase was significantly enhanced at elevated CO_2. In BPH infested rice plants, protein level and catalase activity were reduced significantly at both elevated and ambient CO_2 conditions compared to un infested rice plant.

Effect of crop phenology on rice insect pests. Effect of three sowing dates, viz., 8th July, 22nd July and 6th August was evaluated on brown planthopper population on Pusa Basmati 1121. The BPH population was found to be highest (91.4 hoppers/ hill) in III transplanting followed by II transplanting (46.9 hoppers/hill) and I transplanting (20.4 hoppers/ hill) and these populations differ significantly among each other.

Development of thermal constant for wheat aphid. Newly laid nymphs of wheat aphid were reared at constant temperatures of 10, 15, 20, 25, 30 and 32.5 °C and development periods were recorded until adult emergence. Relationship between developmental rate of the pest and temperatures fitted best to polynomial model.

$$Y = -0.0006 X^2 + 0.0271X - 0.187 \ (R^2 = 0.664)$$

Developmental rate of the pest depicted linear relationship with temperatures of 10, 15, 20 and 25 °C only. By regressing development rates on corresponding temperatures, thermal constant and developmental threshold were determined to be 128.2 degree-days (DD) and 5.3 °C, respectively.



Relationship between temperature and development rate of wheat aphid

5.2.1.2 Vegetables and fruits

Woolly apple aphid (WAA) E. lanigerum infestation rating on different apple accessions. The pooled WAA infestation rating revealed that *M. pumilamill*, Kashmir and Dhak could be categorized as very highly susceptible apple accessions with the highest mean infestation rating of 3.20, 3.17 and 3.00, respectively. The apple accessions MM111, MM106 and Shillong were categorized as highly resistant as these accessions recorded below 0.5 infestation rating.

Cabbage. In Cabbage, thirty two cabbage genotypes were evaluated for their relative tolerance to cabbage aphid, *Brevicoryne brassicae*. Five germplasms, viz., C 1, 9 A, 9 B, KIRC 8 and KTCBH 822 were found to exhibit low to moderate level of tolerance. Four lines, viz., AC 204, Chakki 6, MR 1 and RRM mix were found to be highly susceptible to *B. brassicae*. Twenty cauliflower genotypes were evaluated for resistance against cabbage aphid *Brevicoryne brassicae*, only one line (KTK 15) expressed low level of resistance. All the remaining nineteen cauliflower germplasms were found to be highly susceptible and suffered significant mortality before curd initiation stage.

5.2.1.3 Soybean

Seasonal incidence of pests. The soybean crop (JS-335) was infested right from its seedling stage by whitefly, *Bemisia tabaci*(Gennadius). The results indicated that mean numbers of whiteflies per plant were quite low compared to last year (2015-16). Incidence of yellow mosaic virus disease transmitted by white flies was slightly higher (maximum average incidence rating of 8.00 on a scale of 1 – 9) compared to earlier year.

Field screening of germplasm for resistance to major insect pests. Six lines of AVT I&II were evaluated against stem fly and YMV of soybean under both protected and unprotected conditions. AVT lines, viz., KDS-753, KDS-869, PS-1347, SL-688, Pusa-9712 were highly resistant to YMV disease. Out of 38 IVT lines of soybean evaluated against stem fly and Yellow Vein Mosaic (YVM) disease, lines, viz., 3, 4, 13, 22, 25, 30, 35 and 37 were susceptible against stem fly.

5.2.1.4 Pulses

Monitoring of chickpea pod borer, Helicoverpa armigera and Spodoptera exigua moths using pheromone traps. Studies were conducted to monitor the adult population of chickpea pod borer, *Helicoverpa armigera* and *Spodoptera exigua* using pheromone traps in early, normal and late sown chickpea crop of IARI plots. Data revealed that the first trap catch of male moth of *H. armigera* was recorded during 51st standard week in normal sown crop, while in early and late sown the trap catches were initiated during 1stand 4th standard week, respectively. *H. armigera* adult trap catches increased gradually and reached

its peak during 10th standard week with 92.33, 134.5 and 77.5 moths/trap/week in early, normal and late sown chickpea crop, respectively. Trap catch data of *S. exigua* revealed that first trap catch was recorded during 1st standard week in all three dates of sowing. The adult trap catches of *S. exigua* increased gradually and reached its peak during 10th standard week with 3.33, 4.5 and 2.0 moths/trap/week in early, normal and late sown chickpea crop, respectively.

Incidence and Seasonal dynamics of insect pests of pigeon pea. Incidence of spotted pod borer, *Maruca vitrata* and blister beetle was commenced on 36th SMW (Standard meteorological week). Pod borer complex was mainly consisted of *M. vitrata, Helicoverpa armigera* and blue butterfly, *Lampides boeticus. M. vitrata* population reached to its peak in the 38th SMW (2.8 webs/plant). Similarly, Blister beetle population (1.55 beetles/plant)) and *H. armigera* population (0.45 larvae/plant) was also at peak in the 38th SMW.

5.2.1.5 Oilseeds

Evaluation of different rapeseed mustard genotypes for aphid resistance. Out of 268 genotypes evaluated for aphid resistance under field conditions, significant variability was observed in the test genotypes across trials as compared to released varieties as checks.

Yield loss assessment for mustard aphid in rapeseed mustard. Yield loss assessment studies in two mustard genotypes, viz., BSH 1 and NRCDR 2 revealed significantly higher yield and lower aphid population in these genotypes under protected as compared to unprotected conditions. There was 86.4% and 99.6% reduction in aphid population in BSH 1, and 83.7% and 97.1% reduction in NRCDR 2 after 1st and 2nd spray of insecticides, respectively.

5.2.2 Storage Entomology

The toxicity of phosphine to immature stages of khapra beetle, *Trogoderma granarium* (Everts) was studied at 25, 30 and 35ºC. Among the larval and pupal stages, first instar larvae were found to be highly susceptible to phosphine. The final instar larvae were found to be least susceptible whereas pupal stage was moderately susceptible to phosphine.

5.2.3 Biological Control

Foraging behavior of the natural enemies. Functional response of adult males and females of *Nephus regularis* (Sicard) against the different densities of cotton mealybug, *Phenococcus solenopsis* (Tinsley) is worked out. The proportion of prey consumed by male and female *N. regularis* increased curvilinearly with increase in prey density up to some extent. Predator showed the Type-II functional response based on the shape of curve obtained after plotting prey density (No) against the consumed prey by predator (Na). The results regarding the functional response study of adult female showed higher number of consumed prey as compared with the adult male of *N. regularis*.

Effect of storage temperature on the shelf-life extension of different stages of *chrysoperla carnea* *Storage of eggs*. Duration of storage and temperature significantly affected the egg survival of *C. carnea*. When eggs were stored at 7 and 9 ºC, 18.9 and 19.78 per cent eggs survived in their first week, respectively, all eggs were killed beyond one week of storage. Egg survival was 22.88 to 26.64 % at 15ºC and 17.33 to 21.94 % at 13 ºC when stored for up to three weeks. Survival reduced when stored for three weeks and all eggs died when stored for four weeks.

Storage of larvae. Low temperature had negative effect on the survival of *C. carnea* first instar larvae. There was less than 25% larval survival at 15ºC for storage of one week. All larvae died when they were stored for more than one week at any temperature regime of present study. Second instar *C. carnea* larvae showed better tolerance to lower temperature and survival during their first week of storage compared to first instar larvae.

Storage of pupae. Compared with eggs and larvae, pupal stage of *C. carnea* was more sensitive to temperature. Only 28.60 and 41.92 pupae survived when stored at 13 and 15ºC, respectively, for one week, beyond that period, all pupae died at all temperature regimes tested.

Storage of adults. Temperature and duration of storage significantly affected the pre-oviposition, oviposition and post-oviposition period of *C. carnea* adults. All these biological parameters were prolonged prominently when *C. carnea* adults were kept at low temperature for longer period of time. At 5ºC post-oviposition of *C. carnea* after one week of storage was 17.1 days, at the same temperature after two weeks, storage was 22.10 days, after three weeks storage was 30.35 and after four weeks of storage was 32.48 days while at 15^{0}C it was 6.1, 6.6, 8.85 and 10.6, respectively. Significant adverse effects were observed with respect to duration of storage and temperature on the fecundity and per cent hatchability of eggs of *C. carnea*. Adult male and female longevity was also affected. Longevity was reduced significantly at lower temperature compared to high temperature range.

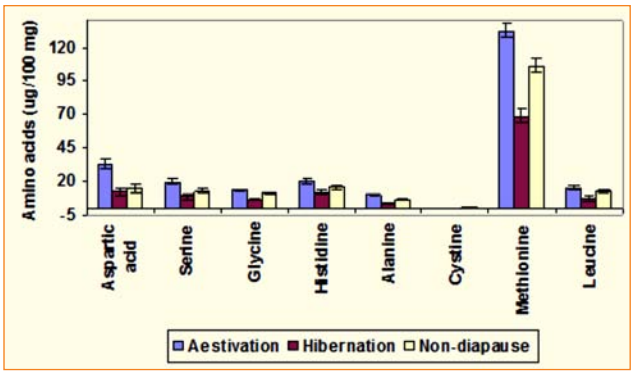
5.2.4 Insect Physiology

About, 23 gut bacterial isolates have been identified and characterized from white grub *Anomola dorsalis*. Biochemical characterization of isolated bacteria revealed Beta Galactosidase enzyme activity in most of the isolates. Marked differences in distribution of different microbial groups were observed across insect gut segments. Lower levels of gram-positive bacteria (8.99%), higher level of gram- negative bacteria were detected in different gut compartments.

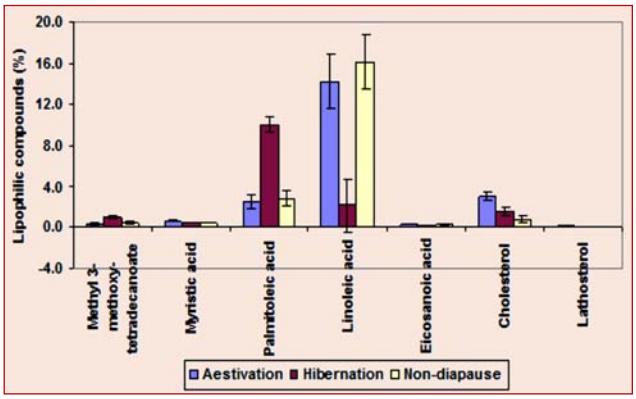
Analysis of anaerobes from the gut of Lepidiota mansueta. The gut bacterial isolates belonging to Bacteroidetes and Proteobacteria, viz., *Chryseobacterium* sp. and *Dysgonomona stermitidis* were detected from the midgut and rectum regions. Two isolates, viz., *Enterobacter* sp. and *Comamonas* sp. belonging to Proteobacteria were detected, respectively, from midgut and fermentation chamber of *L. mansueta.* Functional characterization of gut bacterial isolates from white grub could be utilized for exploitation of the same for control of white grub pests like *A. dorsalis* infesting sugarcane and other crops.

Diets for the mass rearing of tephritid fruit flies. Among the different diets tested, larval rearing of *Bactrocera cucurbitae* on liquid diet (LD-I) was found most suitable. This diet resulted in significantly high pupal weight with maximum adult emergence (81.00%) and active adult fliers (85.58%). The addition of fatty acids to liquid diet increase fertility by 39% and egg hatching by 15%, over the control diet. The diet supplemented with linolenic acid (LD-II) resulted in 68.85% pupae recovery with 78.33% adult emergence and 81.68% adult fliers. Although, pupal recovery and weight increased with increase of brewer's yeast but resulted in low adult emergence and poor fliers. In the present study the quality parameters of melon fruit fly reared in LD-I was found very near to the recommended pre-irradiation standards of FAO/ IAEA/USDA for sterilization of male flies.

Biochemical changes in diapausing and non-diapausing larvae of Chilo partellus. The amounts of Aspartic acid, Serine, Glycine, Histidine, Alanine, Cystine, and Leucine were significantly higher in aestivating, while lower in hibernating *C. partellus* larvae as compared to non-diapausing counterparts. Conversely, the amount of Methionine was significantly higher in non-diapausing as compared to hibernating and aestivating *C. partellus* larvae.



Variability in amount of certain amino acids in Chilopartellus larvae under diapause and non-diapause conditions. The amounts of Myristic acid, Eicosanoic acid, Cholesterol and Lathosterol were significantly higher in aestivating as compared to hibernating and non-diapause larvae of *C. partellus*. However, the hibernating larvae were found with significantly higher amounts of Methyl 3-methoxytetradecanoate

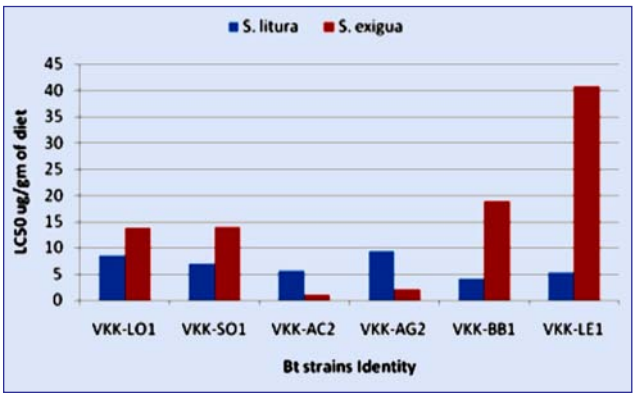


Variability in composition of certain lipophilic compounds in *Chilo partellus* larvae under diapause and non-diapause conditions

and Palmitoleic acid as compared to aestivating and non-diapause leave of *C. partellus*. The amount of Linoleic acid was significantly lower in hibernating as compared to aestivating and non-diapause larvae of *C. partellus*. Present studies indicated significant role of certain amino acids and lipophilic compounds in life processes during diapause in *C. partellus*.

Bioactivity of Bacillus thuringiensis (Bt) against aphids. *Bt* var. *kurstaki* (*Btk*-HD1) and *Bt* var. *israelensis* (*Bti*) strains were evaluated for the insecticidal activity in three different forms, viz., pre-solubilized form (PSF), solubilized form (SF), trypsinized form (TF) by feeding bioassays against adult of three aphids, viz., *Lipaphis erysimi, Myzus persicae* and *Brevicorne brassicae* by diet incorporation method at single concentration along with respective buffer based controls. The result showed that *Btk*-HD1 was found to be most effective in all the three forms against *M. persicae* (80-100%) >*B. brassicae* (20-63%) >*L. erysimi* (46-54%). *Bti* was found to be most effective in PSF against *M. persicae* &*B. brassicae* (76% and 70%) followed by SF and TF against *L. erysimi* (53% and 50%, respectively).

Characterization of Bacillus strains against Spodoptera litura and Spodoptera exigua. Out of forty native Bacillus strains evaluated by feeding assays, 13 strains each, viz., VKK-EV, VKK-LO, VKK-SO, VKK-AC2, VKK-AG2, VKK-BB1, VKK-LE1, VKK-GA4, VKK-GA10, VKK-GJ2, VKK-GJ4, VKK-OL5, VKK-OL6 against neonates of *S. exigua* and VKK-HA1, VKK-LO1, VKK-SL1, VKK-SO1, VKK-AC1, VKK-AC2, VKK-BB1, VKK-LE1,VKK-AG2, VKK-MP2, VKK-OL1, VKK-OL2, VKK-OL4 against *S. litura* showed mortality e"50% at 10 µg/g of diet on 7th day. LC_{50} values varied from 0.87 µg/g of diet (VKK-AC1) to 14.41 µg/g of diet (VKK-OL1) against neonates of *S. litura* whereas against *S. exigua* LC_{50} values varied from 1.00 µg/g of diet (VKK-AC2) to 40.78 µg/g of diet (VKK-LE1). Out of shortlisted strains, six strains (VKK-LO, VKK-SO, VKK-AC2, VKK-BB1, VKK-LE1, VKK-AG2) were effective against both *S. litura*as and *S. exigua*. *Cry* genes, viz., *cry1(cry1Ac, cry1Ab, cry1Ac & cry1C), cry2, cry6, cry14* and *cry20* were identified in potential native *Bt* strains against *S. litura* and *S. exigua*. Protein level characterization of potential *Bt strains* based on the SDS-PAGE, showed the banding patterns from 20 - ≥236 kDa. The protein profile can be categorized in four groups i.e. group I (20-60 kDa), group II (60-80 kDa), Group III (80-120 kDa) and Group IV (120-≥236).



Comparative toxicity of six common potential *Bt* strains against neonates of *S. litura* and *S. exigua.*

Effect of temperature on toxicity of Bt Cry toxin against Helicoverpa armigera. Efficacy of Bt toxins *viz.*, Cry1Ac, Cry2Ab, Cry1Ac+Cry2Ab (mixture), Cry 1B, Cry 1C, Aug5 (native Bt strain) and BGII cotton seed powder at 1ppm dose was evaluated at 20°C, 25°C, 27°C (standard), 30°C, 35°C and 40°C against neonates of *Helicoverpa armiger*a. Perusal of data showed that temperature had no effect on highly toxic Aug5 & Cry1Ac+Cry2Ab, but extreme temperature (20°C, 35°C and 40°C) enhanced the toxicity of Cry

toxins (Cry1Ac, BGII and Cry2Ab) showing moderate toxicity at standard temperature.

5.2.5 Insect Toxicology

Field populations of adult cotton white fly, *Bemisia tabaci* (Fabricius) were collected from Delhi, Khandwa, Sriganganagar, Ludhiana and Varanasi and evaluated for their susceptibility to Fipronil and Flonicamid through laboratory bio-assay. Variation in their susceptibility was observed among these field populations with respect to their median lethal concentration (LC_{50}) values. A high degree of tolerance was observed in Amravati population against both insecticides. Among the two insecticides fipronil gave better efficacy as compared to Flonicamid and its LC_{50} was 20.80 mg/l when treated with fipronil, whereas in case of Flonicamid treatment with the same population was obtained as 749.91 mg/l. Tolerance ratio of fipronil was maximum in Amravati population(x3) followed by Sriganganagar (x2.6), Ludhiana(x2) and Khandwa (x1.3) against fipronil bioassayed. Amravati strain showed maximum tolerance to Fipronil as well as Flonicamid. Enzyme systems such as esterase, glutathione S-transferase and cytochrome P450 monooxygease were estimated from five different *B. tabaci* populations. The CYP450 levels were found to be highest in Amravati population (793.70) nmol/mg of protein).

5.3 NEMATOLOGY

5.3.1 Management through Transgenic Approach

Utility of host delivered RNAi of two esophageal gland genes, *msp18* and *msp20* was demonstrated for the first time to interfere with nematode penetration due to their oscillating effect on cell wall modifying enzymes using C^{14} labeling of brinjal plants, which established that nematode genes could be silenced even before they start feeding through the feeding cells. Evaluation of transgenic brinjal plants of T_3 and T_4 generations expressing double stranded RNA of *flp14, flp18, msp1, msp18* and *msp20* genes of *Meloidogyne incognita* was repeated for the second year to confirm the stability in their performance that confirmed the reduction in nematode multiplication factor by 65-70 %. The transgenic plants did not show any unwanted effects on the growth and development of the plants. All the transgenic plants of different events and genes were confirmed for gene integration by PCR amplification of the target gene and also the presence of both sense and antisense strands essential for the generation of double stranded RNA. Expression of transgene in the transgenic plants was confirmed by qRT-PCR. 1047 bp long cuticle collagen gene, *Mi-col-5* was isolated from root-knot nematode, *Meloidogyne incognita* that showed 92% sequence identity with that of *Mj-col-5* at protein level. Expression of *Mi-col-5* transcript was found to be maximum in eggs followed by adult females and J2s.

5.3.2 Evaluation of Direct-seeded Rice Varieties against *Meloidogyne graminicola*

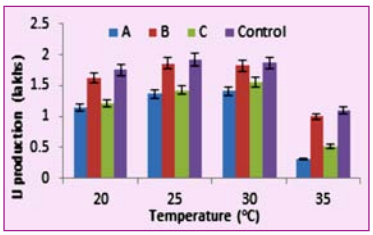
Out of certified seeds of 33 DSR rice *Oryza sativa* L. cvs./landraces were procured from different KVKs of Bihar, West Bengal, and Division of Genetics. NDR 97, an upland rice cultivar was found resistant against *Meloidogyne graminicola* which can be utilized by the breeders for incorporating resistance. Expression of genes (*OsEDS1, OsPAD4* and *OsWRKY13*) involved in plant innate immunity revealed that at 6DAI, the mRNA levels of *OsEDS1, OsPAD4* and *OsWRKY13* were found significantly repressed as compared to 2DAI in susceptible variety PB 1121. However, *OsWRKY13* significantly down-regulated 2DAI but, it

Differential expression patterns of OsEDS1, OsPAD4 and OsWRKY13 genes in the root tissue of susceptible and resistant cultivars of rice infected with *Meloidogyne graminicola*

was significantly up-regulated 6DAI in the resistant cultivar, NDR 97.

5.3.3 Entomopathogenic Nematodes

Starvation of 4th instar, *Galleria mellonella* larvae for 72 h prior to infecting them with *H. indica* resulted in suppressing the co-infection of *Bacillus bombysepticus* by 98.6% compared to 76.5% when starved for 48 h. Three different inert materials (A,B,C) were tested for their efficacy as coating agent on *Galleria* cadavers infected with EPN at four different storage temperatures (20,25,30, and 35°C). The material B was found to be at par with the control in terms of production of fresh progeny of infective-juveniles (IJ), was maximum when the *Galleria* cadavers coated with material B was stored at 25°C (1.86 lakhs/cadaver). Coating the cadavers with material B prior to packaging and transport can effectively maintain the integrity of each cadaver and prevent them from sticking to each other. *S. litura* fed on castor for 3 generation supported

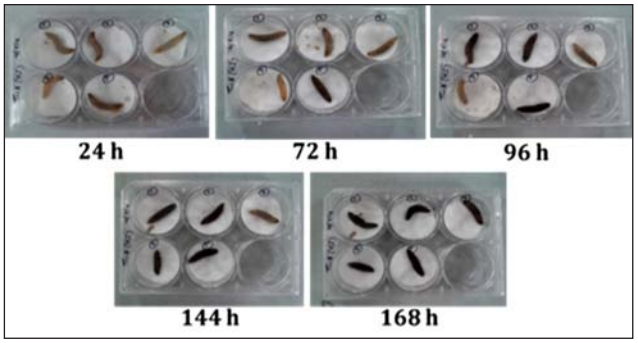


Effect of inert packaging materials for coating *Galleria* cadavers infected with EPN

Coated *H. indica* infected *Galleria* cadavers ready for packaging and transport

16.6% more eggs/hermaphrodite, 32% eggs/second generation females and 28.9% infective juveniles of *H. indica* in comparison to those fed alternatively on cabbage-castor-cabbage, suggesting the nutrition status of the host insect is directly correlated with the entomopathogenic growth and development.

Rapid virulence annotation (RVA) assay was undertaken to identify the potential virulence loci in the toxin genes of *Photorhabdus luminescens*. Insect mortality was achieved within 72 h of injection with six toxin genes such as Txp40, TcaA, TcaB, PirB, TccA and TccC. These six genes containing the complete reading frame were PCR amplified, cloned in pGEMT



RVA assay of TccA toxin isolated from *P. luminescens* sub spp. *akhurstii* Strain H1 against *G. mellonella* larvae

vectors and sequenced. Using plasmid PCR identity of the insert was confirmed again. Those genes are in the process to be cloned in the protein expression vector, pET 29a.

Understanding the tripartite interactions involving entomopathogenic nematodes, their bacterial symbionts and insect hosts. To identify the nematode genes and processes involved in host specificity and symbiosis with its symbiont bacteria, *Heterorhabditis bacteriophora* immune pathway genes *Hbdaf2_1, Hbhsp4_1, Hbhsp4_4, Hbjnk_1, Hbkgb_1, Hbtol_1, Hbmpk_1, Hbdaf4_1, Hbhsp4_3* were cloned and re-sequenced. Sequencing results identified that six sequences showed addition, one showed deletion and two sequences showed both addition and deletion as compared to published data. dsRNA of daf2_1, daf4_1,hsp4_1,hsp4_4 and kgb_1 have been prepared, RNAi by soaking protocols are being carried out. Eight C-type lectin orthologs were found in *H. bacteriophora*, whereas 4 C-type lectin orthologs were found in *H. indica.*

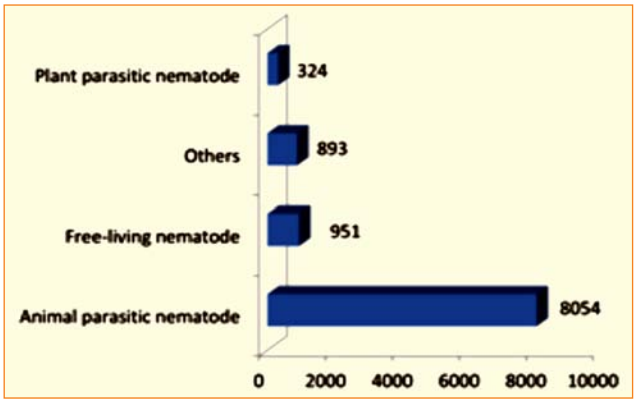
5.3.4 Biocontrol Agents

An isolate of *Trichoderma harzianum* MTCC 3928 was observed to cause 78 per cent mortality in juveniles of *M. incognita* with 82.47 % inhibition in the mycelial growth of *F. oxysporum* in lab with 50.82% wilt disease suppression in tomato. The isolate is a potent producer of both cell degrading lytic enzymes (chitinase and ß-1, 3 glucanase) as well as antimicrobial metabolites. Among the indigenous isolates of *T. harzianum*

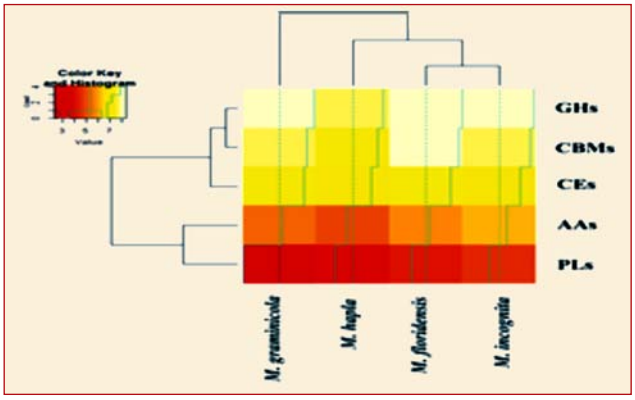
collected from different agroclimatic zones of the country and screened for antibiosis caused by the secondary metabolites against *M. incognita;* the isolate ITCC 6888 exhibited 90.6% mortality in J2s within 24 h and up to 87% per cent egg hatch inhibition compared to water control. Chitinase assays revealed that the isolate had a chitinolytic activity of 51.4 U/ml and proteolytic activity of 4.27 U/ml.

5.3.5 Nematode Genomics

The genome of *M. graminicola* was sequenced along with the transcriptome of two populations of the species. The *M. graminicola* genome size is estimated to be approximately 53.1 Mb. The dataset showed presence of 88.93% of the core eukaryotic genes indicating a high quality of the assembly. There were 5,463 supercontigs (>500bp) in the final assembly comprising of 55,651,837 bp, with the largest scaffold being 2,29,097 bp long. A total of 12,302 genes encoding 14,823 proteins were discovered at the density of 239 genes/Mb genome were predicted, of which 10,494 genes could be annotated. Almost 79% of the annotated genes showed similarities to animal-parasitic nematodes, followed by free-living nematodes.



Genome annotation of *M. graminicola* showing orthologues present in nematodes of different feeding habits



The heat map of all the *M. graminicola* CAZyme families as compared to other sequenced *Meloidogyne* genomes

M. graminicola genome shows 39.79% repetitive elements, the majority of which could not be associated with known transposable element (TE) families. The fraction of repetitive sequences in the *M. graminicola* genome is comparatively higher than *M. incognita* (36%), *M. hapla* (15 %), *H. avenae* (23 %) and *C. elegans* (14 %). The heat map analysis of all the *M. graminicola* CAZyme families as compared to other sequenced *Meloidogyne* genomes. *M. graminicola* genome data is available through the HATDB (http://insilico.iari.res.in/).

5.3.6 Transcriptome Sequencing of *Polianthes tuberosa*

The transcriptome sequencing of Tuberose (*Polianthes tuberosa*) was carried out using Illumina sequencing to obtain a *de novo* assembly of the tuberose RNA-seq. A total of 15 GB of high quality reads were assembled using velvet-oasis pipeline. We obtained 7,876 unigenes, which were further annotated using blast2go and KEGG pathways were also assigned. In 7876 EST sequence of tuberose, 87 copies of miRNA have been identified. Our study provides abundant genomic data for tuberose and offers comprehensive sequence resources for studying it. These data will provide the foundation for research on gene expression, genomics and functional genomics in *Polianthes tuberose* and other important members of Amaryllidaceae.

5.3.7 Nematode Profiling in Nilgiris

Soil survey for profiling nematodes in wheat and wheat based cropping system in The Nilgiris was initiated and the results indicated the wide spread presence of several parasitic nematodes, viz., *Helicotylenchus, Tylenchorhychus, Trichodorus, Aphelenchus, Aphelenchoides,*

Meloidogyne, *Hoplolaimus*, *Hemicycliophora*, *Criconema*, minor Tylenchids. Free living nematodes such as Rhabditis, Cephalobids, Mononchids, Diptherophorids and Dorylaimids were also observed. Among them, *Helicotylenchus* spp. dominated the wheat fields of IARI with the population maximum of 350 nematodes /100cc soil and *Tylenchorhychus* spp. dominated the Kenthorai area (wheat belt in Nilgiris) with population of 50 nematode/100cc soil. Cyst profiling of ICAR-IARI farm depicted the presence of *Globodera* spp., *Heterodera* spp. and other pseudocysts. In vegetable areas the *Meloidogyne incognita* was found to dominate than the M. *hapla*. These Root Knot nematodes causes severe forking in carrots, thereby reducing its market value to a great extend. Hence sick plot of M. incognita was established to do further research.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Development of Active Molecules for Crop Protection

5.4.1.1 N-alkyl-5-fluoro/3,5-dichloro-N-[1-(2-hydroxyphenyl) ethyl] amine

Nineteen substituted amines were prepared by reacting corresponding Schiff bases (N-alkyl-2-hydroxy acetophenonimine) derivativeswith sodium borohydride and were characterized using IR, ^{1}H-NMR and ^{13}C-NMR. Antifungal assay suggested that N-heptyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine was the most active against *Rhizoctonia solani* (ED_{50} 24.59 mg/ L) and N-hexadecyl-5-fluoro-N-[1-(2-hydroxyphenyl) ethyl] amine (ED_{50} 20.03 mg/ l) against *Sclerotium rolfsii*.

5.4.1.2 Furoic acid carboxamides and hydrazones

Sixteen furoic acid carboxamides and hydrazones were synthesized, characterized and evaluated as succinate dehydrogenase inhibitors (SDHI). Amides were found to have better interaction than hydrazones with the target protein. *In vitro* bioactivity assay against three isolates of phytopathogenic fungi, *S. sclerotiorum* suggested 2-hydroxyphenyl-3-furamide (glide score of -8.79) as the best antifungal compound with EC_{50} 13.1-37.9 ppm.

5.4.1.3 Nanosized azomethines

Previously synthesized azomethine derivatives were nano sized employing poly (ethylene glycol). Nano-azomethines were significantly superior in conserving the ammonium-N (nano-azomethine 146.45-166.26 mg kg^{-1}, conventional products 113.87-148.08 mg /kg). Control (urea alone) showed very less retention of ammonium-N (23.85 mg/kg). The nitrite-N content remained insignificant in most of the samples while significantly lower nitrate-N content was observed in the test chemicals (2.86-43.43 mg/ kg) than urea (132.94 mg/kg). The observed ammonium, nitrite and nitrate-N contents suggested that azomethines compounds inhibited the first step of the nitrification (oxidation of ammonium to nitrite by *Nitrosomonas* spp.) All compounds were effective nitrification inhibitors (NI (%) 60.22-97.71) and 2,4–dichloro substituted azomethine was the most effective.

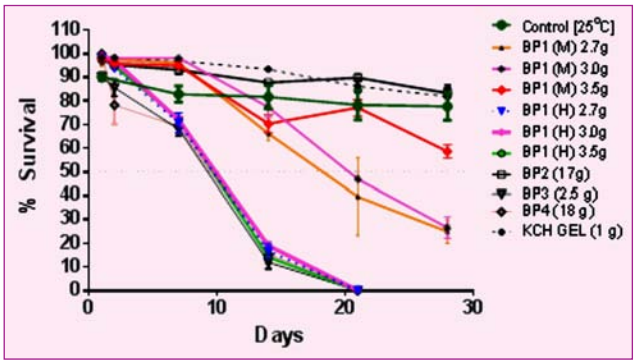
5.4.1.4 Curcumin terpenoids as bioavailability enhancers

The turmerones of turmeric fixed oil were assessed for improvement of bioavailability of curcuminoids. Antioxidant assay using DPPH & ABTS methods found that IC_{50} value of curcuminoids mixture were 78.8 and 145.7 µg/ml, respectively. Effect of turmerones on bioavailability revealed that turmerone alone or turmerone mixture increased bioavailability of curcumin by 2 folds. The information will serve as lead in the development of improved bioavailable curcumin formulation with enhanced bioavailability properties.

5.4.2 Development of Formulations for Smart Delivery of Crop Protection Inputs

5.4.2.1 Biogel based EPN formulations: Effect of auxiliaries and other factors on nematode survival

In continuation to the ongoing efforts to develop improved EPN bioformulations, effect of pH of carrier on nematode survival as a limiting factor was assessed. Duration of survival of pre-standardized number of EPN juveniles immobilized in gel matrix



Nematode survival in different biogels at 25°C

was longest between pH 6 -7.8. To assess the suitability of viscosity of gel carriers as a determining factor for EPN formulations, a polysaccharideBP1 was screened at various consistencies. Nematodes survived up to 80 days at concentrations to values corresponding to 0.69 and 0.94 whereas at higher consistencies of 1.38 and 1.88, nematodes died in around 20 days. Screening of eight biopolymers was done to determine the effective concentration required to achieve viscoelastic properties similar to Pusa hydrogel. The viscoelastic and steady state rheological profile at 25°C of the gels were determined at varying concentration levels. The effective concentration for attaining hydrogel like consistency was: CC1 3g; GRG 4.5g; CCH 3.5g; GT 16g CCM 4.5g. KG, AG and PT exhibited viscoelastic profile significantly different from Pusa hydrogel and were rejected. First four biopolymers with visco-elasticities at par or near Pusa Nemagel were screened for suitability as carrier. Biogel (KG) performed best in close proximity with Pusa Nemagel (KCH gel), exhibiting 85% nematode survival. Nematodes could not survive in BP3 (GRG) and BP4 (GT) beyond 20 days suggesting that these were not suitable for the nematodes. Better porosity and low bulk density of BP2 as compared to the other test materials explains the observed trend, confirming that aeration and porosity of the matrix are determining factors in quality of EPN formulations.

5.4.2.2 Nano-formulations of mancozeb: Bioefficacy evaluation

PEG based amphiphilic nano-formulations of mancozeb were evaluated for fungicide release. The cumulative release pattern showed that nano-formulations extended fungicide release by 5 to 7 times as compared to commercial 42% SC and 75% WP formulations. The half-time release ($t_{1/2}$) values ranged between 17.4 to 35.1 days and the period of optimum availability (POA) of mancozeb ranged from 18.54 to 35.42 days for nano-formulations.

The i*n vitro* ED_{50} values of nano-formulations vary from 1.31 to 2.79 mg/l for *Alternaria solani* and 1.6 to 3.14 mg/l for *Sclerotium rolfsii*, which were at par with the commercial formulations. A pot experiment against early blight of tomato (*A. solani*) suggested that number of infected leaflets/plants were less in developed formulation treated plants (2-4) than in plants treated with commercials products (4.5). Numbers of fruits/plant at 50 ppm dose were more (5-7.5) in nano-formulation treated plants than 4.5-5 in commercial products treated plants. In field experiment at recommended dose of application (50 ppm) number of infected leaflets/plant was 2.4-4.6 (nano-formulation) and 6 (commercial) while number of fruits/plant was 6.4-9 (nano-formulation) and 5.7 (commercial). Importantly, as evident from cumulative release pattern, sufficient amount of active ingredient remained available for a reasonable period of time after application which may lead to reduced number of application of pesticide.

5.4.2.3 Controlled release formulations of essential oils

To develop essential oils based insect pests repellent products, efforts have been made to prepare slow release formulations of essential oils to counter the quick volatile nature of the same. Amphiphilic solid foams, prepared by reacting organic triacid and poly (ethylene glycol) of different molecular weights, were employed to prepare solid formulations of essential oils. The optimized foam was further used to prepare solid formulations of different essential oils (viz., lemongrass oil, eucalyptus oil, citronella oil, turpentine oil, palmorosa oil, geranium oil). Extended release of essential oil ranging from 4 to 10 days depending on the volatile nature of the essential oil was observed. Spray able microcapsule formulations of these essential oils using poly (ethylene glycol),

gelatin and carboxy methyl cellulose were prepared. Gelatin based microcapsule formulation of lemongrass oil showed better slow release properties as compared to solid foam formulation by exhibiting release for 15 days.

5.4.2.4 Controlled release formulation of anthocyanin for improved bioavailability

A stable controlled release formulation of anthocyanins was developed using pectin-chitosan polyelectrolyte coacervate to improve its bioavailability and ensure target specific delivery. The biopolymeric coacervates were prepared by varying the concentration of pectin (4-6%), chitosan (0.5-0.7%), calcium and pH of the medium and jamun anthocyanin was encapsulated *in situ* during the formation of coacervates. Yield of coacervates and encapsulation efficiency varied from 69-86% and 30-58%, respectively. *In vitro* release study showed that anthocyanin release from formulation was more at acidic pH as after 1h compared to 6.8% release at pH 7 nearly 73% of encapsulated anthocyanin was released at pH 4.

5.4.3. Standardization and Validation of Methods for Detection and Quantification of Contaminants in Raw Agricultural Commodities, Processed Food and Environmental Samples

5.4.3.1 Chromogenic reagent for pesticide detection

A method for the synthesis of chromogenic reagent (azastilbenes) using 2-picoline/quinaldine and p-dimethyl amino benzaldehyde (DAB) was standardized. The synthesized 2-picoline-azastilbene and quinaldine-azastilbene were characterized by NMR. Yellow azastilbenes on reaction with edifenphos (organophosphate) gave orange (2-picoline-azastilbene) or pink (quinaldine-azastilbene) colored complex. Further, quinaldine-azastilbene used as chromogenic reagent to detect ediphenphos using colorimeter as pink coloured complex had absorption maximum at 525 nm (λ_{max}). The method was found to be linear in the range of 10-100 ppm ediphenphos.

5.4.3.2 Magnetic molecularly imprinted polymers as clean up tool for imidacloprid detection from honey and brinjal samples

Magnetic molecularly imprinted polymers (MMIP) were synthesized using nano Fe_3O_4 particles as magnetic cores, imidacloprid as template, acrylic acid as functional monomer, ethylene glycol dimethacrylate as cross linker and azo-bis-isobutyronitrile as initiator. Adsorption experiments revealed excellent binding capacity of MMIPs for imidacloprid over non-imprinted polymer (MNIP) and adsorption was best explained by the pseudo-second-order kinetic model. Scatchard plot analysis indicated the presence of two types of binding sites in the MMIPs with the dissociation constants of 0.197 µg/ml and 7.576 µg/ml. The feasibility and applicability of MMIP were tested in fortified honey and brinjal samples. About 87.1 and 90.6% of the added imidacloprid was recovered from MMIP in case of brinjal and honey extract, respectively.

5.4.3.3 Silver nanoparticles for pesticide detection

Silver nanoparticles were synthesized from silver nitrate using eucalyptus bark powder. The effect of pH and temperature on nanoparticle synthesis was evaluated. Characterization of the silver nanoparticles was done using FT-IR, UV spectrophotometer and spectro-fluorimeter. The fluorescent nanoparticles showed a λ_{max} of 430 nm and could detect atrazine in water up to 0.5 ppm concentration.

5.4.3.4 QUECHERS based LC-MS/MS multiresidue method for analysis of 40 insecticides in cereals

A method for simultaneous analysis of 40 insecticides commonly used in wheat, rice and maize was standardized. LC-MS-MS parameters and MRM transitions were optimized for different insecticides. Instrument detection limit of different pesticides varied from 5-20 ppb with 2 µl injection volume. Samples were processed using QUECHERS method and method validation was carried out at 1 and 0.5 ppm fortification levels. Recoveries of majority of the pesticides varied in the range 74-95%.

5.4.3.5 LCMS/MS multiresidue method for estimation of 65 herbicides in vegetables (eaten raw)

A LC-MS/MS method for identification and quantification of herbicides in tomato, cucumber, carrot and capsicum was developed. The herbicide mixture of 8 different concentrations were injected in the optimized method, eight point linear calibration curves covering a range of 0.01-10 µg/g were obtained for each herbicide showing correlation coefficient (r) value more than 0.9 for more than 97% of herbicides. Matrix match calibration curves were prepared to nullify matrix interferrace in validated method. More than 88% of the herbicides gave recovery in acceptable range of 70-120% with accepable repeatability (RSD ≤20%) when compared with matrix match standards. The LOD and LOQ of the method was 0.01 and 0.1 µg/g, respectively.

5.4.4 Management and Assessment of Contaminants in the Agricultural Commodities and in the Environment

5.4.4.1 Persistence evaluation of pesticide mixture product on brinjal

Acommercial mixture product of thiamethoxam 12.6% +λ-cyhalothrin 9.5% was sprayed @ 200 and 400 g/ha on brinjal (variety Pusa Kranti) at fruit formation stage. The half-life of dissipation for thiamethoxam and λ-cyhalothrin were found to be 2.1-2.7 days and 1.5-1.9 days, respectively. Based on the individual MRL of 0.3 and 0.2 ppm for thiamethoxam and ë-cyhalothrin, safe waiting period of one day has been suggested for the product.

5.4.4.2 Effect of biochars on pyrazosulfuron-ethyl degradation and bioactivity

Effect of wheat (WBC600) and rice straw (RBC600) biochars on pyrazosulfuron-ethyl degradation was studied in a pot culture experiment in rice planted soil. Unlike results obtained in laboratory incubated soil, effect of 0.5% biochar-amendment on herbicide degradation was less pronounced. The half-life values of herbicide in control, 0.5% WBC600 and RBC600 biochar-amended rice planted soils were 7, 8.6 and 10.4 days, respectively. Presence of three pyrazosulfuron-ethyl metabolites was confirmed and among them, dimethoxy pyrimidine was persistent in nature. Biochar application had no effect on microbial biomass carbon (MBC) content, dehydrogenase, FDA and acid/alkaline phosphatase activities. However, pyrazosulfuron-ethyl application significantly affected MBC content, dehydrogenase, FDA and acid phosphatase activities in soils, but these effects might be due to higher pyrazosulfuron-ethyl concentration used. Bioefficacy of herbicide, assayed by effect on mustard seed germination method, suggested that WBC400 and RBC400 had no negative effect on mustard plant, even at 0.5% amendment levels. However, WBC600 and RBC600 biochars even at 0.2% amendment levels, significantly reduced herbicide bioavailability.

5.4.4.3 Sorption of atrazine and imidacloprid on biochars

Agri-wastes biochars, viz., eucalyptus bark (EBBC), corn cob (CCBC), bamboo chips (BCBC), rice husk (RHBC) and rice straw (RSBC) and acid treated RSBC (T-RSBC), prepared at 600°C were characterized for their physico-chemical properties and sorption of atrazine and imidacloprid was studied. Among the five normal biochars, the RSBC showed the maximum atrazine (37.5-70.7%) and imidacloprid (39.9-77.8%) sorption at 1:1000 biochar : solution ratio. The phosphoric acid treatment of RSBC further enhanced the sorption of both pesticides in T-RSBC. The Freundlich adsorption isotherms were highly nonlinear and percent adsorption decreased with increase in pesticide concentration in solution. Results indicated potential of rice straw biochars as adsorbents for pesticide removal from contaminated water.

The Freundlich adsorption data of atrazine and imidacloprid sorption on RSBC and T-RSBC were modeled to develop single or multi-staged adsorber plants for pesticide removal from water. Both biochars showed significantly high adsorption capacity for imidacloprid and atrazine. Amounts of RSBC and

T-RSBC required for 95% of atrazine removal (10 mg/l) in single-, two- and three-staged adsorber plant models were 8.84, 2.44, 1.61 kg and 4.47, 1.42, 0.98 kg, respectively. Corresponding amounts for 95% imidacloprid removal (10 mg/l) were 3.97, 1.22, 0.84 kg and 3.98, 1.38, 0.96 kg, respectively. Single and two-staged adsorber plant model findings validated for atrazine removal using T-RSBC suggested that amounts calculated using modelling studies were fairly accurate.

5.4.4.4 Synthesis of tri-sodium citrate modified magnetite nano-particles for pesticide decontamination

The Fe_3O_4 nanoparticles were synthesized from iron (II) and iron (III) chloride salts. Further, they were modified using trisodium citrate to prevent them from possible oxidation as from agglomeration. They were characterized using FT-IR and DLS Zetatrac. The magnetite nano particle was successfully utilized for the decontamination of the atrazine residues in water. The nano-particles were able to remove 77-83% of atrazine from aqueous solution at 1-5 ppm.

5.4.4.5 Effect of ozonation on pesticide removal in citrus fruits

Grapefruit and kinnow fruits from IARI orchard pre-treated with dimethoate, imidacloprid and carbosulfan during the growth period of plant and fruit formation were analyzed for pesticide residues and only imidacloprid residues were detected. Fruits were subjected to ozonation treatment and results suggested that 30 min ozonation removed 64.15 and 57.20% imidacloprid from grapefruit and kinnow fruits, respectively. Effect of ozonation on fruits phytochemicals content, viz., organic acids (oxalic, tartaric, malic, malonic, ascorbic and citric), β-carotene, lycopene, hydroxycinnmic acids (ferulic acid and p-coumaric acid) and polyphenols were evaluated. Ozonation did not have much effect on organic acids content except ascorbic acid in kinnow, where 24.04% reduction was observed. Lycopene content in grapefruit was decreased less (2.35%) in comparison to β-carotene (24.8%). Ferulic acid and p-coumaric acid were decreased but effect was less in grapefruit.

5.5 WEED MANAGEMENT

5.5.1 Weed Management in Conservation Agriculture-based *Kharif* Onion-Wheat Cropping System

Integrated weed management was attempted in a conservation agriculture-based *kharif* onion-wheat cropping system with three main plots (i.e., CT flatbed (FB); ZTFB + wheat residue; ZT raised bed (RB) with wheat residue), supplemented with seven sub-plot treatments, viz., weedy check; weed-free check; two hand weeding (2 HW); pendimethalin (pre-emergence/PE)1.0 kg/ha + quizalofop(post-emergence/POE)0.05 kg/ha; pendimethalin (PE)1.0 kg/ha + ethoxysulfuron(POE) 0.015 kg/ha; tank-mix quizalofop 0.05 kg/ha+ metsulfuron0.005 kg/ha (POE); tank-mix quizalofop 0.05 kg/ha + ethoxysulfuron0.015 kg/ha (POE). Among tillage and residue treatments, ZT raised bed (ZTRB) with wheat residue resulted in significant reduction in weed biomass and gave higher weed control efficiency (WCE) than conventional tillage flatbed (CTFB) and ZT flatbed (ZTFB) with wheat residue. It gave significantly higher onion and wheat yield. Among weed management treatments, the application of pendimethalin 0.75kg/ha PE and quizalofop 0.15 kg/ha POE resulted in higher weed control efficiency and onion and wheat yield, but lower than that in weed-free check and two HW treatments. This treatment combined with ZT raised bed (ZTRB) with wheat residue provides higher yield and income through better weed management in onion-wheat cropping system. Tank-mix quizalofop + metsulfuron POE resulted in complete (100%) control of weeds but was highly phytotoxic to onion crop and as a result gave very low yield of onion.

5.5.2 Weed Dynamics in CA-based Rice-Wheat and Rice-Mustard Systems

Rice-wheat cropping system is the most predominant cropping system in the Indo-Gangetic plains of India. But, rice has encountered a host of

problems, leading to lower productivity and resource-use efficiency. With an aim to replace transplanted rice (TPR) with CA-based direct-seeded rice (DSR), which could be similar or more remunerative than TPR, an experiment was carried out for six consecutive years in direct rice -wheat and rice-mustard systems. We observed gradual reductions in weed populations in CA-based DSR, wheat and mustard over the years, but there was dynamics of weed species in the form of weed shift observed over the years.

5.5.3 Density and Nitrogen Effects on the Interference and Economic Threshold of *Phalaris minor* in Wheat

An experiment on density and N effects on the interference and economic threshold of *phalaris minor* retz. in wheat was conducted with different doses of nitrogen combined with different density of *Phalaris minor*. All yield attributing characteristics of wheat, *viz*., effective tillers, number of grains/spike and grain yield were significantly improved as the doses of N increased from 100 to 180 kg /ha. Significantly higher grain yield of wheat (5.7 t/ha) was observed with the application of 180 kg N/ha.

Interaction effect of N doses and *P. minor* density on grain yield of wheat (t/ha)

P. minor density (no./m²)	N doses (kg/ha)		
	100	150	180
10	4.52	5.55	6.30
20	4.11	5.37	6.12
40	3.62	4.98	5.80
80	3.08	4.65	5.47
N doses at same level of densityLSD (*P*=0.05)		0.26	
Density at same level N dosesLSD (*P*=0.05)		0.25	

Economic threshold level (ET) of Phalaris minor in wheat

A rectangular non-linear hyperbolic regression model (Eq. 1) (Cousens, 1985) was used to simulate wheat yields (Y) across the density of *P. minor* (d).

$$Y = Ywf\ [1–id/100(1+id/A)] \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where Y, simulated wheat yield at 'd' weed density; Ywf, weed-free crop yield; i, per cent yield loss per unit weed density (d) as density approach to 0, and A, the asymptotic value of the maximum yield loss (%) as density (d) approach to infinity. An iterative method was used for fitting data to nonlinear equations in the 'SAS 9.3' package and the values of 'i' and 'A' were estimated. The data and fitted curves are presented in terms of per cent yield loss (Y_L) using Eq. 2.

$$Y_L = id/\ (1+id/A) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where Y_L, yield loss (%); i, d and A are defined above. The ET of *P. minor* (Cousens, 1987) was determined using quadratic equation (Eq. 3).

$$1+\ (i/A)[2\ –H–(YPAH/C)]\ T\ +(i/A)^2\ (1–H)\ T^2\ =0 \quad \ldots\ldots(3)$$

where 'i' and 'A' are defined above; Y, weed-free wheat yield; P, unit price of wheat seed (i.e. minimum support price); H, efficiency of herbicide sulfosulfuron; C, cost of *P. minor* control (i.e. cost of sulfosulfuron and its application); T, economic threshold density. Economic threshold level and regression equation are given in the table.

Economic threshold level of *Phalaris minor* in wheat as affected by N doses.

N-dose (kg/ha)	Regression equation	Economic Threshold level (plants/m²)
100	$0.00000735T^2$ - 0. 16365T – 1 = 0	6.11
150	$0.00000997T^2$ - 0. 1167T – 1 = 0	8.56
180	$0.00000466T^2$ - 0. 09181T – 1 = 0	10.89

5.5.4 Effect of Tillage, Method of Establishment and Weed Management Practices on Performance of Wheat in Maize-Wheat Cropping System in North Eastern Plains Zone (NEPZ)

Field experiment was conducted at Pusa, Samastipur, Bihar to work out the effect of tillage, method of establishment and weed management practices on performance of wheat in maize-wheat cropping system in NEPZ. Results showed that the

lowest density and dry weight of weeds were observed in CT-flat bed amongst all the tillage and establishment methods. Among weed control measures the lowest weed density, weed dry weight and highest yield attributes and yield were recorded in the plot with two hand weeding followed by application of Isoproturon as POE at 30 DAS + one hand weeding at 45 DAS. Among herbicide mixture and ready mix herbicide the highest weed control efficiency and weed control index was recorded with the application of ready mix herbicide- FIT (Sulfosulfuron + metsulfuron) @ 40 g/ha as POE at 30 DAS.

5.5.5 Effect of Pre-emergence Herbicides on Seed Yield and Quality of Maize Seed

Seed yield in pre-emergence application of Atrazine and Pendimetalin followed by hand weeding were significantly superior to Pendimethalin and Atrazine fb Halasulfuron, Carfentrazone ethyl, sole application of Halosulfuron and weed check and were at par with weed free.

5.5.6 Effect of Integrated Weed Management on Seed Yield and Quality of Onion Seed

The weed flora of onion field comprised of *Medicago denticulata* (44.6%), *Coronopus dydimus* (27.2%), *Anagalis arvensis* (9.2%), *Phalaris minor* (7.2%) and other weeds (11.2%) which included *Lathyrus aphaca, Melilotus indica, Poa annua* and *Euphorbia helliscopia.* Maximum reduction in weed density and weed dry weight (87.1 and 91.1%) was recorded with Oxyflorofen 150 g/ha fb HW at 35 DAP compared to weed check. Pendimethalin, Alachlor and Oxyflourofen fb Quizalofop recorded significantly higher weed density and dry weight compared to Oxyflorofen 150g/ha and Pendimethalin 1.5 l/ha fb HW

6. BASIC AND STRATEGIC RESEARCH

The basic and strategic research at IARI during this year was focused on deciphering the molecular basis of plant stress tolerance, characterization of genetic resources, development of molecular markers, mapping of genes for economically important traits, the physiological basis of crop yield, mitigation studies on climate change, development of remote sensing and GIS techniques for assessment and management of crops and natural resources. This section briefly covers some of the significant achievements in these areas.

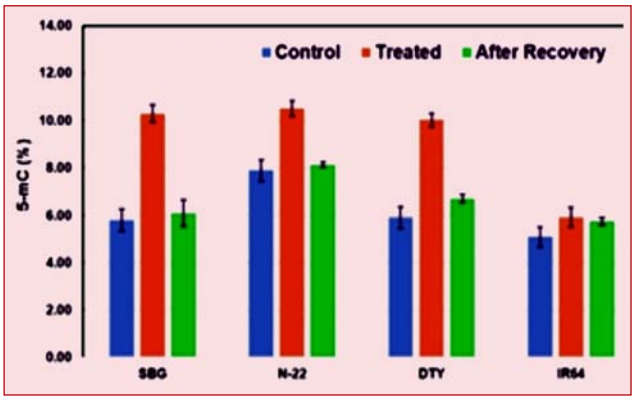
6.1 PLANT MOLECULAR BIOLOGY

6.1.1 Expression Analysis of Drought Responsive AP2/ERF Transcription Factors from Rice

In silico analysis of the drought stress upregulated OsAP2 promoter cloned from drought tolerant cv. Nagina 22 revealed the presence of two ABA responsive element (ABRE), three drought responsive element (DRE), 19 *MYB* recognition element and ten *WRKY cis*-elements. This promoter was cloned and by using reporter system (P_{OsAP2}::*GUS*), drought stress inducible nature of the cloned promoter region was confirmed by transient assays in *Arabidopsis* and rice. Seed priming with biotic elicitors viz., methyl jasmonate (MJ), paclobutrazole (PBZ) and salicylic acid (SA) suggested that drought-responsive transcription factor (RD1 and RD2) of AP2/ERF family were upregulated by these treatments, and thus confer enhanced drought tolerance at seedling stage.

6.1.2 The Qdty1.1 Enhances DNA Methylation in Rice

To investigate the mechanisms by which qDTY1.1 confers drought tolerance, global cytosine methylation (5-mC) was analyzed in Nagina 22 (qDTY1.1 donor), Sahbhagidhan, IR64 and qDTY1.1 NIL of IR64 (IR64-qDTY1.1). Rice genotypes grown in pots were subjected drought stress at reproductive stage and flag leaf samples were analyzed for global cytosine methylation (5-mC). Drought stress enhanced 5-mC in drought tolerant rice cv. Nagina 22, Sahbhagidhan, and IR64-qDTY1.1 but not in IR64. Introgression of the qDTY1.1 in IR64 caused about 65% increase in global methylation under drought stress in IR64-qDTY1.1 NIL. About 20% of global methylation was retained even after recovery from the drought stress.



Global methylation status of rice genotypes with contrasting drought tolerance (SBG= Sahbhagidhan, N-22= Nagina-22, DTY= IR64-DTY$_{1.1}$)

6.1.3 Differential Regulation of High-affinity Potassium Transporters (HKTs) under Salt Stress in Wheat

High-affinity potassium transporters (HKTs) play crucial role in sodium and potassium homeostasis under salt stress. Cytosine methylation pattern and expression pattern of HKTs were analyzed in salt tolerant wheat cv. Kharchia 65 and salt sensitive wheat cv. HD 2329 under control and 200mM NaCl stress. Salt stress downregulated the expression of *TaHKT2;1* and

TaHKT2;3 in shoot and root of Kharchia 65. *TaHKT1;4* showed root-specific expression and minor change in 5-mC content due to the salt stress.

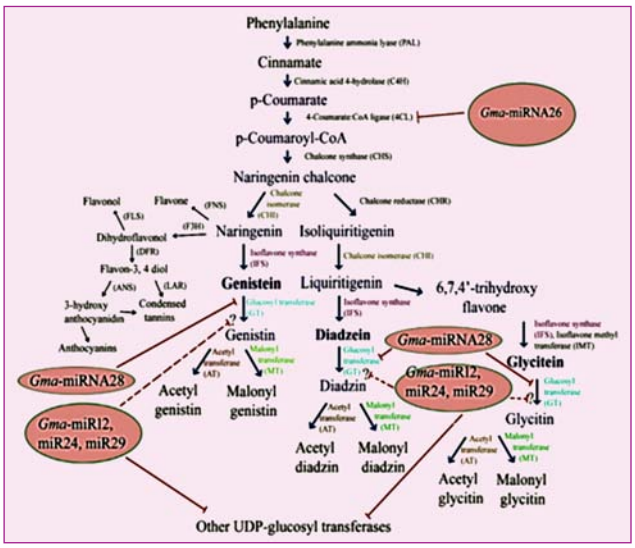
6.1.4 Methylome and Proteome Analysis in Wheat under Heat Stress

Whole genome bisulfite sequencing was carried out in pooled tissue samples collected from with genotypes with contrasting thermotolerance Raj 3765 (thermotolerant) and HD 2329 (thermosensitive) at anthesis stage. Analysis of methylome data sequencing data for differentially methylated regions (DMR) between control and heat stress treated samples revealed that Raj 3765 had 25% more DMRs than HD 2329. Among the DMRs, 33% hypermethylations and 13% hypomethylation were more prominent in thermotolerant cv. Raj 3765 over thermosensitive cv. HD 2329.

Two-dimensional gel electrophoresis analysis was carried out in leaf, stem and spike tissues of wheat cv. HD 2967 to identify heat stress regulated proteome study. This study revealed 66, 72 and 58% increase in number of proteins in leaves, stem and spikes, respectively, during heat stress.

6.1.5 Characterization of miRNAs regulating enzymes of isoflavone biosynthesis pathway in soybean seeds

Soybean seed is rich in health-promoting bioactive compound isoflavones. To understand the regulation of isoflavonoid biosynthesis in seeds of soybean, 31 new microRNAs (miRNAs) along with their 245 putative target genes were from soybean seed-specific ESTs. Five miRNAs (GmamiRNA12, Gma-miRNA24, Gma-miRNA26, Gma-miRNA28, and Gma miRNA29) and their target genes were predicted and confirmed by qRT-PCR analysis. Gma-miR26 targets the 4-coumarate CoA ligase (Glyma.10G197900) which controls the flux movement towards isoflavone biosynthesis, while GmamiRNA12, Gma-miRNA24, Gma-miRNA28, and Gma-miRNA29 miRNAs regulate genes involved in downstream control of glycosylation



Potential role of miRNAs in regulating isoflavonoid biosynthesis in soybean seeds

of synthesized isoflavones. Differential expression of Gma-miR26 and Gma-miRNA28 and their corresponding target genes (Glyma.10G197900 and Glyma.09G127200) showed a direct relationship with the total isoflavone content in soybean seeds.

6.1.6 Identification of DCL-interactome from Rice

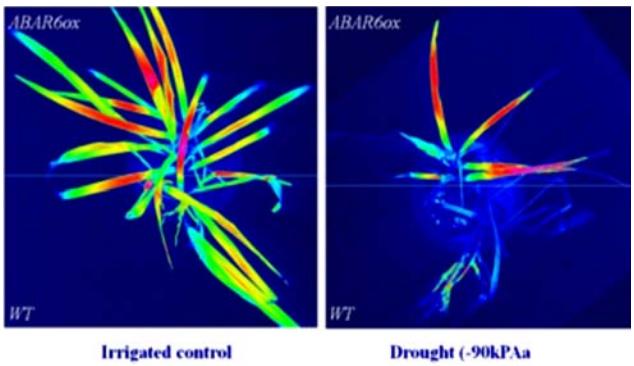
To elucidate the microRNA biogenesis in rice under abiotic stresses, yeast-two-hybrid (Y2H) screen was carried out with Dicer-Like 1 (DCL1), an enzyme involved in microRNA biogenesis, as bait. The PAZ domain of DCL1 and DCL4 proteins were successfully cloned in bait vectors pGBKT7 and transformed in Y2H Gold yeast strain. The Bait clone was checked for the absence of autoactivation and toxicity. Prey library was constructed in pGADT7 vector using RNA samples from abiotic stress treated tissues sample of rice cv. Nagina 22. Prey library has been checked for interaction with DCL1 bait. Blue colonies depicting interaction between bait and prey partners were initially selected on DDO (Double drop out) SD medium, further on QDO (Quadruple drop out) SD media and confirmed on QDO with auriobesidin antibiotic resistance. Several putative DCL1 partners were identified using this approach.

6.1.7 Genome Editing of Genes for Drought Tolerance in Rice and Nutritional Quality in Soybean

Genome editing is emerging as an important tool for functional genomics and crop improvement. Towards functional validation of genes for ABA-dependent and – independent pathway of drought tolerance in rice, CRISPR-Cas9 genome editing constructs were developed for *ABA Receptor 6* (*ABAR6*), *ABAR10*, *ABAR11*, Enhanced Response to *ABA 1* (*ERA1*), *Protein farnesyl transferase-alpha* (*FTA*) and *Drought and Salt Tolerance (DST)* genes in rice. The guide RNAs for specifically targeting these genes were separately cloned under the transcriptional control of U3 promoter. The sgRNA-Cas9 cassette was then subcloned in to pCAMBIA1300 for plant transformation. In soybean, for editing the late genes of phytate biosynthesis *pCas9-IPK1* binary constructs were developed. Similarly CRISPR/Cas 9 system was applied to generate genome edited mutants to target tocopherol pathway genes (ã-*TMT3*) as well as *DE-ETIOLATED1* (*DET1*), a regulatory gene for simultaneous increase in tocopherol, isoflavones, carotenoids, saponins and anthocyanins.

6.1.8 *Abscisic Acid Receptor 6* (*ABAR6*) Gene Protects Photosystem II under Drought Stress

To elucidate the functions of plant stress hormone ABA receptors (ABARs), transgenic rice lines (PS 2 background) overexpressing *ABAR6* under the transcriptional control of stress inducible *AtRD29A* promoter were developed. Previous year, it was shown that *RD29A:ABAR6* transgenic rice lines (ABAR6ox) are more tolerant to drought stress than non-transgenic wild type (WT) plants through better water loss minimization strategy. Now we analyzed the stress tolerance of photosynthetic light reaction complex, specifically maximum quantum efficiency of PSII photochemistry (Fv/Fm), by using chlorophyll fluorescence imaging platform at IARI plant phenomics facility. ABAR6 transgenics and WT or RNAi-*ABAR6* and WT rice plants were grown in the same pot till booting and soil moisture stress was imposed till the soil matric potential reached to -90 kPa. Visual RGB and Chlorophyll fluorescence images were taken and analyzed using Scanalyzer 3D software. The results clearly showed the PSII yield (Fv/Fm) of both *ABAR6* overexpressing lines, RNAi-*ABAR6* lines and WT were similar under well irrigated conditions, and under drought stress, the PSII yield decreased drastically in WT and *ABAR6-RNAi* lines, while *ABAR6* overexpressing lines maintained PSII yield. Further analysis showed that drought stress reduces Fm drastically in WT plants while transgenic *ABAR6* overexpressing lines could maintain Fm. This result suggests that enhanced stability of PSII is an important component of drought tolerance conferred by *RD29A::ABAR6* gene.



***ABAR6* confers enhanced PSII stability to transgenic rice plants under drought stress (green, red and blue color indicates high, medium and low PSII activity, respectively)**

6.2 BIOCHEMISTRY

6.2.1 Anthocyanin Fingerprinting in Pigmented Soybean

Anthocyanin fingerprints of 57 pigmented soybean genotypes revealed genotypic variation of 2 - 940 mg anthocyanin/100g seed coat. Based on the most abundant anthocyanin form, cyanidin-3-glucoside (Cy3G), the genotypes were subdivided into five groups. Highest concentration of Cy3G was observed in black variety DS 241 (939.56mg/100g), followed by chocolate type GG 252 (214.32mg/100g), brown JS 9214 (58.11mg/100g), green G 2144 (19.06mg/100g) and yellow DS 9712 (2.31 mg/100g). To understand the nutraceutical potential of Cy3G in disease etiology, an *in vitro* cell line (BEAS2b) mimicking model was

used. A decrease of 78% ROS levels were observed when cell lines treated with seed extracts of soybean genotype BS 1 with 1023mg/100g Cy3G as compared negative control (Bragg).

6.2.2 Engineering of Rubisco Activase (RCA) Protein for Improved Thermostability

RCA activates Rubisco enzyme. The reduction in photosynthesis at high temperature stress is due to inactivation of RCA and Rubisco. Hence, thermostable RCA is necessary for maintaining photosynthesis under heat stress. Towards this, 12 putative *RCA* genes were identified using transcriptome analysis and a stress regulated RCA (KP257297) was cloned from wheat. The identified wheat RCA showed maximum homology of 97% with RCA reported from rice (AAL87177) and 87% homology with RCA identified from *Arabidopsis*. Multiple sequence alignment was carried out with the cloned wheat RCA protein sequence and 37 *RCA* protein sequences from different plants by using ClustalW. Six potential hot spots were identified as candidate amino acid residues for thermostability. Site directed mutagenesis was carried out to engineer RCA with K115Q, D117N, F118L, E138D and F144L mutations.

6.2.3 Characterizationof9-cis-epoxycarotenoid dioxygenase (NCED) from Rice

OsNCED1 gene (1917 bp, Genbank Accession: KX013221) was cloned and characterized from rice var. Nagina 22. It was found to encode a protein with 638 amino acids, pI of 6.07, Mwt of 68.62 kDa. Conserved domain architecture revealed that the OsNCED1 belongs to RPE65 super family, responsible for neoxanthin cleavage in plants. Water-deficit stress was found to downregulate the expression of *OsNCED1* gene within four days of water withdrawing.

6.3 PLANT PHYSIOLOGY

6.3.1 Establishment of State-of-Art Plant Phenomics Facility

Phenomics, the next generation phenotyping (NGP), is emerging as a tool to bridge phenotype-genotype gap. A state-of-art automated high throughput plant phenomics facility for non-destructive and accurate characterization of a large number of germplasm and recombinant inbred lines under defined environmental treatment conditions was established at IARI, New Delhi. The facility consists of hi-tech climate controlled greenhouses,

Plant phenomics facility at IARI

moving field for handling of 1,200 plants within the greenhouse and to transport them to imaging stations, different imaging platforms, viz., IR Thermal, Chlorophyll fluorescence, Visual RGB, NIR root, NIR shoot, VNIR Hyper-spectral, SWIR Hyper-spectral sensors, with computational support for image capture and analysis, and five weighing and watering stations in order to impose various drought/water-logging/ nutrient deficiency stresses, and to assess input use efficiency. Several researchers from India and abroad visited the facility.

6.3.2 Phenomics of Nocturnal Transpiration in Rice under Drought Stress

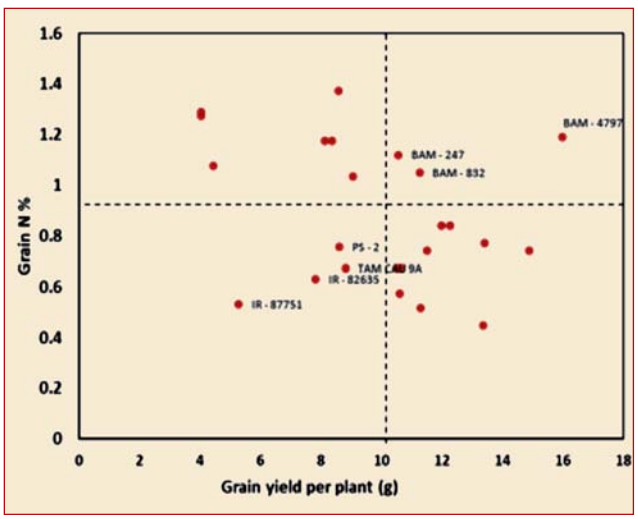
Minimizing transpiration and enhancing efficient use of water are critical for sustaining rice productivity under global climate change conditions. Nocturnal transpiration is expected to increase due to high night temperature. To identify donors for low nocturnal transpiration, an experiment was conducted with sixty rice genotypes at automated Plant Phenomics Facility, IARI. Rice genotypes grown in pots under non-stress conditions till booting, and then subjected to drought stress. The total water use during day and night time were recorded by using automated weighing and watering stations, and plant stress responses were measured by using visual, IR and NIR imaging platforms. Day time transpiration varied from 150 to 300 mL, while night time transpiration varied from 50 to 150 mL per day in different rice genotypes. The genotypes identified with low nocturnal transpiration will be useful for improving water use efficiency (WUE) of rice.

6.3.3 Rice Grain Quality under Post-Anthesis High Night Temperature Stress

High night temperature (HNT) of 3ºC higher over an average ambient night temperature of 25ºC from anthesis to maturity significantly affected grain quality in rice. The early and medium duration cultivars had reduced peak viscosity (range 9-57%), while most of the cultivars showed an increase in pasting temperature. Holding strength of starch was low under HNT in the early duration cvs. Vandana, Parijat and Nagina 22. A decrease in breakdown values of all the cultivars under HNT indicated the resilience of starch granule leading to more non sticky cooked rice. The presence of large proportion of long chain of amylopectin may apparently help in formation of resilient starch granule during grain development under high night temperature.

6.3.4 Nitrogen Use Efficiency (NUE) of Rice Genotypes under Field Conditions

Total 25 rice genotypes, selected based on *kharif* 2015 field screening and seedling stage hydroponic screening, were phenotyped for NUE under N0 and N120 conditions during *kharif* 2016. Based on grain N% and grain yield per plant under N deficient (N0) conditions, genotypes were classified as high and low NUE types. Genotypes, BAM 247, BAM 4797, BAM 832 and Rasi were identified as high NUE genotypes, and Pusa Sugandh 2, TAMKAU-9A, IR 82635 and IR 87751 were identified as low NUE genotypes. Total N uptake was higher in high NUE genotypes, which indicate higher NUE and N uptake or N utilization, or both components. Significant variation in glutamine synthetase (GS) activity was found between high NUE genotypes and low NUE genotypes. In N0 treatment, GS activity was almost two-fold higher than that in N120 condition. Low NUE genotypes did not show



Genotypic variation for grain N and grain yield per plant. Values are based on N uptake and grain yield of 25 rice genotypes grown without fertilizer N (Soil N 195 kg/ha)

much change in GS activity with changed N levels. These contrasting genotypes will be useful as donors for NUE in rice.

6.3.5 Interaction between P-deficiency and Heat Stress on Rice Physiology

The effects of low soil P and high temperature on rice genotypes IR 64 and IR 64- Pup1 (IR 64 NIL carrying P uptake1 QTL) was studied during *kharif* 2016. The low-P soil had 2.0 mg P/ kg soil, while control soil contained 41 mg P/ kg soil. At 50% anthesis stage, half the number of pots containing both P levels was transferred to polyethylene-tunnel for imposing high temperature treatment for five days, while the other half were kept under ambient temperature. Low P significantly reduced biomass and leaf area, and elevated temperature further exacerbated this leading to severe reduction in biomass and yield. P concentration in plants grown under low-P increased considerably when exposed to heat stress. High temperature induced upregulation of miR399b appears to be one of the causes for regulating P starvation response. IR64-Pup1 showed increased sugar concentration, while IR64 showed increased starch concentration at low P irrespective of temperature treatment. Low-P induced increase in sugar levels in shoots down-regulated miR156 which lead to reduction in juvenility period. High sugars also enhanced the expression of miR172 which mediates transition from juvenility to flowering. As a result, early flowering was observed in low P grown plants compared to sufficient P.

6.3.6 Phenotyping of Rice Genotypes for CO_2 Responsiveness

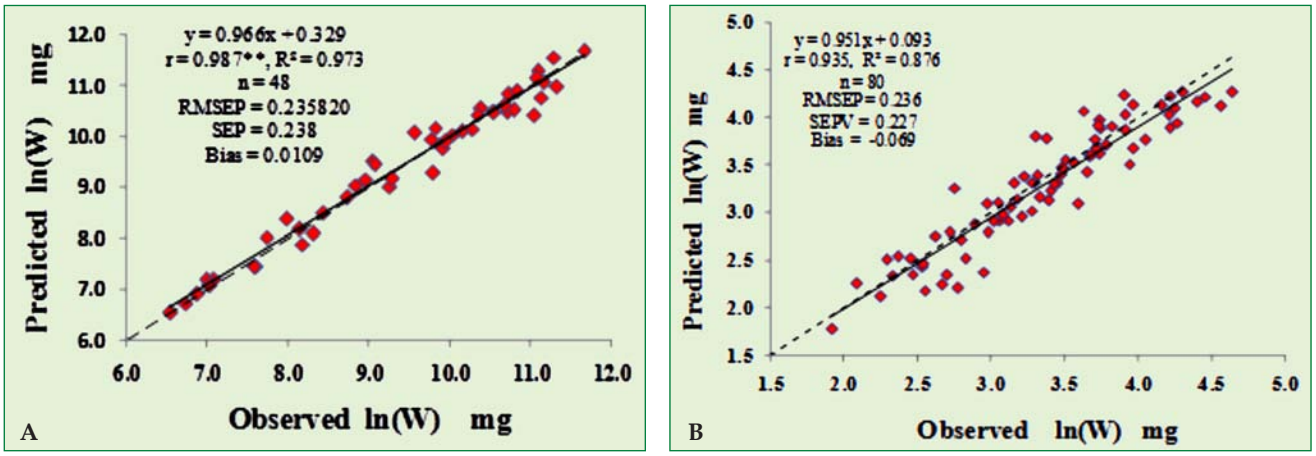
A diverse set of 241 rice germplasm including indica, japonica, glaberrima, basmati and elite high yielding cultivars were screened for CO_2 responsiveness using planting geometry technique. Gas exchange traits and yield components were used to identify potential genotypes for further detailed analysis under elevated CO_2 and high temperature. A response index (R) was calculated to quantify genetic response to major CO_2 responsive traits such as flag leaf chlorophyll, number of tillers and panicles under low planting density. One hundred five genotypes were analyzed on the basis of phenology, tillering capacity, panicles number and SPAD values, and for gas exchange parameters. All the selected genotypes showed significantly higher rate of photosynthesis, stomatal conductance and transpiration rate under low planting density. These 105 selected genotypes recorded higher panicle weight (59%), total biomass (104%) and grain yield (80%) under low planting density as compared to normal planting density. The contrasting rice genotypes will be grown under FACE and OTCs and exposed to elevated CO_2 to confirm their responses

6.3.7 Evaluation of Heat Tolerance in Wheat

A field experiment was conducted to evaluate a set of 205 wheat genotypes for heat tolerance based on physiological traits. High temperature treatment was imposed by delaying the sowing dates i.e., normal (30th November, 2015) and late sowing (12th January, 2016). On average, heat stress reduced the MSI, total chlorophyll, carotenoids and quantum yield of PSII by 11, 19, 22 and 12.8%, respectively, while CTD was increased by 30%. The following genotypes were identified with stable MSI (~80%) and PSII yield (>0.7) under late shown conditions: EC445054, BOLLER1, DL1266-1, BT Schomburgk, CHIRIA-7, BACOMOVE, BACANORA88, Bevy-1(med), BABAX, and EC445254.

6.3.8 Rapid and Non-Destructive Field Phenotyping of Crop Biomass in Wheat and Rice

Crop biomass is one of the most important traits of crop performance. The traditional method for biomass estimation requires destructive sampling, time and labour intensive. A new method and apparatus was developed for capturing side view image profiles from wheat and rice crop in the field to measure biomass. Highly significant linear relation between log (biomass) and log (projected area) was observed in both wheat and rice crops. This relationship can be used for non-destructive estimation of biomass



Relationship between the observed crop biomass measured by destructive sampling and predicted biomass (image based) in wheat (A) and rice (B)

under field conditions as indicated by the significant correlation between observed and predicted biomass in wheat and rice.

6.4 GENETICS

6.4.1 Wheat

6.4.1.1 Identification of QTLs for drought and heat tolerance

Backcross-derived populations were screened for validation of previously identified QTLs and identification of new QTLs linked to drought and heat tolerance. Genotyping was carried out with SSR markers. Ten selected lines each from five marker-assisted backcross breeding populations were evaluated in multi-location yield trials. Expression of introgressed QTLs were found to be higher in few selected lines compared to the recurrent parent. SSR markers developed from transcriptome data of heat-stress tolerant and susceptible genotype are being validated in wheat germplasm lines and an international core set for drought and heat tolerance. Four markers were found to be linked and associated with heat tolerance, physiological and yield contributing traits. Work was initiated to develop Multi-parent Advanced Generation Intercrosses (MAGIC) population for drought and heat tolerance. A total of 70 double crosses were attempted from 28 single crosses.

6.4.1.2 Development of locally adapted host differentials for Indian pathotypes of wheat leaf rust

To overcome the maintenance problem of leaf rust differential set in winter genotypes used as source for breeding, work was initiated to develop near-isogenic *Lr* lines in the background of a locally adapted variety NP 4. The differential sets were developed in NP4 background viz., HI KK1 (NP4+*Lr1*) (IC0620368, INGR16024), HI KK 2 (NP4+*Lr2a*) (IC0620369, INGR16025), HI KK 3 (NP4+*Lr2c*) (IC0620370, INGR16026), HI KK 4 (NP4+*Lr3a*) (IC0620371, INGR16027), HI KK 5 (NP4+*Lr9*) (IC0620372, INGR16028), HI KK 6 (NP4+*Lr10*) (IC0620373, INGR16029), HI KK 7 (NP4+*Lr15*) (IC-0620374, INGR16030), HI KK 8 (NP4+*Lr17a*) (IC0620375, INGR16031), and HI KK 9 (NP4+*Lr20*) (IC0620376, INGR16032).

6.4.1.3 Identification of novel leaf rust resistance gene in wheat

A leaf rust resistant stock "Selection G 12" was developed from the cross between bread wheat line CM 108-31 x *T. timopheevii* Zhuk (2n= 28, A^tA^tGG). Characterization of leaf rust resistance in Selection G12 by multi-pathotype testing displaying high degree of broad spectrum resistance to prevalent important Indian pathotypes of leaf rust pathogen (*Puccinia triticina*). Genetic analysis of leaf rust

resistance using most virulent and prevalent pathotype 77-5 revealed that resistance in Selection G12 is governed by a single recessive gene. Molecular mapping and linkage analysis was used to map the leaf rust resistance gene on long arm of 3B chromosome flanked by markers *Xgwm547* and *Xgwm114* at 6 and 28.3 cM, respectively. As no other leaf rust resistance gene has been designated on chromosome 3BL so far, the novel leaf rust resistance in Selection G12 is tentatively named as *LrSel.G12*. This leaf rust resistance gene is expected to be of immense value in diversifying the genetic base of leaf rust resistance in wheat varieties.

6.4.1.4 Development of wheat double haploids (DH)

Forty-two haploid plants obtained by crossing of wheat F_1's with *Imperata cylindrica* were treated with different concentration of colchicines (0.04, 0.06, 0.08 and 0.10%) for five hours followed by washing for two hours to estimate an optimal colchicine concentration. Colchicine concentration (0.08%) was found to be the best showing two plants converted to DH followed by 0.06% producing one DH plant.

6.4.1.5 QTLs and genes for zinc uptake, translocation and sequestration

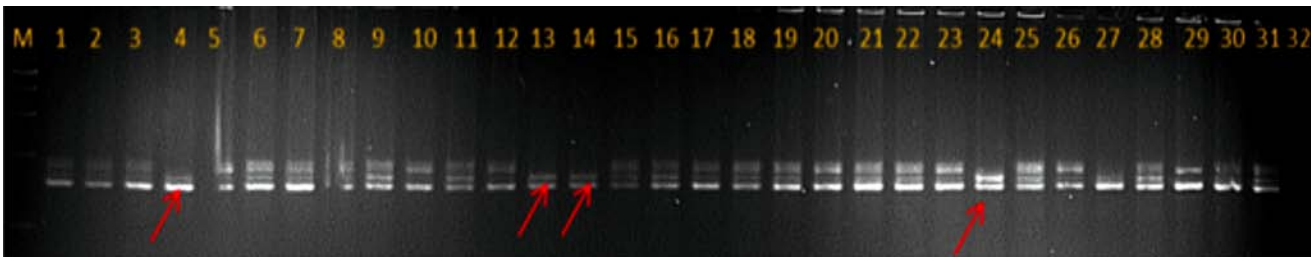
Wheat genotypes HPYT404 with high grain Zn, and DPW621-50 with low grain Zn content were grown in sufficient (5.0 ppm) and deficient (0.3 ppm) Zn concentration soil. Differential expression patterns of 53 genes including *IRT, ZIP, HMA, YSL, NRAMP* gene families were observed between these genotypes. *HvZIP5* gene was found to be upregulated in both the genotypes under Zn deficiency. Mapping for grain iron, zinc and protein was carried out with SSR markers in a biparental mapping population with 176 RILs. Eleven QTLs were identified for grain iron, zinc and protein.

6.4.1.6 Development of genotypes with better biscuit making quality

Backcross (BC_1F_1) populations of DBW14 x Barham and HI1563 x Barham were planted in off season nursery, and MAS was exercised for *PinAD1a*, *GluB3b* and *Lr37* genes. A total of 100 segregants positive with *PinA, GluB3b* and *Lr37* were backcrossed and selfed. Simultaneously for background selection, parental polymorphism was carried with 1000 SSR primers, and about 100 polymorphic SSRs were identified. MAS have again been exercised for *PinAD1a*, *GluB3b* and *Lr37* genes.

6.4.1.7 Development of durum lines with low immunogenic gluten

Loci on chromosomes 1D, 1A and 6D, 6A in wheat are implicated in causing celiac disease. As *T. durum* is devoid of D genome, a *durum* line was chosen for creating nullidisomics and ditelosomics for the mentioned chromosomes. Cytogenetic stocks were procured, multiplied and used in crossing with *durum* line HI 8663. The F_2 plants were screened for the presence/absence of the relevant chromosomes with EST derived primers. Only 3-4 plants were found to have the absence of unwanted chromosome or arm. Crosses have been made between these homozygous F_2 plants nullisomic for 1A (N1AT1B) and nullisomic for 6AN6AT6B, and Homozygous F_2 plant, DilL.1AL & Ditl.6AL.



Polymorphism of *SWES 206* in F_2 plants of the cross N6AT6B x HI8663. Arrows show plants without the 6A and 6D genome amplification for the marker

6.4.2 Rice

6.4.2.1 Identification of rice genotypes with low phytic acid

A set of EMS induced mutants of an upland variety Nagina 22 were screened for the low phytic acid (*lpa*) trait using high inorganic phosphate (HIP) colorimetric assay. The identified *lpa* mutants, showed wild type marker alleles when screened for already reported mutations. This suggests presence of either novel mutation in the same gene or mutation in other genes of phytic acid pathway.

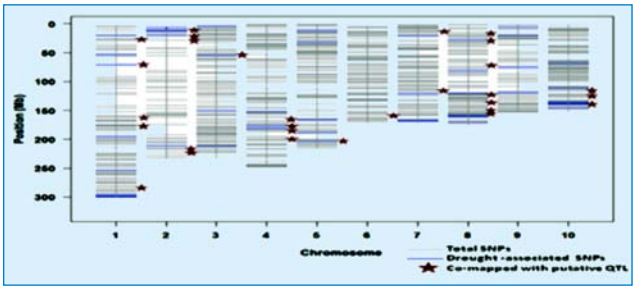
6.4.2.2 Genetic analysis and mapping of herbicide tolerance gene in rice

Phenotyping of F_2 progenies (Pusa1656/Herbicide Tolerant Mutant of Nagina 22) for their tolerance to the herbicide (Imazethapyr) suggested a dominant monogenic inheritance pattern. Further, herbicide tolerance gene was mapped on Chromosome 2 at a genetic distance of 1.2 cM from the SSR marker RM6844.

6.4.3. Maize

6.4.3.1 Genomic selection for drought tolerance in maize

Breeding values of 240 maize subtropical lines phenotyped for drought at different environments using 29,619 cured SNPs were tested using seven GS models (ridge regression, LASSO, elastic net, random forest, reproducing kernel Hilbert space, Bayes A and Bayes B). Though prediction accuracies of Bayes B, Bayes A and RKHS were comparable, Bayes B outperformed the other models by predicting highest *Pearson correlation coefficient*. From Bayes B, a set of the top 1053 significant SNPs with higher marker effects was selected across all datasets to validate the genes and QTLs. Out of these 1053 SNPs, 77 SNPs associated with ten drought-responsive transcription factors for different physiological functions viz., stomatal closure, root development, hormonal signaling and photosynthesis. These SNPs will be useful for the selection of superior genotypes and candidate genes for breeding drought-tolerant maize hybrids.



Distribution of total SNPs, drought-associated SNPOs and co-mapped putative QTLs

6.4.3.2 Variable level of dominance of candidate genes for drought tolerance traits in maize hybrids

A set of five hybrids and their parents with different levels of drought tolerance were studied to analyze the magnitude and direction of 52 drought–responsive candidate genes. The tolerant parents, HKI 1105 and CML 425, and their hybrid, ADWLH 2, maintained stability in chlorophyll content, root length and relative water content. All the genes were up–regulated in ADWLH 2, many were down–regulated in HM 8 and HM 9, and most were downregulated in PMH 1 and PMH 3 in shoot and root. The nature of the gene expression was controlled by the parental combination rather than the parent *per se*. The differentially expressed genes in all five hybrids explained mostly non–additive gene action over additivity. The non–additive gene action may be driven by allele polymorphism, small RNAs and other regulatory mechanisms.

6.4.3.3 Molecular characterization of waxy corn inbreds

Waxy green cob is popular as breakfast item in South Asia, and is also used as paper, adhesive and in textile industries due to higher amylopectin (95-100%) as compared to normal maize (70-75%). A set of 24 diverse waxy inbreds (MGUWX-1 to -24) developed at IARI were analyzed using 77 SSRs and a total of nine unique- and 20 rare- alleles were detected. Cluster analyses grouped the waxy inbreds into three major clusters. The study identified a set of potential cross combination to develop highly heterotic waxy hybrid combinations.

6.4.3.4 Haplotype of recessive opaque2 in QPM inbreds

A set of 46 QPM inbreds of exotic and indigenous origin were genotyped using *opaque2* (*o2*) gene-based two SSRs viz., *umc1066* and *phi057*, present on exon-1 and exon-6 of the gene, respectively. Among the haplotypes, *o2*-AE had the highest frequency (76.09%), followed by *o2*-AD (15.22%) and *o2*-BD (4.35%). *o2*-BC and *o2*-AC haplotypes were observed in 2.17% each of the inbreds. Haplotype, *o2*-BE was not found in the inbred panel. Inbreds from IARI had *o2*-AE and *o2*-AD haplotypes. In contrast to the one recessive *o2* allele known in the population, the present study reports the presence of at least five versions of recessive *o2* allele.

6.4.4 Pearl millet

6.4.4.1 Genome-wide association studies for high grain iron and zinc content

An association mapping panel comprising 130 pearl millet genotypes including two checks (ICMB 98222 and Dhanshakti) for high grain Fe content were evaluated at IARI, New Delhi, RS-IARI, Dharwad and RS- NBPGR, Jodhpur. Grain iron content ranged from 32.3 to 111.9 ppm whereas grain zinc content ranged from 26.6 to 73.7 ppm. Structure analysis using DARwin classified genotypes to the three sub-populations with admixture. *Xipes* 0096, *Xipes* 0810 and *Xpsmp* 2261 were associated with high grain iron and zinc contents over location and year. The amplicons of *Xipes* 0096, *Xpsmp* 2261 and *Xipes* 0810 for seven genotypes were compared with reference genome Tift23D_2B_1-531 P_1-P_5. *Xpsmp* 2261 amplicon landed in intergenic region on pseudomolecule 5, while *Xipes* 0810 was observed to be overlapping with gene on pseudomolecule 3. This flanking gene was annotated to be aspartic proteinase (*asp1*) gene. On comparison with the reference sequence, two putative SNPs and a 15bp InDel were observed.

6.4.4.2 Multi-year testing for grain iron and zinc in pearl millet RILs

Pearl millet RILs consisting of 210 genotypes developed by crossing PPMI 683 (high Fe) & PPMI 627 (low Fe) were evaluated for phenotypic traits with checks over three years (2014, 2015 and 2016, *kharif* season) at Delhi. Large phenotypic variation was observed for days to flowering, plant height, spike length, spike girth, productive tillers, and grain iron and zinc contents. Bi-directional transgressive segregation was observed for all traits. Most of the traits were approximately normally distributed at all three years. It was observed that grain Fe and Zn contents were highly correlated (r=0.69) and grain Fe content is negatively correlating with spike length. But Zinc contents showed positive correlation with spike length. GGE biplot analysis using 31 genotypes which have higher mean Fe content than check (ICMB 98222) identified PPMI 904, RIL 69, RIL 28 and RIL 35 as high performance stable genotypes.

6.4.5 Lentil

6.4.5.1 Genetic diversity analysis of lentil lines differing in grain Fe and Zn concentrations

Fifty lentil genotypes were evaluated at three locations for grain Fe and Zn concentrations to analyze G x E interactions using the additive main effect and multiplication interaction model (AMMI). The AMMI analysis of variance for both grain Fe and Zn detected significant effects for G, E and GEI. For Fe, P 13143, P 13135, ILL 2581, P 2130, LL 147, PL 101 and Globe mutant, and for Zn, P 2205, P 13143, P 13122, P 2239, P 3204 and L 11-245 were found stable. Based on these results, crosses are being made for development of grain Fe and Zn rich varieties (P 3220 x L 4649 and VL 103 x P 2130) and mapping populations (P 13122 x L 11-287 and LL 931x P3220) for mapping of QTLs/ gene(s).

6.4.5.2 Transcriptome analysis of drought stress responses in seedlings

Transcriptome analysis of leaves of the lentil seedlings subjected to drought stress by RNAseq led to the identification of a total of 18,369 transcripts. These transcripts were successfully annotated by mapping them to KEGG pathway databases and expression of 10 genes were validated by using qRT-PCR analysis. From the transcripts, SSRs (9949), SNPs (8260) and

INDELs (1248) were identified which can be further for future genetic and functional genomics studies on drought tolerance in lentil.

6.4.6 Soybean

6.4.6.1 Inheritance and mapping of Cowpea mild mottle virus (CPMMV) resistance

To study the inheritance of resistance to CPMMV strain D1 in Indian soybean, the resistant genotypes, DS 12-5 and SL 958 were crossed with susceptible genotypes, F4C7-32 and JS 335, respectively. Resistance reactions of F_2 plants and individual F_2 plant derived F_3 families indicated that resistance was controlled by a single dominant gene. Parental polymorphic survey led to the identification 71 and 65 polymorphic markers for crosses DS-12-5(R) x F4C7-32 (S) and SL958(R) x JS335(S), respectively. Bulked segregant analysis with pooled DNA of ten resistant and ten susceptible plants led to the identification of markers Satt635 and Uo8405 which showed good of fitness to 1:2:1 ratio in F_2 segregating population by chi square test. Further analysis of linkage was done by using MAPMAKER version 3.0b. It indicated that Uo8405 and Satt635 were linked to resistant gene and they are located on linkage group H (chromosome 12). The order and genetic distance of marker and resistance gene are Satt635 2.7cM and Uo8405 5.4cM. These two polymorphic markers segregated in the 1:2:1 ratio indicating that markers are co-segregating with the trait. Joint segregation analysis revealed that gene and marker combination deviate significantly from the expected ratio 3:6:3:1:2:1 for RR/MM: RR/Mm: RR/mm:rr/MM: rr/Mm: rr/mm, suggesting that two markers and resistant gene were linked.

6.4.6.2 Mapping of QTLs for yield and domestication-related traits

A set of 206 inter-specific RILs in $F_{2:6}$ were subjected to replicated trial for two years. Molecular genotyping was conducted with 317 SSR markers of which 206 were polymorphic. In total, 48 QTLs were mapped for 12 yield and domestication-related traits, of which 12 were novel and 7 were consistent QTL. RILs with 300-450 pods/plant have also been identified.

Variations in number of pods/plant in soybean RIL population

6.4.7 Mustard

6.4.7.1 Breeding for high temperature tolerance at seedling and seed development stages

To evaluate for seedling and reproductive stage heat tolerance, 126 advance genotypes including station trial entries and F_6 and F_7 progenies along with five checks were raised under early, timely, rainfed and late sown condition. Data on 11 morphological traits has been recorded and tolerant genotypes will be identified based on germination and survival as well as yield and yield attributing traits. Further to workout the genetics of high temperature tolerance, 15 cross were made in diallel fashion involving tolerant (PM 26, Bio 902 and EJ 20) and susceptible (PM 21, EC 597325 and NPJ 119) genotypes. Further, 20 promising genotypes were screened for heat tolerance in phytotron conditions. Two hundred SSR markers were screened to study the polymorphism among parents used for developing RILs for heat tolerance i.e., Pusa Bahar, Pusa Mustard 28, BEC 144 and Pusa Karishma.

6.4.7.2 Phenotyping for identification of '0' and '00' genotypes

For identifying low erucic acid and double low genotypes from various breeding populations, maintenance breeding of double and single low varieties and advance lines, a large number of single plants and bulks are phenotyped through biochemical analysis. For low erucic acid, 7101 single plants/

bulks were analyzed and 6523 lines with <2% erucic acid were identified. Likewise, 2577 single plants/ bulks from double low quality material were also phenotyped for their glucosinolate content and 1056 lines with <30 ppm glucosinolate were identified. Four mapping populations for mapping genes/ QTLs for drought and heat tolerance; and oil content and seed size were advanced for developing RILs which are in different stages from F_5 to F_8.

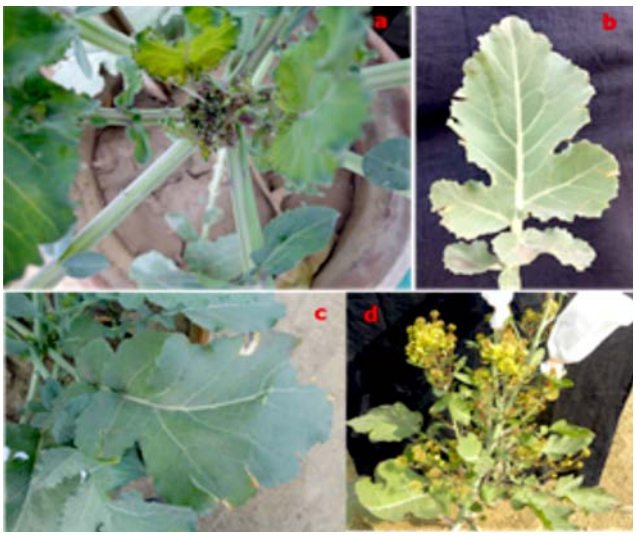
6.4.8 Cauliflower

6.4.8.1 CMS diversification in cauliflower

CMS sterile plants of BC_2 population of *Eru* based CMS background were evaluated, backcrossed with cauliflower and advanced by using *in vitro* embryo rescue technique. Inter-specific crosses were made between cauliflower and *Trachystoma balli, Diplotaxis siifolia, Diplotaxis catholica, Moricandia arvensis, Erucastrum canariense, Brassica oxyrrhina,* CMS Anand and *T. balli* to transfer sterile cytoplasm from these alien species into cauliflower. These inter-specific crosses are in progress through *in vitro* embryo rescue technique.

6.4.8.2 Marker assisted pyramiding of black rot and downy mildew resistance genes

Marker assisted transfer of black rot (*Xca1bo*) and downy mildew resistance (*Ppa3*) genes in the background of Pusa Meghna and Pusa Sharad was initiated. Crosses were attempted and mapping population (BC1 and F_2) was generated. The BC_2 generation of (Cauliflower 'Pusa Sharad' × *Brassica carinata* 'NPC 9') and BC_1 generation of (Cauliflower 'DC 401' × *Brassica juncea* 'Pusa Vijaya') and (Cauliflower 'DC 401' × *Brassica nigra*) were generated using *in vitro* embryo rescue technique. Artificial inoculation of *Xcc* race 1, 4 and 6 were carried out and resistant plants for all the races were selected for backcrossing to recipient parent of Cauliflower. The cauliflower leaf/stem resembling plants resistant to three races (1, 4 and 6) of *Xcc* were selected from the segregating population and were backcrossed with different accessions of cauliflower. Besides, a total of 111 RILs of F_5 generation of *Brassica carinata* (NPC 17 × NPC 9) were advanced to F_6 generation for black rot resistant trait.



Black rot disease reaction under field conditions in BC_2 of (Cauliflower × *Brassica carinata*). a) Inflorescence of resistant plants resembling to broccoli, b) Leaf resembling cauliflower, c) Leaf of BC_1 of showing resistance to *Xcc* race 1, and d) Resistant plants of BC_1 individuals of (Cauliflower × *B. nigra*)

6.4.8.3 Determination of ploidy level of microspore derived plants of *B. oleracea*

Flow cytometry analysis revealed more than 50% of the microspore derived plants as spontaneous diploids thus can be used directly as DH lines. Significant numbers of the microspore derived plants were haploids (15.07%) and tetraploids (17.07%). For diplodization of the haploids, colchicines treatment of 150mg/l for a period of 36 hours was most effective which produced 73.3% DH plants. Morphological and floral characterization revealed that tetraploids can be used directly in breeding programme as inbred line or development of hybrids because of higher economic yield.

6.4.9 QTL Mapping for Various Traits in Bitter Gourd

Genotyping by sequencing (GBS) using Illumina sequence of 93 bitter gourd libraries was taken to map gynoecism, sex ratio, earliness, architectural traits, fruit related traits and yield traits. High quality 2013 SNPs were identified and used to construct linkage map on 20 LGs. The linkage map spanned 2329.2 cM, with an average of one marker for each 1.16 cM distance.

The gynoecious (*gy-1*) trait was mapped on LG-12 and flanked by TP_54865 and TP_54890 markers. The ridgeness (*cr*) and fruit tubercles (*Tb*) were mapped on LG-4 and LG-13, respectively. Two major QTLs for node at first pistillate flower appearance, five for days to first pistillate flower appearance, four for sex ratio (♂:♀), one for vine length, two for number of primary branches, three for fruit length, one for fruit diameter, one for fruit weight, two for fruit shape index, one for number of fruits per plant and one for yield per plant were identified. Two minor additive QTLs were identified for fruit flesh thickness. Six QTL hotspots (clusters) were identified on six linkage groups (LG3,5,9,4 and two on LG7) for traits such as length, diameter, weight and number of fruits per plant and yield per plant.

6.4.10 Mapping of Gynoecious Trait (*F* Locus) in Cucumber

A total of 213 F_2 plants of the cross Pusa Uday × Pant Parthenocarpic Cucumber 2 were analyzed using SSR markers. The *F* locus was flanked by five linked markers viz., SSR13251, UW020605, SSR11798, SSR007281 and UW084131 located at 1.0, 4.5, 5.9, 5.0, and 7.0 cM distances, respectively, to the *F* locus. This will be useful for selection of stable gynoecious lines with high efficiency using marker assisted breeding.

6.4.11 Development of Mapping Populations for Various Traits in Carrot

F_3 and BC_1F_2 from 'White Pale × IPC-126', 'White Pale × IPC-122' and 'White Pale × Pusa Meghali' were evaluated and grouped into 119 groups based on extrinsic and intrinsic root colour to develop recombinant inbred lines (RILs). Seeds obtained from crosses between root knot nematode susceptible genotypes viz., Pusa Vrishti, Pusa Rudhira, IPC 11 Orange and IPC 104 Orange, and reported exotic resistant sources, namely, 6526, 8502, 8524 and 8542, were sown to raise F_1 generation. Molecular marker *SQ1* linked to root knot resistance gene *Mj1* was validated to facilitate marker assisted selection. *In vitro* screening to study nematode invasion in carrot was standardized using *pluronic* gel technique.

***In vitro* pluronic gel method for phenotyping of root knot nematode response in carrot**

6.4.12 Development of Haploid Induction Protocol in Onion

A haploid induction protocol in onion cultivar Pusa Riddhi was developed through *in-vitro* gynogenesis. Forty five media combinations, using B5 and MS media, were tested and HAP02 and HAP04 were found to be better combinations. These two media were tried for haploid induction in 7 genotypes. Pusa Madhavi, AKON007 and PWF were found to be highest responsive genotypes whereas AKON008 and AVON1101 were least responsive towards *in-vitro* gynogenesis and HAP04 was found to be the best media for haploid induction.

Haploid induction in onion: a) flower stage for bud picking; (b) Callus formation in flower buds; (c) Hyperhydric buds; and d) Direct shoot induction as seen under stereozoom microscope

6.4.13 *Fusarium* Wilt Resistance Garden Pea

Studies on *Fusarium* wilt resistance in 160 F_2 population of Arkel (susceptible) and GP 6 (resistant) showed a segregation of 3.44:1 (124 resistant: 36 susceptible) which was non-significant with $\chi 2$ value of 0.533 (P value > 0.05 = 0.465) from expected ratio suggesting monogenic dominant inheritance. Molecular marker linked to *Fusarium* wilt resistance gene was analyzed in F_2 population where ISSR marker (UBC-812) and SCAR primer Y15_999*F*w fitted well with the expected ratio (3R:1S). A new ISSR marker (UBC-812) has been found to be linked at 5.011 cM distance to the resistance locus *Fw* in the resistant genotype GP 6 which could be used for marker assisted selection to develop *Fusarium* wilt resistant genotypes.

6.4.14 Tomato

Characteristic markers specific for different *Ty* genes viz, *Ty2, Ty3 Ty5* have been validated for genes *Ty2* and *Ty3* in accessions carrying these genes and F_1s with elite tomato varieties and F_2s. *S. habrochaites* and *S. cheesmania*e acessions were crossed with cultivated tomato (*Solanum lycopersicum*). Embryo culture technique initiated for transferring genes from *S. chilense* and *S. corneliomulleri* to cultivated tomato. The interspecific hybrids of cultivated tomato lines (N 5 and GF 1) with wild accessions, namely, EC803493 (high TSS), EC803501 (heat tolerance) and EC803502 (late blight resistance) were advanced to BC_1F_1, F_2 generations. The *Ty* gene specific markers were validated in wild species to find out leaf curl virus resistance genes. Nine exotic pure lines carrying *obv, sp, u* genes (EC803459, EC803464, EC803468, EC803477, EC803480, EC803481, EC803490, EC803474, EC803476) were evaluated for fruit colour, fruit shape and fruit weight.

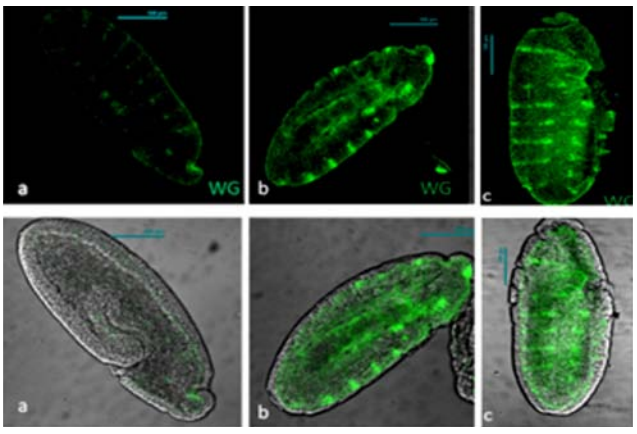
6.4.15 Post Harvest Study in Iris

An experiment was conducted to study the ability of Thidiazuron (TDZ), to improve iris flower opening and longevity. A post harvest pulse with 25 µM to 150µM TDZ for 24 hours at room temperature was given to the cut spikes. Pulse treatment with 50 µM TDZ extended the vase life of flowers up to 2.3 days in Dutch iris (*Iris ×hollandica*) and 2.5 days in *Iris× germanica*. TDZ treatment also stimulated growth of pedicel, in turn, led to more complete opening of flowers.

Post harvest study in iris: Left) *Iris hollandica*, and Right) *Iris germanica*

6.4.16 Regulation of *Wingless* gene expression by Dwnt4 in Drosophila

DWnt4 and wingless genes act antagonistic to each other in Drosophila. Immunolocalization of *wingless* protein after overexpressing *DWnt4* using UAS-Gal4 system showed reduced expression of *wingless*, while down regulation of *DWnt4* resulted in enhanced expression of *wingless*. *Wingless* expression is also enhanced in *DWnt4* mutant embryos isolated in the lab. The change in expression of *wingless* was only seen in ventral ectoderm of embryos and not in dorsal ectoderm. These results validate $DWnt4^{AL7}$ has reduced wingless activity and can be the cause of reduced number of denticles on ventral ectoderm during embryo development.



Over expression of *DWnt4* Down regulation of *DWnt4*

Expression of wingless protein in embryo, a: *DWnt4* over expression, b: *DWnt4* down regulation, and c: *DWnt4AL7* mutant embryo

6.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS, AND METEOROLOGY

6.5.1 Bio-physics and Crop Simulation Modeling

6.5.1.1 Simulation of tillage, crop residue mulching and nitrogen management on yield, evapotranspiration and WUE of wheat using DSSAT model

Field experiments were conducted during *rabi* season for two years (2014-15 and 2015-16) on wheat cultivar HD2967 in a sandy loam soil (Typic Haplustept) at IARI with the objective of simulating the yield, evapotranspiration and water use efficiency (WUE) of wheat under different tillage, residue and nitrogen management practices. DSSAT model (ver. 4.6) was calibrated with this field experiment data during the year 2014-15 and validated with the independent data set collected through field experiments during the year 2015-16. The results showed that crop residue mulch treatment increased the moisture storage profile. The evaporative flux was lower but deep percolation flux was higher under mulching than non-mulch treatment. No significant difference between tillage and crop residue mulch with respect to grain yield of wheat. Yield and WUE increased with the increase in the N levels, while WUE of wheat was not influenced by tillage. The statistical summary showed that DSSAT model under-predicted the grain yield and ET of wheat. Evaluation of the model with respect to WUE of wheat showed that the RMSE between the observed and simulated WUE of wheat was 3.14 kg/ ha/ mm, which accounted for 21.0 % of the mean observed WUE of wheat. The nRMSE value indicates fair agreement between the observed and simulated WUE of wheat. The coefficient of determination (R^2) between the observed and simulated WUE was low (0.414), which indicates that DSSAT model could not satisfactorily simulate WUE of wheat under present condition.

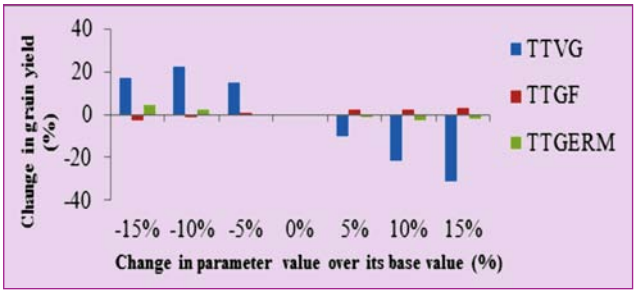
6.5.1.2 Sensitivity Analysis of soil hydraulic and crop varietal parameters of Infocrop model for wheat

The sensitivity of various soil, management and varietal parameters in Infocrop model were investigated to understand their impacts on yield. Infocrop model was initially calibrated to predict wheat grain yield. Sensitivity analysis was performed for various soil parameters such as bulk density (BD), soil texture, soil organic carbon, pH, EC, volumetric water contents at saturation (WCST), field capacity (WCFC) and permanent wilting point (WCWP); plant parameters such as thermal time for sowing to germination (TTGERM), thermal time for germination to 50 % flowering (TTVG), thermal time for 50 % flowering to 50 % physiological maturity (TTGF), specific leaf area (SLAVAR), potential grain weight (POTGWT) and index of storage organs (GNOCF), relative growth rate of leaf area (an indicator of early vigour (RGRPOT) and sowing date. Sensitivity analysis was performed by successively decreasing and increasing parameter value by 5, 10 and 15 % over its base value and studying its effect on wheat grain yield. Variations in wheat yield was mainly found to be sensitive to WCFC, WCWP, TTGERM, TTVG, TTGF and sowing dates. WCFC, TTVG and sowing dates were the three most sensitive parameters affecting grain yield. BD, % sand and % clay, soil OC,

Statistical summary comparing observed data with simulated values for wheat crop grown under different tillage, residue and nitrogen management during validation of DSSAT wheat simulation model

S. No.	Parameter	PE	R^2	RMSE	nRMSE	D	CRM	RMSEs	RMSEu
1	Grain yield	-5.6	0.759	412.0	13.0	0.98	0.047	66.2	98.8
2	ET	-12.1	0.904	44.60	20.3	0.97	0.144	12.9	1.27
3	WUE	9.2	0.414	3.14	21.0	0.98	-0.069	0.48	0.77

PE = Prediction error; R2 = Coefficient of determination; RMSE = Root mean square error; nRMSE= Normalized root mean square error; D= Index of agreement; CRM = Coefficient of residual mass; and RMSEs = Root mean systematic error; RMSEu = Root mean unsystematic error



Analysis of sensitive input varietal parameters

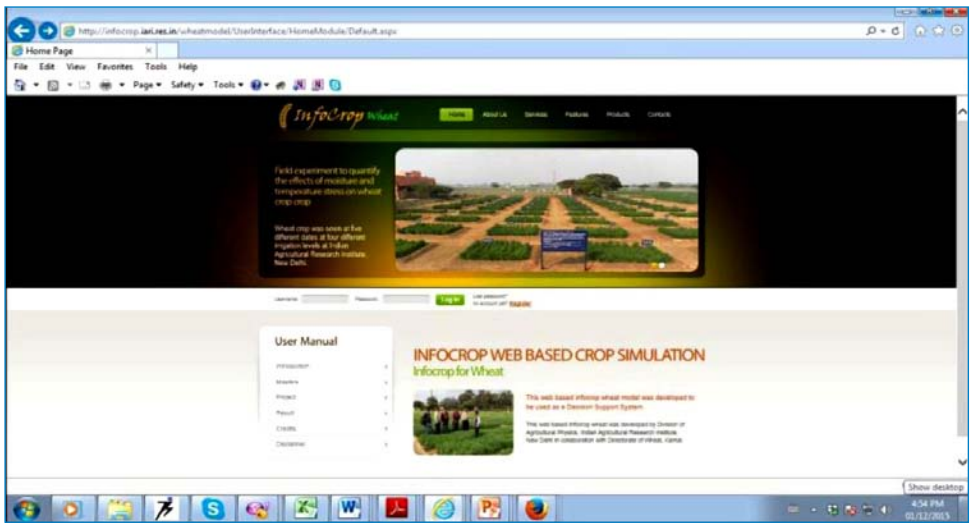
EC, POTGWT, GNOCF, RGRPOT, and SLAVAR did not affect wheat yield significantly.

6.5.1.3 Rooting behaviour of wheat in response to conservation tillage practices

The bulk density at below plough layer (15-30 cm) was marginally lower in conservation tillage (CT) practices in rice-wheat rotation. There was 2-8% reduction in compaction at this layer under the zero-tilled direct-seeded rice (ZTDSR) followed by zero-till wheat (ZTW) practices with retention of residues, compared to conventional transplanted rice (TPR)-conventional wheat (CW) system. Soil macro- and meso-pores draining at 100 cm suction constituted 27-34% of total pores at the root zone, and were extremely variable. Pores that can retain water (i.e., small meso- and micro-pores) corresponding to a suction >100 cm was higher in conservation agriculture (CA), especially in DSR+brown manuring-ZTW+rice residue treatment, implying that higher plant-available water content in the CA. The DSR had marginally higher root length and root surface area at 0-15 cm compared to TPR. Wheat residue+ZTDSR+MR-ZTW+RR+Relay cropping had better root morphological characteristics in wheat. In rhizobox experimentation, wheat roots in the plough layer with compacted sub-surface, were thick and had higher surface area and root volume. Soil with higher clay content facilitates more water retention and could negate the effect of sub-surface compaction on the root growth, even in limited water condition.

6.5.1.4 Web InfoCrop – Wheat to simulate the growth and yield of wheat

Crop simulation is useful for characterizing and predicting the crop growth and yield under abiotic stress and climate change events under different agronomic management options. A web-based application of the crop simulation model 'Web InfoCrop - Wheat' was designed and developed by the Institute using Visual Studio Express, SQL Server, NET framework 4.0 and hosted at http://InfoCrop.iari.res.in. Crop model users after registration without any payment, have the right to insert, edit or update and delete data within their private domains. The users can run the model to simulate the wheat crop growth and

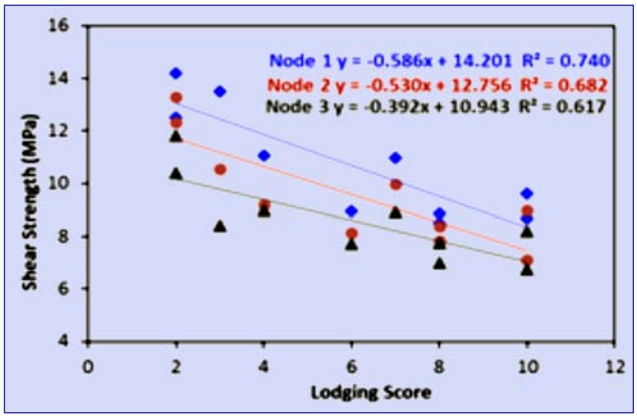


Web InfoCrop - Wheat crop model (http://InfoCrop.iari.res.in)

yield, at a single day interval or as defined. This web-based model performed well under different irrigation and nitrogen management practices for the observed and predicted yield and biomass with significant R^2 (0.958 and 0.947, respectively) and RMSE (0.054 and 1.318, respectively). The 'Web InfoCrop – Wheat' crop model provides an efficient approach to be used as a decision support tool in the agricultural production system.

6.5.1.5 Analysis of shoot shear strength to determine the lodging tendency in wheat

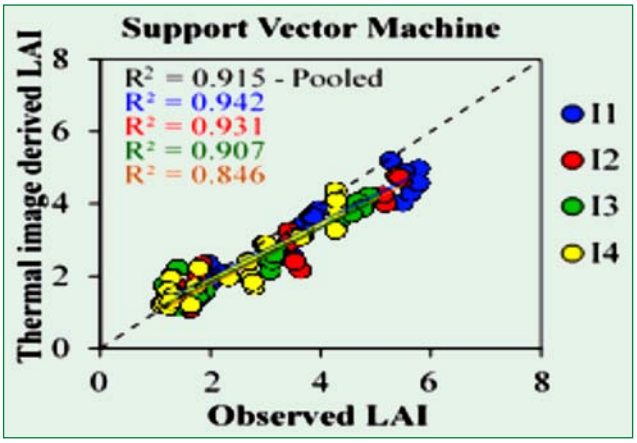
Lodging in wheat crop degrades the grain quality and yield. Traits such as plant shoot diameter, wall thickness, shear strength were investigated to characterize the lodging resistance in 10 wheat cultivars under two different temperature conditions (ambient, +3°C). Shear strength ranged from 7.89 to 14.55 MPa in different wheat cultivars. Temperature stress decreased it by about 6.38% in all the cultivars, with the least reduction (0.99%) in C 306. Estimates of the lodging significantly correlated with the shear strength values suggesting that the shear strength can be a reliable trait to screen wheat cultivars for lodging resistance.



Lodging significantly correlated with the shear strength in wheat

6.5.1.6 Thermal imaging of wheat crop to estimate LAI

Thermal image directly gives the temperature of the crop canopy and provides a better distinguishability between the leaf and soil using



Thermal image derived LAI of wheat crop grown under different moisture stress conditions

image classification techniques. In this study thermal imaging was used to determine the canopy coverage and Leaf Area Index (LAI) of the wheat crop. Thermal Images were analyzed with five different supervised image classification techniques, namely, Maximum likelihood, Mahalanobis, Minimum distance to mean, Parallelepiped and Support Vector Machine (SVM) methods using ENVI - image analysis software. Results showed that the best estimation of LAI was possible using SVM method. This is further supported by the statistical analysis based on the comparison with instrument observed LAI and digital image derived LAI. In general Support Vector Machine method estimated the wheat crop LAI from the thermal image meaningfully with high R^2 value of 0.915 and low values of RMSE and MBE. Thus the present study clearly showed that thermal image analysis could be applied as a non-destructive, rapid, less erroneous technique to characterize the crop canopy temperature and estimate the LAI of the wheat.

6.5.2 Remote Sensing and GIS

6.5.2.1 Pan India vegetation dynamics monitoring through remote sensing

Time series 16 days maximum value composite of Enhanced Vegetation Index (EVI), of 250 m resolution derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) data for the period 2000 to 2015, was analyzed to understand the spatial

and temporal dynamics of vegetation. The mean monthly and annual EVI was computed and mean annual variability of EVI over 15 years was computed indicating variability in crop condition. Higher percentage of annual variability >30% is seen in the Himalayan plain region, where as Indo-Gangetic Plains and other region of India has the average annual variability from 5 to 20%. Seasonal mean variability indicates more variability in *rabi* season compared to *kharif*.

6.5.2.2 Airborne campaign of Hyperspectral Remote Sensing- AVIRIS-NG of JPL in India

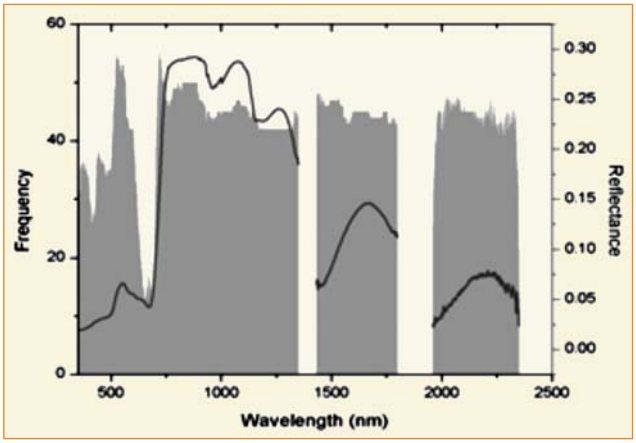
IARI is a part of science team of ISRO for ambitious ISRO - NASA Airborne Hyperspectral campaign in India with AVIRIS-NG (Airborne Visible InfraRed Imaging Spectrometer- Next Generation) of Jet Propulsion Laboratory (JPL), USA, participated in field campaign at eight different sites along with team from SAC, ISRO and other Institutes. Ground collected spectra observation and air borne fly of AVIRIS NG over Sabour, Bihar was done during February 23-24, 2016. Comparative spectra collected at ground and from image of AVIRIS NG and classified image of the crops over BAU farm with accuracy of 87 %.

6.5.2.3 Non-destructive hyperspectral phenotyping of sucrose in rice

The capacity of rice to store sucrose in the stem is regarded as a promising trait to buffer yield in environments with limited water availability. A study was conducted for noninvasive estimation of sucrose in rice stem using hyperspectral reflectance data collected in the spectral range of 350 to 2500nm for different rice genotypes grown under soil moisture deficit stress levels. Plant samples were collected synchronizing with spectral measurements for estimation of sucrose. Two spectral indices like ratio sucrose index (RSI) and Normalized Difference Sucrose Index (NDSI) in NIR range were proposed with reliable accuracy of sucrose estimation. Different multivariate spectral models such as Partial least squares regression (PLSR) and multiple regression model (MLR), Multivariate adaptive regression splines (MARS), Support Vector Machine (SVM) and random forest (RF) were also evaluated and MARS was found to predict the sugar content with better accuracy. The proposed non invasive *in situ* method was found to be alternate fast reliable method to labour intensive laboratory methods.

6.5.2.4 Discrimination of rice genotypes using field spectroradiometry

Spectral observations of 14 rice genotypes grown in the field were taken using field portable spectroradiometer in the spectral range of 350 to 2500 nm. The pre-processed collected reflectance spectra were statistically analyzed using one-way analysis of variance (ANOVA) to find significantly sensitive wavelengths for discrimination. Classification and regression tree analysis (CART) technique was implemented on selected wavelengths to select most sensitive wavebands for discrimination of genotypes. The spectral separability between each pair of rice genotypes at the selected wavebands was quantified using Jeffries-Matusita (JM) distance. JM distance analysis of 91 pairs of 14 genotypes revealed spectral separability of all the pairs. The performance of selected sensitive wavebands was also evaluated by using quadratic discriminant analysis and overall accuracy found was 98%. The sensitive bands were found to be distributed over entire region of spectral range 350 to 2500 nm. The variation in biophysical



Frequency of statistically significant different genotype pairs of the mean reflectance of 14 rice genotypes at every waveband

and biochemical attributes of genotypes has been captured through differential spectral reflectance at selected wavebands could make the discrimination possible.

6.5.3 Agricultural Meteorology

6.5.3.1 Development of indices for terminal heat stress in mustard

During the *rabi* season of 2015-16, a field experiment was conducted at IARI farm with mustard crop to find out the pattern of phenology, biomass accumulation and seed yield if the cultivars were exposed to different thermal regimes. The crop was sown in 3 dates: October 15 (D1), October 30 (D2), November 19 (D3) with three cultivars, namely, Pusa Vijay (V1), Pusa Mustard 21 (V2) and Pusa Bold (V3). The crop took 120 days (D3V1 & D3V3) to 149 days (D1V2) to mature. As the sowing got delayed from 15th October, the crop experienced lower daily mean temperature during vegetative phase and higher daily mean temperature during reproductive phase. Mean temperature during vegetative phase (Tmean-V) reduced significantly from 20.1°C (D1) to 14.8°C (D3) and mean temperature during reproductive phase (Tmean-R) increased significantly from 15.0°C (D1) to 18.0°C (D3). Correlation between the duration and Tmean of phenological phases and yield components showed that the correlation coefficient values improved for ratio indices particularly with the temperature based indices,(i.e., -0.89 for Tmean-V/ Tmean –R vs. final biomass and -0.94 for Tmean-V/ Tmean –R vs. seed yield). These temperature based indices can be used for estimation of yield reduction in mustard due to delayed sowing and sudden rise of temperature during reproductive period.

6.5.3.2 Agromet advisory services

Agro-met advisory bulletins were prepared in Hindi as well as in English on every Tuesday and Friday, and were uploaded on the Institute website (www.iari.res.in), IMD website (www.imdagrimet.gov.in) and farmer portal (http://farmer.gov.in). These advisories along with crop status were sent to IMD, Pune for preparation of national bulletins, which were sent to the farmers on the real time through SMS / telephone / E-mail. The bulletins were also sent to ATIC, KVK Shikohpur, KVK Ujawa, IKSL, NGO, e-choupal, Krishi Darsan, DD Kisan, and local Hindi newspaper through E-mail for wider dissemination among farmers. During 2016-17, total 105 agro-advisory bulletins were prepared in Hindi as well as in English. SMS were sent to the farmers through m-Kisan portal. The agromet advisory bulletin is useful to the farmers to take decision on crop management, application of nutrients, irrigation scheduling, sowing, harvesting, etc. Feedback received from the farmers from different villages of NCR Delhi showed that agromet advisory bulletin is fruitful for farmers as it helps them to select high yielding varieties of different crop and vegetables and timely implementation of management practices such as sowing, weeding, irrigation, fertilizer, pesticides spray (time & doses at right time). It helps in reducing cost of cultivation, saving of input resources and increases in net profit. Farmers who followed the agromet advisories were able to reduce the input cost by reducing the irrigation, based on the rainfall forecast, number of spray, seed rate and timely management practices based on agromet advisories.

6.6 NATIONAL PHYTOTRON FACILITY

The NPF was intensively used by scientists and students from IARI and other ICAR institutes, and other Institutes including University of Delhi (South Campus) to conduct critical experiments related to climate change, transgenic crops, gene regulation, physiology of nutrient use efficiency, plant-pathogen interaction, biochemical and genetic interventions for crop improvement, etc. During 2016-17, 204 new experiments were conducted along with a few on-going experiments. Bulk of these experiments were from the in-house projects of the ICAR institutes (54.90%) followed by the post-graduate research scholars experiments (39.22%), which were free of charges. However, 5.88% of the experiments were on payment basis from non-ICAR institutes and could earn ₹11,31,559/= as users fee. During

Soil less multiplication of nematode parasite in rice in the Phytotron. A) Rice seedling inoculated with nematode and parasite; and B) Gall formation in the rice roots due to nematode infestation along with the parasite

this period, the NPF was visited by a number of domestic and foreign visitors. The Phenomics facility erected within NPF aroused immense interests among the visitors.

7. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

Recent years have witnessed a significant increase in agriculture business, the reason being the growing agricultural technologies. The major contributing factor in achieving the phenomenal increase in agricultural production is the value and number of improved technologies.

The accessibility to technologies coupled with agricultural knowledge has led to quality crop production throughout the nation. With the initiatives undertaken by the Institute, hybrid varieties and crop diversification have led to productive results. Nutritional security and gender empowerment have been the focus areas of technological development and farmers' growth. Trainings were conducted to provide information and vocational awareness to farmers, farm youth and rural women to take up alternative employment and agricultural initiatives. A plethora of field-trips, awareness programmes and training workshops were conducted by IARI in various significant areas which benefitted the farming communities.

Research in the school is focused on assessing the impact of governmental programmes on reducing rural poverty, role of institutional and non-institutional agencies, crop diversification, e-*mandis* and economic impact of IARI vegetables. Research efforts in extension are initiated to leverage agriculture for nutrition, to develop alternate extension models and upscale farmer led innovations, entrepreneurial development of rural women and youth. *Krishi Unnati Mela* has been organized at ICAR-IARI, New Delhi and the important government initiative, *Mera Gaon Mera Gaurav* programme is being executed by the institute for the welfare of farmers. ATIC is serving its purpose of single window delivery and KVK at Gurgaon is working as per the mandate

7.1 AGRICUTLURAL ECONOMICS

7.1.1 Drivers of Agricultural Growth and Risk Management for Enhancing Small Holder's Productivity in India

It is a global fact that technology, investments, credit, institutions, crop diversification and policies have driven agricultural growth and poverty reduction. The trend in real public expenditure in agriculture and allied sectors showed modest growth of 3.91 per cent during the period of 1992-93 to 2003-04. A surge in investment at a growth rate of 26 per cent per annum was observed during 2004-05 to 2008-09, mainly due to Central Government's investment driven program like RKVY focusing on increase in rural incomes, transforming countryside, narrowing rural-urban poverty through agricultural modernization and public services expansion in rural areas. The co-integration analysis based on state panel data for the period 2007-08 to 2014-15 indicated that RKVY expenditure witnessed an enhancement in state investment capacities in the agriculture sector, with the rise in state gross domestic product, and a vice versa only in the short run. Enhanced expenditure on rural public goods is complementary to private on-farm investment; and investing in former invariably enhances investments in the other. The analysis of private on-farm average fixed capital expenditure (investment) based on 70th round of unit level NSSO data for rural households shows that average value of all kind of fixed capital expenditure in farm business was estimated to (₹13,664/-) per household. The expenditure on fixed capital by cultivator households (₹14,450/-) was twice that of non-cultivator households (₹7,186/-). As for business expenditure, majority of the expenditure was on acquiring transport equipment and livestock and poultry... The determinants of investment in farm business by cultivator households

using binary logit model revealed that household size, age of head of the household and dummy variables for gender of head of household, access to credit, social groups, regions, education status, size of holding and income from livestock sources showed significant influence on cultivator household's decision to invest or not in the farm business.

The recent All-India Debt and Investment Survey (AIDIS) carried out by National Sample Survey Organization (NSSO) during 2013 (70th round) showed that though the share of both institutional and non-institutional agencies has increased during the last decade but the non-institutional agencies had advanced credit to 19 per cent of rural households, while the institutional agencies had advanced credit to 17 per cent households. At micro level, the indebtedness of farmers in rain fed regions of India by taking primary data from 500 farmers of Telangana and Maharashtra reveals that co-operatives emerged as the most important institution which contributed to the institutional credit flow in Maharashtra; whereas it's relatively lower presence has led to higher dependence on non-institutional sources in Telangana. More than 90% of farmers in Maharashtra and 85% farmers in Telangana remains credit constrained. Overall, the study calls for greater role of cooperatives, spread of self help groups, and more accelerated efforts of commercial banks to enhance rural credit flow.

An analysis of crop diversification at all India level across crop groups revealed that agriculture is got more diversified in the eastern states (Assam, West Bengal, Bihar and Odisha), western states (Rajasthan, Gujarat and Maharashtra) and southern state of Karnataka. Also, a trend is witnessed in diversification towards fruits and vegetables. A farm level study in Uttar Pradesh indicated that large farms were more diversified followed by small and marginal farms. The low diversification on marginal farms could be due to cultivation of crops under food grains to meet the household requirements. The regression analysis indicated that the size of operational holding, number of farm fragments, cropping intensity and ownership of electric operated tube well were significant factors, which positively influence the crop diversification.

Risks in agriculture and its management are important in insuring farmers against risks. Farm income decomposition carried out using district level yield and farm harvest prices for the period of 1991-2011 for cotton and 1990- 2009 for paddy, indicated that for both the crops, the farm income variance has increased over the years. A study of risks in agriculture and risk management strategies adopted by the farmers was carried out by using primary data collected from 500 cotton farmers in the rain-fed regions of Maharashtra and paddy farmers of Telangana. The major source of farm risk was weather related. The usage of seeds, fertilizers and pesticides are highly dependent on markets; but are priced differentially for various farmer categories. Lack of quality assurance is a major problem in these inputs. Information on newer methods like bio-control agents and bio-fertilizers, which are currently unavailable, needs to be provided. Custom hiring centers for farm machineries are inadequate and are reported to charge exorbitantly. Groundwater depletion and drying up of wells are major threats. Risk Management mechanism adopted by farmers such as mixed farming, varietal diversification and crop insurance proved to be minimal. Only 30% of cotton in Maharashtra and 3.1% of paddy farmers of Telangana used insurance due to institutional constraints such as non-payment of claims, late payment and inadequate payment.

7.1.2 Impact Assessment of Improved Agri-cultural Technologies

Advent of online marketing of agricultural commodities has revolutionised the same in India. A study of e-markets (e-*mandis*) in Karnataka showed increased competition among traders and reduced scope for collusion. Average market arrivals and prices were higher, and variability in price was lesser in e-*mandis* in comparison to non e-*mandis*. All stakeholders mentioned increased transparency, reduced delay in payment in e-*mandis*. Minimum support prices (MSP) is an important component of administered price policy of Government. MSP

for all crops is continuously rising and conscious effort by the policy to favour pluses, oilseeds and minor cereals can be seen particularly after 2007-08. Analysed farmer's awareness about Minimum Support Price (MSP) of crops grown by them using a nationally representative data collected by NSSO (70th round). The data revealed that only 23.72 and 20.04 per cent of rural agricultural households in India are aware of MSP of crops grown by them. Awareness was high for rice and wheat in states like Haryana, Punjab and Chhattisgarh. Using probit analysis, it was inferred that MSP needs to be backed up by effective procurement coupled with extension efforts so that more farmers can take benefits of price support. The widely cited criticism that MSP for rice and wheat had made farmers to allot more area to one of these crops (specialise) if the farmer is aware about it is tested in the study. But, empirical evidence rejects the null hypothesis that knowledge of MSP leads farmers to specialisation instead of diversification.

A study for understanding the impact of various policy reforms on Food Processing Industries (FPI) was taken up. Based on the number of industries, states have been classified in to three categories, small (0-499 units), medium (500-1499 units) and major FPI states (>1500 units). Andhra Pradesh, Tamil Nadu and Maharashtra were the top 3 major states, which were having highest number of FPI industries. In total, 7 states comes under major state category and they share about 70% of FPI (63% all industry).The annual average growth rate (AAGR) was about 4 % in these states during 2008-03 to 2013-14. Gujarat, Kerala and Assam were the top 3 states in the medium FPI states with a total of 8 states coming under this category and they share about 25% (63% all industry) and registered 14% AAGR.

The labor intensity was about 4% in FPI units and for all industries, it was 5% indicating all industries slightly more labour intensive than FPI. Among FPI, average number of workers per unit was high in meat and fish sector. Women employment was more in FPI (21%) than all industries (15%), in particular higher in fish and F&V. The employment elasticity was higher in all industries (0.6) than FPI (0.24). Among the FPI, highest elasticity was found to be dairy industry (0.75), which indicates 1% increase of output in dairy will lead to 0.75% employment. The determinants of growth of FPI were analyzed by taking state wise number of FPI as dependent variable. Structural variable (state wise Gross State Domestic Product) and demand pull factors (population, Monthly per capita expenditure, monthly per capita consumption of food commodities), supply push factors (Agriculture Gross State Domestic Product, agricultural production, labour supply, minimum wages, infrastructure), dummy variable for policy impact (introduction of FPI policy before 2005) and geographical dummies (North east or otherwise) were taken as independent variables in the model. The Agriculture Gross State Domestic Product, GSDP, labour supply were the major factors, which positively influenced the growth of FPI. Further, compared to states, which introduced exclusive policy on FPI before 2005 are likely to have about 1,755 FPI units higher than other states, which clearly indicates policy incentives played a major role in growth of the FPI.

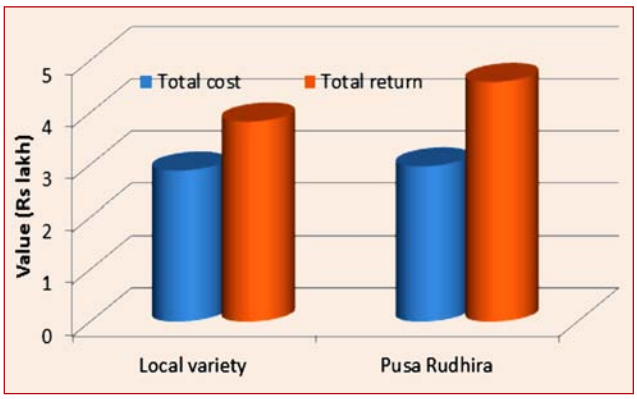
7.1.3 Commercialization and Impact Assessment of Improved Agricultural Technology

Economic impact of Pusa Rudhira variety of carrot. The impact of Pusa Rudhira variety (Carrot) has been evaluated by estimating the direct cost involved in development of this variety such as human capital (costs on scientific and labours technical man power and other labours), field level costs and institutional overhead charges has been estimated. The R & D cost includes only direct paid out costs such as manpower (scientific, technical and supporting), operational costs and 10 per cent of operational costs of overhead charges. The direct R&D cost invested in varietal development is Rs 1.85 crore at the 2014-15 price. However fixed costs related to infrastructure and cost of failure were not accounted for. The benefits of varietal development has been worked out by considering two aspects i.e., (i) directs benefits which are received by IARI in sales of seeds and (ii) indirect benefits or social benefits through increased net returns to the farmers. The total returns on R&D

investment on Pusa Rudhira was ₹1.65 crore at 2015-16 prices. The breakeven point for R&D investment on Rudhira variety development will be reached in 9th year (2016-17). At the farm level, the net returns from Pusa Rudhira was higher than other varieties. The farm level income statement has been worked for Pusa Rudhira and other carrot variety. It was found that net returns from Pusa Rudhira was ₹1.61/- lakhs / ha and BCR was ₹1.54/-, which was higher when compared to the other competing carrot varieties, respectively. Although, yield was on par with other varieties, premium price (15-25%) for better quality was major reason for increased net retuns in Pusa variety in the study area. Non-availability of seed was the major constraint in adoption of Pusa variety. The higher price and non-availability at village level were other constraints leading to low adoption. Resistance to high temperature and flexibility in harvesting were the major preferred varietal traits of carrot by the farmers.

Returns on R & D investment

Particulars	Amount (in ₹ crores)
(A) Total costs	1.846
(B) Total returns on R&D	
a. Social benefit (spread of variety)	3.04
b. Direct benefit to IARI (seed sale)	0.073
Total returns	3.113
(C) Net returns on R&D	1.267
(D) B:C ratio	1.69
(E) IRR	32%



Cost and returns on farmers field

7.1.4 Adoption of Crop Insurance Programmes

The study of factors influencing the decision to insure and its impact using the National Sample Survey Organization (NSSO) survey data revealed that the extent of adoption of crop insurance to be just 4.80 and 3.17 per cent in *kharif* and *rabi*, respectively. The majority of farmers were unaware about the crop insurance product, which was also the main reason for its low spread. It was found that education of farmers especially those trained in agriculture, past experience of crop loss and subsidy on premium positively influenced the crop insurance uptake decisions. On the other hand, factors like lower social caste, tenancy and exposure to deficit rainfall in previous year were negatively associated with decision to insure. The results of propensity matching weren't conclusive to prove that insured farmer assumes higher risks in farming compared to uninsured.

The farmers' preference for different crop insurance products was studied through primary data of 600 wheat farmers spread across 50 villages (10 districts) of Punjab using double contingent valuation to elicit and analyze amount of money, farmers are ready to shell out to insure their crops. Results indicate that farmers are ready to pay 297 and 460 ₹/ acre for crop based insurance product. Considering an average yield of 1.6 t/ acre, the premium amount translates to approximately 360 to 400 ₹/acre at the rate of 1.5% premium on SI (according to *Pradhan Mantri Fasal Bima Yojana*, 2016). So, the new crop insurance programme can ensure high enrolment of farmers into the scheme.

Adoption of crop insurance by farmers (self reported)

Particulars	Crop insured	*Kharif*		*Rabi*	
		Number	%	Number	%
Insured	Loanee	2,212	4.1	1,335	2.8
	Voluntary	398	0.7	180	0.4
	Sub total	2,610	4.8	1,515	3.2
Not insured	Not insured	51,749	95.2	46,314	96.8
	Total	**54,359**	**100**	**47,829**	**100**

Sum insured as a percentage of value of crop in different insurance schemes

Programmes	Claims to premium ratio	Sum insured as % of value of crop
NAIS	3.14	35.43
WBCIS	0.69	39.80
MNAIS	0.73	49.82

Farmers willingness to pay for weather based index based insurance product in Punjab

Variable	Coefficient
Constant	-72.95
Male headed HH	416.51
Age	-6.89
Risk preference	80.81*
Literate	-41.55
Agriculture- primary occupation	310.16*
Backward class	-49.97
Land owned	-35.25
Experience in farming	12.92*
Use Zero tillage	-0.69
Willingness to pay	297

7.1.5 Wheat Varietal Diversity and its Determinants

The varietal diversity has bearing on the productivity and sustainability of crop production, hence, an important aspect of varietal adoption studies. The effect of the varietal demand and supply factors, and agro-ecological factors on the spatial distribution is calculated through unrelated regression method. Five major wheat producing Indian states viz., Bihar, Haryana, Madhya Pradesh, Punjab and Uttar Pradesh were considered for the present study. The data pertains to the period from 2010-11 to 2015-16. The spatial diversity analysis for the wheat varieties grown in five selected states of India from 2010-11 to 2015-16 indicated that richness is highest in the states of Uttar Pradesh (UP) and Madhya Pradesh (MP) in comparison to other states. Bihar had the least diversity, followed by Punjab and Haryana. The dominance of a single wheat variety estimated by using appropriate dominance indices method is higher for the state of Punjab, Haryana and MP in the year 2015-16. The popularity of the variety HD 2967 in Haryana and Punjab lead to its dominance in these states. In MP, Lok 1 is the most popular variety with highest share in seed distribution. The degree of equality in the area share of the varieties in a particular state suggests that the equality in distribution is highest in the state of UP and least in Punjab. The determinants of spatial diversity were evaluated through SUR estimation, which showed that the richness in the varieties grown is positively related to the average yield value. Other varietal traits also affect the variation in the spatial diversity like higher the average hardness value of the grain of the most popular variety, greater will be its ability to dominate the scene. This is because, hardness is the most important trait of a variety that determines it's milling quality. Spatial distribution is also made more equitable by the higher hardness value. The supply of variety is another important factor that could determine the spatial diversity. Results revealed that varieties released in the last five years are positively affecting the spatial diversity. Among the agro-ecological factors, the average rainfall did not affect the spatial diversity of wheat grown in the selected states. Wheat grown in MP lead to more spatially diverse in terms of richness, than that those grown in Bihar, Haryana and UP.

7.2 AGRICULTURAL EXTENSION

7.2.1 Development of Innovative Extension Model

IARI-Post Office Linkage Extension Model. An institutional mechanism for up scaling IARI Post Office Linkage Extension Model was developed with the Department of Posts, Government of India. Department of Posts recognized the role of Branch Post Masters (BPMs) in improved agricultural technology and information dissemination and instructed the Chief Post Master Generals (CPMGs) of all 14 identified states. Institutionalization of the model facilitated involvement of BPMs in delivering their roles and responsibilities. It was mutually agreed in principle to pay remuneration to the BPMs

@ ₹ 6500/- per annum to each BPM for their additional time involvement in agricultural information dissemination. KVKs associated with IARI-Post Office Linkage Extension Model are able to utilize this mechanism and extend outreach in the district through identified BPMs. Disseminated quality seeds of improved IARI varieties of 2.3 t paddy (P 1612, P 2511 and PB1121) in 46 districts of 12 states, 5.37 t wheat (HD 3118, HD 2967, HD 3059 and HD 3086) in 34 districts of 10 states, 165 kg vegetables (*Palak*, *methi*, brinjal, bottle gourd, carrot and radish) in 45 districts of 13 states, 900 kg mustard (Pusa Mustard 26, Pusa Mustard 28 and Pusa Mustard 30) in 53 districts of 12 states and 1 t mungbean (Pusa Vishal) in 27 districts of 7 states.

Climate change adaptation. Vulnerability analysis in flood prone regions along Teesta and Jaldhaka rivers in West Bengal revealed that the risk to the climate led hazard, especially flood, was perceived very high in terms of its probability (30%), exposure (24.67%) and consequences (31.33%), by the farmers of the area. The findings of vulnerability profiling revealed that a significant portion of the farmers (one-fourth to one-third) of sample villages namely Singimari (31%) Mainatali (24 %) and Bangkandi (20%) belonged to highly vulnerability group. The findings of regression analysis confirmed that the factors like land holding, knowledge, education and infrastructure were the major determinants of vulnerability. Impact of climate change on large cardamom and Darjeeling mandarin was studied in Darjeeling hill. A majority of the respondents reported about increased incidence of viral diseases like Chirkey of large cardamom under changing climatic condition. Majority of the respondents (46%) reported that people were leaving Darjeeling mandarin cultivation in the hill and shifted towards large cardamom (72%), and offseason vegetables (23%) cultivation. More than half of the respondents (53%) told that good quality mandarin was shifting upwards under changing climatic condition.

With demonstrations, the technologies for climate resilience like raised bed (20 ha), zero tillage (110 ha), direct seeded rice (20 ha), biofertilizers and leaf colour chart based fertilizer scheduling (20 ha), pheromone traps (30 ha), green manuring (30 ha), summer moong (20 ha) were disseminated in Mewat and Gurgaon districts of Haryana and Gaya district of Bihar. In order to protect large scale lodging of wheat due to terminal rain and high speed wind, raised bed planting in wheat was demonstrated in Gurgaon district of Haryana. It not only protected the crop against lodging but also helped in saving 1 to 2 irrigations.

Demonstration of raised bed system in wheat in Gurgaon, Haryana

With information kiosk, video based social learning was experimented. It helped farmers and farm women to learn and apply the technologies of zero-tillage in wheat.

Use of video based learning with Information Kiosk in Mewat, Haryana

7.2.2 Maximizing Farm Profitability through Entrepreneurship Development and Farmer Led Innovations

Agriculture being the engine of economic development of our nation needs to be supported with

efficient marketing system, secondary agriculture, reduction of post harvest losses, diversification of agriculture towards high value crops and promotion of agri-entrepreneurship in wake of shrinking resource base and rampant unemployment in rural areas. Also, the farmers' wisdom in the form of their innovations needs to be incorporated during the process of agri-preneurship development. In order to develop the model for making farming a business venture and replicating farmers' innovations, an action research study is being conducted in three NCR Delhi villages, namely, Fatehpur Biloch, Manjhawali and Swamika.

Expressed training needs of farm women and interventions. Training interventions were conducted after assessing training needs of farmers and farm women. Farmers and farm women expressed needs for training in four areas-technical production skills, project launching skills, marketing skills and enterprise management skills. Most of them were found to be confident of production and technical skills for taking up value addition enterprises but were found to skeptical of marketing and enterprise management skills. This may be due to the traditional nature of enterprises as they have been taking up value addition of surplus vegetables / fruits at their household level. The social processes of group management skills were also mentioned by farm women for formulating self help groups (SHG) as one significant training need area. In villages *Manjhawali* and *Swamika*, farm women were proactive in forming SHGs, whereas more intense efforts of convincing on part of researchers were needed in Fatehpur Block for mobilizing farmers/farm women to take up group entrepreneurship.

Based on the needs, two kinds of training modules were designed; on campus and off campus for entrepreneurship development in project villages. One training course was administered at IARI campus in which selected participants from all three villages (10 each) participated. Participants were apprised of technological innovations of IARI based on their prioritized potential agri-enterprises to be taken up as identified earlier through micro-screening exercises. Afterwards, specific technical training courses (3) and entrepreneurial labs (3) were conducted in all the three respective villages with 110 participants. The participation of various stakeholders, viz., Non Governmental Organization, government departments (Agriculture, Horticulture), bankers (Syndicate Bank, Corporation Bank), established entrepreneurs (in value addition, post harvest processing of flowers and seed production) and researchers in each village was also elicited. The training courses resulted not only in enhanced motivation, aspirations, entrepreneurial orientation but also in creating a facilitative entrepreneurial climate in the form of effective business linkages among various stakeholders. Backward - forward linkages of various agri-enterprises were done and efforts for facilitation in strengthening these linkages were also undertaken.

Identification of two farmers' led innovations and documentation were done which were screened for scalability. A one day Farm Innovators Meet was organized on September 29, 2016 at IARI where 85 farm innovators from all over the country, research managers and researchers deliberated to develop a strategy of upscaling and outscaling farmer innovations. ICT use including social media need to be utilized to have a strong network of Innovative Farmers/ Federation of Innovative. A whatsapp group involving Farm innovators and scientists is functional with this purpose of sharing experiences, extending advisories and exchanging information.

For risk mitigation, farmers' awareness campaign was organized on the newly launched *Pradhan Mantri Fasal Bima Yojna* with the help of State Agriculture Department in the project villages. Later on farmers' awareness level was assessed. Majority of farmers perceived low awareness level (78%), malpractices at different levels (72%), issue of non compensation (68%), procedural complexities (66%), and faulty methods for crop loss assessment (54%) was perceived as major constraint by majority of the respondent farmers. Unfavourable attitude, perceived low level of risk coverage (34%), perceived high rate of premium (32%) along with perceived more beneficial to large

farmers only (30%) were the constraints perceived by relatively fewer numbers of respondents.

7.2.3 Enhancing Nutritional Security and Gender Empowerment

In spite of record food production, the level of nutrition in our country is disturbing. According to NFHS 3 (2005-06) survey, in India, about 30 per cent of all adults have BMI<18.5. More than one third (36%) of women have a BMI below 18.5; about 36 per cent women suffer with chronic energy deficiencies; and 56 per cent women are anemic. It shows that food security does not directly translate into nutritional security. There is a disconnect between agriculture and nutrition, which needs to be bridged. To address these issues, a project titled "Enhancing Nutritional Security and Gender Empowerment" was initiated. This project comprises of two components such as research and establishment of agriculture-to-nutrition (A2N) smart village model and understanding the linkages between agriculture and nutrition by secondary as well as primary data. A2N smart village model has been conceptualised and is being experimented in project villages of Baghpat district, U.P. and Sonipat, Haryana. Activities like awareness campaigns, capacity building programmes and agricultural interventions are being undertaken in nutri-smart villages.

Although, many crop diversification studies focused on farm productivity, income and livelihood, less attention was given on its impact on consumption diversity. In this context, this study examined the food production and consumption diversity across the states.

The multivariate regression analysis of 28 states has suggested that dietary diversity significantly increased with production diversity and per-capita income and is significantly higher in other states vis-a-vis north-eastern states. A significant nonlinear relationship has been observed between dietary diversity and literacy. The study has highlighted a significant impact of local production diversity on consumption pattern and therefore, policies should target the diversification of agricultural production, particularly in the north-eastern states to bring out dietary diversity and desired nutritional outcome in India.

By conducting primary survey, the knowledge on nutrition, food consumption pattern and nutritional status were assessed across seven districts from seven states of India (total sample size was 840) which revealed existence of under nourishment among female is comparatively more than male. Women and children especially girls are more vulnerable. In general, the study registered a slight mark of overweight and obesity in the respondent groups. It was also revealed in this study that majorly, the respondent groups had low level of knowledge about nutrition. Hence, it concludes that next to underweight, overweight is emerging as a major problem; dietary diversity is poor. Across all the districts, medium dietary diversity was noticed. The most consumed food groups were cereals, vegetables, milk and milk products and the majorly missing food groups were pulses, millets and fruits. Hence, the efforts to improve nutritional status must address the issue of nutrition education, dietary diversity and nutrition sensitive agriculture.

Capacity building of farm women and men for nutritional security

S. No.	Programme	No. of Beneficiaries
1,	Awareness Campaign at Lahchoda Village, Baghpat, on the importance of balanced diet, fruits and vegetables.	100
2.	Soymilk training at Baghpat, U.P.	50
3.	Field day on high iron content, pearl millet (Pusa Composite 443 & 701) at Sonipat, Haryana	60
4.	Training on propagation of mixed vegetable pickle, ginger–lemon squash and *Amla* candy	50
5.	Farmer-scientist interface (2) on importance of food fortification and one on production technology	100
6.	Nutri-quiz competition at Lachoda, Baghpat, U.P.	30
7.	Exposure visit	100
8.	Stakeholder workshop at Lachoda, Baghpat, U.P.	80

Under A2N smart village model, which is being experimented in project villages of Baghpat district, U.P. and Sonipat, Haryana, India, as part of the Behavioral Change Communication (BCC) interventions, a number of interventions were organized. Videos related to nutrition and agricultural technology (PM-30) were shown to project location farmers and SHG members to increase their awareness level on nutrition and to sensitize them about agricultural technologies

Various field demonstrations were conducted on various crops like vegetables, mustard (PM 30), summer moong (Pusavishal), lentil (pusavaibhav), pearl millet (Pusa Composite 443 & 701), etc. The details are given below

Year 2016-17	Name of the crop	No. of demonstrations
Baghpat	Vegetables	619
	Mustard	180
	Summer Moong	214
	Bajra	368
	Lentil	8
Sonipat	Vegetables	222
	Mustard	23
	Moong	37

7.2.4 *Mera Gaon Mera Gaurav*

To promote the direct interface of scientists with the farmers to hasten the lab to land process, *Mera Gaon Mera Gaurav* is being implemented by IARI in 120 cluster comprising of 600 villages by 480 scientists of the Institute along with IASRI and NBPGR. The objective of this scheme is to provide farmers with required information, knowledge and advisories on regular basis by adopting villages.

7.3. TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Outscaling Agricultural Innovations for Enhancing Farm Income and Employment

The project is in operation in four villages, namely, (Palwal, Haryana), Kutbi (Muzaffarnagar, U.P), Rajpur (Aligarh, U.P) and Beenjpur (Alwar, Rajasthan). During *Rabi* 2015-16, a total of 397 assessment trials on location specific improved varieties of wheat, mustard, lentil, gram, spinach and carrot were conducted. Farmers in all the villages liked IARI varieties, although the wheat variety HD 3086 performed better at all locations. Mustard (P Vijay) and carrot (Pusa Rudhira), *gram* (P 1103) were newly introduced varieties in the village Khajurka and Rajpur, respectively. The spinach All Green was well accepted by the farmers for its high yield. Farmers could get three cuts and good market price. Lentil L 4147 was well accepted for its taste. The average yield was 1.22 t/ha.

During *Kharif* 2016, total 212 assessment trials were conducted on five paddy varieties covering an area of 88 ha. The performance of the IARI *Kharif* crop varieties at farmers' field in project villages is depicted in. At Khajurka, Palwal (Haryana) the highest yield of Pusa Basmati 1 (6.00 t/ha) was recorded at farmers' field followed by Pusa 1612 (5.57 t/ha), Pusa Basmati1509 (5.25 t/ha) and Pusa Basmati 1121 (4.82 t/ha). Majority of the farmers preferred Pusa Basmati 1 due to high yield and profit. In terms of profit among paddy varieties in village Khajurka, Pusa Basmati 1 fetched the highest net return, i.e. ₹ 82,725/- followed by Pusa Basmati 1121 (₹ 59,441/-), Pusa 1509 (₹50,261/-), and Pusa 1612 (₹47,663/-). The grain quality was also good in terms of maturity, cooking quality, aroma and weight. In village Rajpur, highest yield of Pusa1509, i.e. 5.06 t/ha was recorded in demonstration plot followed by Pusa 2511 (5.03 t/ha), Pusa 1612 (4.89 t/ha), Pusa Basmati 1 (4.87 t/ha) and Pusa Basmati 1121 (4.78 t/ha). In village Kutubi, three varieties of Paddy were assessed which gave higher yield than the local check. The highest yield of P-1509 i.e. 5.51 t/ha was recorded in demonstration plot followed by Pusa Basmati 1121 (4.53 t/ha) and Pusa Basmati 1 (4.22 t/ha) with economic gain (net return) of ₹ 67,640/- ₹ 57,254/- and 46,358/-, respectively. In Pusa Basmati 1 some incidence of Brown hopper attack was also reported.

In village Beenjpur, the varieties of bottle gourd, onion, cowpea, cucumber, sponge gourd, snap melon,

and spinach (*Palak*) were assessed and gave higher yield than respective local checks. Bottle guard Pusa Naveen was highly preferred by farmers due to high yield and resistance from bacterial blight. Sponge gourd was also liked by farmers as it fetched good market price due to tender and attractive fruits and good taste. Pusa Sukomal gave an average yield of 7.20 t/ha and was well accepted by the farmers for its taste and soft texture. Onion Pusa Red was highly appreciated by farmers for high yield potential, good shape and size and good keeping quality (shelf life) of the onion.

Nutritional status and drudgery assessment of farm women was done in Khajurka and Rajpur villages and it was found that most of the women were malnourished in terms of high Chronic Energy Deficiency among farm women. Food consumption by the women farmers, in both villages, is quite low. Intake of cereals and pulses were less than Recommended Dietary Intake (RDI) in both the villages. Milk consumption was more than RDI in both study locations. Consumption of green leafy vegetables and other vegetables was significantly lower than RDI in both the villages.

7.3.2 Technology Integration and Transfer to Strengthen Farming System in Partnership Mode

The partnership project is being implemented with selected ICAR Institutes / SAUs/VOs in different parts of the country. The analysis of existing farming system was carried out through joint workshops with partner institutions. Suitable farm production, plant protection and post harvest technologies and farm enterprises were identified based on participatory analysis and joint consultations for profitable farming system during workshops held at Institute. The technologies were assessed through demonstrations, trainings, field days etc. by the partner organizations.

Collaborative programme with ICAR institutes and SAUs. During *Rabi* 2015-16, a total number of 268 demonstrations on wheat, mustard, lentil, gram, pea, spinach were conducted covering an area of 57.92 ha across 17 locations.

Wheat

- Farmers reported that HD 2967 was recommended as a variety resistant to yellow rust in place of PBW 343 (Punjab Bread Wheat) by the officials. But at present yellow rust incidence is increasing in HD 2967. The important characteristics observed were semi dwarf and less lodging, profuse tillering and amber colour which make this variety still popular (NDRI, Karnal).
- HD 2967: The variety was in high demand among the farmers and it has very good potential to replace local varieties as far as the yield is concerned (IVRI, Bareilly). The farmers achieved higher yield from variety HD 2967 in comparison to other varieties but lodging was faced by a number of farmers during windy weather (IIVR, Varanasi). Wheat variety HD 2967 was also highly accepted by the farmers due to its high yield and resistance against leaf rust and leaf blight diseases (BAU, Ranchi). Area under HD 2967 increased from 2592.80 ha to 22300 ha between 2013-14 and 2015-16. Significant increase in the productivity of wheat was witnessed from 1.72 t/ha in 2010-11 to 2.59 t/ha in 2013-14. As a result, there was an increase of 51 per cent in productivity in wheat crop (SKUAST, Jammu)
- Farmers appreciated the growth, tillering and yield of HD 3086 and kept the produce for seed purpose for next season. Some farmers reported that the performance of HD 2967 was highly preferred for timely sown conditions at IVRI, Bareilly. Farmers preferred HD 3086 due to less lodging and higher yield against adverse condition. (IIVR, Varanasi). HD 3086 is also preferred variety due to very less incidence of yellow rust as compared to HD 2967 (NDRI, Karnal).
- HD 3059 was good for late sown condition, higher yield with less lodging (IIVR), Varanasi.
- HD 2932: High yielding variety with lower incidences of pest and diseases. Good taste of "*Chapati*" (NAU, Navsari). Variety HD 2932 proved better due to less lodging and profuse tillering (MPUAT, Udaipur)

- HD 2733 was highly accepted by the farmers due to its high yield, dwarf character, early maturity (130-135 days) and resistance to leaf rust and leaf blight (BAU, Ranchi).
- Farmers were interested to continue HD 2985 and HD 3059 due to its suitability under late sown condition as they grow wheat mostly after harvesting of rice (BAU, Ranchi).
- Yield performance, grain quality & size and bread quality of HI 1544 was good as compared to local variety (Lok-1) (MAU, Parbhani).
- The grain size of variety HI 8663 was small as compared to local check. Incidence of infestation of Stem Borer was observed (MAU, Parbhani).
- The performance of new varieties HS 542 and HS 507 were satisfactory in the districts of Una and Kangra over Local Check (HS 295) (CSKHPKV, Palampur)

Mustard

- PusaTarak was appreciated by the farmers due to its higher branching, more number of siliqua, yield and better oil recovery (IIVR, Varanasi).

Lentil

- Lentil L 4076 variety was found less potential to replace local varieties as the farmers of the local area prefer small seeded lentil varieties and this is a bold seeded variety. Cooking quality and taste was good. (IVRI, Bareilly). Farmers preferred L 4076 variety due to more number of branching, medium grain size and higher yield (IIVR), Varanasi.

Gram

- Pusa 1103: Higher yielding as compared to local variety and observed less incidences of pod borer and wilt (NAU, Navsari).

Spinach

- Pusa Bharti: Good quality leaf, more yields, more cutting, early cutting, uniform cutting up to 3-4 harvest (NAU, Navsari).
- *Palak*, Pusa All green: Farmers agreed to adopt the technology, as it is high yielding variety with very good taste and better keeping quality. (IVRI, Bareilly)

During *Kharif* 2016, a total of 388 demonstrations of paddy, palak, bottle guard, *sem*, papaya and brinjal covering an area of 109.41 ha were conducted at ICAR Institutes/SAUs. Major feedbacks are presented as under:

At Birsa Agricultural University (BAU) Ranchi under rainfed condition paddy variety Pusa 1611 gave an average yield of 4.27 t/ha which was 25.22% higher than the local variety. And paddy variety 2511 gave an average yield of 4.36 t/ha, which was 27.36% higher than the local check. The B:C ratio for Pusa 1612 and Pusa 2511 were 2.85 and 2.47 respectively. Both the varieties, especially Pusa 2511 were liked by the farmers for its higher yield, longer grain and good aroma.

At IIVR KVK Badohi, paddy varieties Pusa 2511 and Pusa 1612 gave an average yield of 5.53 t/ha and 5.58 t/ha which were higher to the tune of 64.09% and 65.58%, respectively. The B:C ratio of Pusa 2511 was 2.28:1 and for Pusa 1612, it was 2.30:1. These two varieties have become popular among the farmers as they are short duration and thus give scope for growing vegetable in remaining parts of the season.

At IIVR, KVK, Deoria, paddy varieties is Pusa 2511 and Pusa 1612 had an average yield of 4.62 t/ha and 3.98 t/ha with the corresponding increase in yield of 8.45% and 0.5% respectively over the local varieties. The B:C ratio of the demonstrated varieties were 1.9 and 1.6 for Pusa 2511 and Pusa 1612, respectively.

At KVK Saharanpur (UP), paddy varieties Pusa Basmati 1509 and Pusa Basmati 1121 were demonstrated giving an average yield of 4.98 t/ha and 3.94 t/ha, respectively with the corresponding yield increase of 37.19% and 17.96% over the local check. The B:C ratios for the two varieties were 2.81:1 and 2.72:1, respectively. Farmers of the area especially liked Pusa Basmati 1509 because of its short duration and low insect infestation. The only problem with the variety was Bakanae disease.

Paddy varieties Pusa Basmati 1509 and Pusa 2511 gave average yield of 4.20 t/ha each with corresponding increases in yield of 19.05% and 35.7%, respectively. The B:C ratio for Pusa Basmati 1509 was 3.6 and for Pusa 2511 it was 3.87. Farmers prefer Pusa Basmati 1509 due to desirable traits such as less water requirement, short duration but the farmers of the area reported the problem of breaking grains in Pusa Basmati 1509 during harvesting by combines. Sheath blight and gandhi bug are some of the specific problems of the variety (NDRI, Karnal).

There was problem of breaking of grains during milling and poor market price in variety Pusa Basmati 1509. The performance of the variety was good in terms of purity, crop stand, quality and yield but due to very low market price in local market, farmers could not get proper return as per their expectations in variety Pusa Basmati 1509. Feedback on organoleptic observation also suggested that the quality of rice was good but not as good as compared with Pusa Basmati 1 or Pusa Basmati 1121. PS 2511 was appreciated by the farmers for its short duration, quality of seed and yield potential. It gave very good results under SRI method where 35 to 40 tillers per plant were observed with a yield of 5.68 t/ha and under traditional method resulted in 4.87 t/ha yield. More than 30% produce has already been sold for seed purpose (IVRI, Izatnagar).

Collaborative Programme with Voluntary Organizations. In collaboration with 29 Voluntary Organisations, during *Rabi* 2015-16, a total of 572 demonstrations covering an area of 171 hectares, over 26 locations for wheat, mustard, lentil, spinach, and marigold were conducted. The feedback from farmers is as follows:

Wheat

- Variety HD 2967 was found better than other varieties in terms of production and net return. There was minimum lodging even during heavy rains in February and March. (DRI, Chitrakoot). Farmers prefer this variety due its bold grain (Shamayita Math, WB). There was no lodging due to dwarfness of the variety (KVK Auriya).
- HD 3086: Low yield and small grain size due to high temperature. HD 3086 variety of wheat give good quality of bread (*chapati*). Water requirement more than HD 2967 (KVK Auriya).
- Wheat HS 507: Grain size bigger than that of local (Kalyan) and resistant to yellow Rust. (STD, Mandi)
- Variety HI 1500 suitable in water scarce Gujarat region as compared to the improved variety released by Agricultural University, since less irrigation is required in HI 1500. Plant height of variety HI 1500 is more, so crop lodging occurs. Less potential yield as compared to improved local variety (GW496) (CinI, Dahod).
- Requires less irrigation in HI 1531 so production is less as compared to Trambak wheat variety (CinI, Dahod).
- Wheat variety HD 2967 and HD 3059 performed better to adequate rainfall during cropping season. It gave higher yield than wheat variety PBW 343 (Holy Cross KVK, Hazaribagh).
- HD 3059: Farmers preferred this variety due to its short plant height, low lodging and high yield potential than HD 2967 (Shamayita Math, WB). Late showing variety HD 3059 better than local Halna variety (GSVS, Mathura).

Mustard

- Variety Pusa Vijay gave better production and net return over Varuna (Deen dyal Research Institute, Chitrakoot).

Lentil

- Variety L 4076 gave better production and net return (DRI, Chitrakoot). Mustard cv. Pusa Vijay was unaffected with white rust while demonstrated area's mustard badly affected by white rust (Holy Cross KVK, Hazaribagh).

Palak

- Leaves of variety All Green were observed tender and fetch good price in the market (Holy Cross KVK, Hazaribagh).

Marigold

- Pusa Narangi flower size was attractive and easily acceptable in the market (Holy Cross KVK, Hazaribagh).

During *Kharif* 2016, in collaboration with Voluntary Organisations, 551 demonstrations were conducted on different varieties of paddy, brinjal, bottle gourd, and cauliflower in an area of 207.71 ha. Major feedbacks are presented as under:

Paddy

- Pusa 2511: The variety resulted high yield of 4.46 t/ha, which was 23.97% higher than the local check Gujarat Rice 11. The B:C ratio for the variety was 2.75, unlike 1.86 of local check, showing that this variety is more profitable to the farmers. Farmers preferred this variety due to high yield, good taste, aroma and high market price (₹ 15,000/t). It yields more tillers, longer spikes and longer grains. The variety yielded 4.25 t/ha in DRI, Chitrakoot (UP), which was 51.78% higher than the local check Bejhari. The B:C ratio for the variety was 3.20:1. The market price was ₹ 14,000/t. The variety was majorly infested by stem borer, gandhi bug, leaf spot and bacterial blight. The productivity of the variety was found to be very good in Bundelkhand, so farmers are advised to adopt this variety for better yield. This variety is spreading rapidly due to its less duration and high production. The trial at farmers' field, Ghaziabad resulted in an average yield of 4.9 t/ha, 16% higher than the local check. The average net return obtained was ₹ 88,300/ha. The market price was ₹ 27,000/t. At Participatory Rural Development Foundation (PRDF), Gorakhpur, it yielded 4.79 t/ha. with an average net returns of ₹ 44,040/ha. It is quite popular and well adopted. Reports from KVK, Hazaribag indicated that the average yield of the variety is 4.19 t/ha and the average net returns is ₹ 39,658/ha. The major pests observed were stem borer and leaf roller. The farmers face problem in milling due to cylindrical and long grain size. At PRDF, Gorakhpur, it yielded 4.33 t/ha, with average net returns of ₹ 37,110/ha. The variety is very popular among the farmers. The average yield of the variety is 5.50 t/ha and net returns obtained is ₹ 41,000/ha (SHDA, Kushinagar). At Shamayita Math, West Bengal, it reported an average yield of 3.60 t/ha and net returns of ₹ 78,976/ha with the major problem of dehusking. High economic return is expected from seed production.
- Pusa 1612: The average yield obtained was 4.05 t/ha (DRI, Chitrakoot), 44.6% higher than the local check *Bejhari*. The B:C ratio for the variety was 3.06. The variety was majorly infested by stem borer, gandhi bug, leaf spot and bacterial blight. The major weed seen was Montha. The important features of this variety are it shows high tillering, high productivity, and best quality rice after cooking. The average yield of the variety is 5.05 t/ha and net returns obtained is ₹ 34,700/ha (SHDA, Kushinagar), whereas it was 4.20 t/ha and net returns were ₹ 96,472/ha at Shamayita Math, West Bengal. Farmers preferred this variety because of good scent, nice cooking quality, short duration and expected high returns from seed production. Yield potential and market value was higher than the local variety Gobindobhog.
- Pusa Basmati 1121: This variety gave an average of 5.70 t/ha yield, which is 18% higher than the local check. The average net return obtained was ₹ 1,09,900/ha. Neck blast was seen in few fields but overall, the farmers appreciated yield performance of Pusa Basmati 1121 variety of rice. In GSVS, Mathura, this variety yielded 5.00 t/ha. The average net returns obtained from this variety were ₹ 71,500/ha. There was incidence of infestation by stem borer. It obtains high market price, ₹ 21,000/t due to its aromatic nature and has high potential for adoption, but it has lodging problem. At Auraiya, the variety recorded an average yield of 3.71 t/ha. The net returns obtained were ₹ 41,700/ha. The crop was heavily infested by gandhi bug and sheath blight. Ear head of Pusa Basmati 1121of one plant matures at different time due to which farmer's performance of variety is less. Market price of PB 1121 is ₹ 20,000/t and of local variety (Pro -6444) is ₹11,000/t. At YFA, Punjab, it yielded 4.70 t/ha. It has good marketing system and thus, it could fetch a high price of

₹22000-25000/t. At Herbal Agro Development Gramodyog Society (HADGS), Aligarh, the yield was 4.68 t/ha with net returns of ₹62,130/ha. At Man Mandir Barsana, Mathura, the yield was 3.80 t/ha with returns of ₹37,000/ha, with the major problems of leaf folder, BPH, stem borer, sheath blight, blast and bakanae disease.

- Pusa Basmati 1509: This variety yielded 5.90 t/ha, which is 20% higher than the local check (GSVS, Mathura). The average net return obtained from this variety was ₹ 81,075/ha. It is a short duration variety. At HESCO, Dehradun, it yielded 5.02 t/ha, 46% higher than the local check Sabarmati. Though Sabarmati has a good taste, it was heavily infested with filthy bug and yellow spot disease. It gives a higher yield and a better market price of ₹ 48,750/t. The net returns obtained were ₹ 64,200/ha. At Auraiya, the variety recorded an average yield of 3.97 t/ha. The net returns obtained were ₹ 39,620/ha. The crop was heavily infested by gandhi bug and sheath blight. Market price is ₹ 17,000-18,000/t. At Yong Farmers Association, Rakhra, it yielded 7.20 t/ha. It is short- duration and farmer-friendly. The yield was 5.25 t/ha with net returns of ₹ 62,025 /ha in HADSP, Aligarh. At Man Mandir Barsana, Mathura, the yield was 4.2 t/ha with returns of ₹ 46,000/ha, with the major problems of leaf folder, BPH, stem borer, sheath blight and blast.
- Pusa 2511: It gave an average yield of 3.21 t/ha, which was primarily due to lodging due to rains and winds at maturity [Nand Educational Foundation for Rural Development (NEFORD), Azamgarh]. It matured earlier than check variety Daftari, thus resulting in 23% less yield than the local check. The net returns obtained were ₹ 42,900/ha. It fetched the market price of ₹ 20,000/t. It gives fine and long grain. It is recommended only for big farmers. NEFORD, Ghazipur reported the average yield of P 2511 as 3.29 t/ha and the net returns obtained were ₹ 28,050/ha. NEFORD, Mau reported the average yield of the variety as 2.97 t/ha and the net returns obtained were ₹ 23,365/ha. The problems faced mainly are hulling, milling.
- Pusa Basmati 6 (PB-1401) recorded an average yield of 4.90 t/ha (YFA, Rakhra). Crop suffered from the attack of neck blast. Its grain is liked the most by *basmati* rice consumers. It fetched a higher market price (₹25,000-28,000/t) due to universal acceptance.
- The highest yield of Pusa 44 recorded i.e. 8.50 t/ha at YFA, Rakhra.

Brinjal

- Pusa Shyamala recorded an average yield of 20.0 t/ha, which was 16.66% less than the local check. The major problems in this variety were fruit borer, wilt. It doesn't suffer weed infestation. This variety yields more number of fruits better than local check. Decrease in yield could be due to late sowing (STD, Mandi). KVK, Hazaribag reports indicated that the average yield of the variety was 19.87 t/ha and net return obtained is '89,812.5/ha. The variety showed incidence of wilt attack in patches during rainy season. The average yield of the variety is 39.0 t/ha and net returns obtained is ₹ 3,54,250/ha (SHDA, Kushinagar). At Man Mandir Barsana, Mathura, the yield was 19.0 t/ha with returns of ₹ 50,000/ha, mainly attacked by fruit and shoot fly.

Bottle gourd

- Pusa Naveen recorded an average yield of 18.0 t/ha, which was 10% less than the local check. There was no incidence of insects, diseases and weeds in this variety. Decrease in yield could be due to late sowing. (STD, Mandi). The average yield of the variety was 28.2 t/ha and net returns obtained was ₹ 2,52,200/ha (SHDA, Kushinagar). At Man Mandir Barsana, Mathura, the yield was 19.5 t/ha with returns of ₹ 98,000/ha as it was attacked by red pumpkin beetle and fruit fly.

Cauliflower

- Pusa Meghna yielded 13.0 t/ha on average and net returns obtained was ₹ 1,57,600/ha (SHDA, Kushinagar). The variety has average potential for adoption because of its average production capacity.

7.3.3 Participatory Seed Production of Improved Varieties of IARI

Under Participatory Seed production of improved varieties of wheat, during *Rabi* 2015-16, HD 3059 (4.56 t), HD 2967 (8.50 t) and HD 3043 (4.38 t) wheat seeds were produced at PRDF Gorakhpur, and 20.4 t of HD 2967 and 30.3 t of HD 3086 wheat seed was produced at YFAP, Rakhra. During *Kharif* 2016, 14.4 t of PB 1509, 93.5 t of Pusa 44 and 44.65 t of Pusa 1121, 18.38 t of PB 1401 seed were produced at Rakhra.

7.3.4 Front Line Demonstrations on Wheat (in collaboration with IWBR)

During *Rabi* 2015-16, 16 FLDs on wheat at village Rajpur, of district Aligarh (UP) were conducted of newly released wheat variety WH 1105 and use of bio-fertilizer (*Azotobacter* + PSB) in WH 1105. Yield was affected due to heavy rain and hailstorm during maturity of the crop.

7.3.5 *Krishi Unnati Mela*-National Agriculture Fair

The *Krishi Unnati Mela* 2017 was organized from March 15-17 at the campus of IARI, New Delhi jointly by ICAR and Ministry of Agriculture & Farmers Welfare. The *mela* was inaugurated by Hon'ble Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh on March 15, 2017. Shri Sudarshan Bhagat, Hon'ble Minister of State for Agriculture and Farmers Welfare, Dr. Trilochan Mohapatra, Secretary DARE and DG ICAR also graced the occasion. Hon'ble Minister of Agriculture and Farmers' Welfare conferred Pt. Deen Dyal Upadhyay *Krishi Vigyan Protsahan Puraskar* for the outstanding works of KVKs, one award at national level and 11 zonal awards. He also released publications, viz., *Krishi Ayam: Jigyasa avam samadhan*, Farm calendar and *Prasardoot*. He also released two bilingual (Hindi and English) portals developed by IARI, New Delhi and NIAIM, Mau, which will facilitate an easy access to quality knowledge by the end users. Besides, eighteen extension leaflets and folders on salient technologies were also published in Hindi.

The mega event, that celebrated the great contribution of Indian farmers to agriculture, witnessed the participation of 342 public and private exhibitors. Exhibition of improved technologies of agriculture, horticulture, animal husbandry, dairy, fisheries, farm machinery and equipments, etc. including live demonstrations at the Pusa farms were the major highlights of the fair. Display and sale of high yielding seeds and plants of different crops, fruits and vegetables were another attraction of the event. Fifty innovative farmers and entrepreneurs also displayed and sold their products. Farmers' interactive sessions were also organized in which experts and scientists provided advanced technological knowledge in simple

Hon'ble Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh inaugurating *Krishi Unnati Mela* – 2017 at IARI

Hon'ble Minister of State for Agriculture & Farmers Welfare & Panchayati Raj, Shri Parshottam Rupala felicitating a farmer in *Krishi Unnati Mela* – 2017

way along with details of the various government schemes launched for the benefit of the farmers.

The valedictory function was held in the gracious presence of Hon'ble Minister of State for Agriculture & Farmers Welfare & Panchayati Raj, Sri Parshottam Rupalaji as the Chief Guest. He bestowed upon IARI Fellow Farmer Award on 5 farmers and innovative farmer awards on 39 farmers.

7.3.6 Off-campus Exhibitions

CATAT organized / participated in eighteen national/international agricultural exhibitions for display /sale of IARI technologies, products, services and publications.

7.3.7 Agricultural Technology and Information Centre (ATIC)

National Agricultural Research System has generated number of agricultural technologies for the benefit of the farmers. But the farmers are not able to use these technologies due to lack of access to the information. To bridge this gap of information, Agricultural Technology Information Centers (ATIC) have been established in the country. ATIC of IARI, New Delhi was established in 1999 as a 'single window' delivery system for the technology, services and products of the Institute for the benefit of the farming community. ATIC provides farm advisory services and facilitate information-based decision making among farmers. ATIC is effectively providing products, services, technologies and information services to the different stakeholders through a 'Single Window Delivery System'. Besides farm advisory services at ATIC, farmers are given farm advice through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), PusaAgricom 1800-11- 8989, exhibitions, farm literatures and letters. Second level of *Kisan Call Centre* (1800-180-1551) has also been established at ATIC to answer the problems/queries of farmers of Delhi state. Information and advisory needs of the visitors are also being catered through touch panel *kiosks*, revolving scrollers, laminated posters information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples and bio-fertilizers displayed at the centre.

ATIC laid out live demonstrations of paddy varieties Pusa Basmati 1, PB 1121 Pusa Sugandh 5 (P.S. 2511), Pusa 1401 (PB 6), Pusa Basmati 1509, maize, mung var. Pusa Vishal. In *rabi* live demonstrations of wheat varieties HD 3086, HD 2851, HD 2967, and HD 3059; mustard varieties Pusa Vijay and Pusa Mustard 26 were laid out. Demonstrations of vegetables in summer season pumpkin var. Pusa Vishwas, okra (*bhindi*) var. Pusa A-4, *lobia* (cowpea) var. Pusa Sukomal, cucumber var. Japanese Long Green, onion var. Pusa Red, *bathua* var. Pusa Bathua 1, sponge gourd

var. Pusa Sneha, brinjal var. Pusa Uttam, bottle gourd var. Pusa Naveen, *palak* var. Pusa Harit, chilli var. Pusa Sadabahar, tomato var. Pusa Gaurav, and Amaranthus var. Pusa Kiran; and in winter season cauliflower var. Pusa Hybrid 2, broccoli var. KTS 1, radish var. Hybrid 1, beet var. Crimson globe, *knol khol* var. W. Vienna, tomato var. Pusa Rohini, *methi* var. PEB, Methi Pusa Kasuri were laid out. In flowers demonstrations on five varieties of Gladiolus, viz., Shabnam, Sinayana, Srijan, Kiran and Cidushi and one variety of marigold var. Pusa Narangi Gainda were laid out.

Drip irrigation system was demonstrated for fruit orchard and nutri-garden in crop cafeteria for the benefit of the visitors. High density fruit trees orchard planted with lemon (KagziKalan), mango (Amrapali), guava (Lucknow 49, Allahabad *Safeda* and Lalit), *ber* (Banarasi Karaka and Gola) were grown in current season. For awareness of farmers, herbal block was developed in crop cafeteria which includes medicinal plants of aloevera, *ashwagandha*, *satavar*, coleus, *giloe*, *mushkdana*, *sadabahar*, mint, *tulsi* (Basil), lemon grass, Java citronella, etc.

New technological additions in ATIC

1. Three illuminated posters having success story of IARI Fellow farmers have been fixed in ATIC building corridor.
2. Seven LED posters with farmer friendly information about the IARI technologies have been fixed in the ATIC training hall.
3. One POS machine has been fixed in ATIC for cashless transaction.

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

Farmers and farm women from Gujarat visited ATIC

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

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

7.3.8 *Krishi Vigyan Kendra,* Shikohpur

The Institute's *Krishi Vigyan Kendra* (IARI) at Shikohpur, Gurgaon is playing a catalytic role in combating unemployment of rural youth through technological empowerment and improving the farmer's awareness and farm productivity through

following TOT programmes. Programmes & activities executed during 2016-17 were: field problem based on-farm testing; Front Line Demonstrations on oilseeds, pulses & cereals; trainings for different target groups; empowerment of women in agriculture; and agricultural extension activities & farm advisory services.

7.3.8.1 On-farm testing

This activity is mainly focused to test developed technologies which might be helpful to solve the most important and widely spread problems of the groups of farmers in a defined area with their farming system perspective with their active participation and under their management. The major objective of the programme is to provide tailor-made recommendations to the farmers by testing the location specific technologies to solve their field problems. During the period, 7 On-farm trials were conducted on different field/farm based problems including one trial on animal based problems.

7.3.8.2 Front line demonstration programme

FLDs on oilseeds, pulses and cereal crops are playing a key role in transferring and dissemination of the location specific crop technologies in the area. During the period, 398 demonstrations (*Rabi* 2015-16 & *Kharif* 2016), covering 166.8 ha on oilseeds, pulses cereal and vegetable crops under different schemes were organized.

7.3.8.3 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community, the KVK celebrated/

Extension activities organized/celebrated by KVK, Shikohpur

S. No.	Name of the Programme	No. of Programmes	No. of Participant
1.	Field days	18	825
2.	*Krishi Shiksha Diwas*	01	70
3.	*Jai Kisan Jai Vigyan*	04	480
4.	Honey day	01	54
5.	Farmers visit at KVK for FAS	—	987
6.	Field visit of SMSs in farmer's fields	170	4066
7.	Farm advisory service on telephone	—	4563
8.	Radio & TV talk	27	—
9.	Lectures delivered by SMS of KVK in farmers trainings/ meetings organized by line department/ NGOs	39	2258
10	Method demonstration	26	205
11.	*Kisan gosthi*/workshop	05	914
12.	Group meetings/discussion	42	627
13.	Popular articles	03	—
14.	Camp /campaign (agriculture)	29	766
15.	Camp /campaign (animal)	01	95 animals diagnosed and treated
16.	News letter (quarterly)	04	500 copies of each issue were distributed to the farmers
17.	Diagnostic service(animal) at KVK	11	32 Milk and fecal samples analyzed
18.	Soil & water samples analyzed	1826	1646 (soil samples)180 (water samples)
19.	Exhibitions	04	—
20	Exposure visit of farmers& farm women	11	1075
21.	Press releases	05	—
22.	World Soil Day	01	300
23.	*Kisan sammelan*	02	802
24.	SMSs sent to the farmers through *kisan* mobile services	20	Sent to 1500 farmers of the district
	Total	**2250**	—

organized various extension activities in the villages and at KVK campus.

7.3.9 Transfer of Technologies through IARI Regional Stations

7.3.9.1 Regional Station, Indore (M.P.)

During 2015-16 a total of 31 demonstrations of 11 wheat varieties were conducted in 14.3 hectares area in Indore and Dhar districts of M.P. using recommended package of practices. Increase in yield was recorded as 1.3 t/ha or 31%. Best performing varieties were: HD 2987 (Yield- 3.8 t/ha and 73% yield increase over check), HI 1544 (Yield-7.6 t/ha and 65% yield increase over check) and HI 1531 (Yield- 4.5 t/ha and 60% yield increase over check).

7.3.9.2 Regional Station, Shimla (H.P.)

Three front line demonstrations on wheat variety HS 562 were organized in different villages of Himachal Pradesh for popularizing the cultivation of high yielding new variety among the farmers.

The Station also organized/participated in the following activities:

- A '*Kisan Diwas*' at Hadaboi Village and 'Farmer's Interest Group' interaction at Nihri village of Mandi district of Himachal Pradesh were organized. Farmers and members of 'Farmer's Interest Group' were educated about new wheat and barley varieties.
- Farmers day was organized at Horticultural Research Farm, Dhanda on January 16, 2017 and more than 60 farmers participated and saplings of different fruit crops, viz., apple, pomegranate, kiwi, walnut, stone fruits, etc. sold and extension folders were also distributed.
- Field day organized in Kinnaur district of Himachal Pradesh under TDP at Nichar, Bari, Sungra, Ponda, Yangpa, Kafnu and Katgaon in the Nichar Block, Kinnaur Distt., H.P. from August 10 to 13, 2016. Number of farmers participated: 93
- Field day was organized in Kinnaur district of Himachal Pradesh under TDP at Rogi, Kalpa, Koti, Pangi, Kamroo, Sangla, Themgrang and Batseri in the Kalpa block, Kinnaur Dist., H.P. from September 6 to 10, 2016. Number of farmers participated: 128
- Field day was organized in Kinnaur district of Himachal Pradesh under TDP at Nako and Sumara in Pooh Block, Kinnaur Dist., H.P. on October 15 and 18, 2016. Number of farmers participated: 60
- Participated in *Kisan Mela* and Conducted *Kisan Gosthi* in association with Ambuja Cement Foundation, Darlaghat on October 25, 2016. More than 500 farmers participated and extension folders and strawberry planting materials were distributed.

7.3.9.3 Regional Station, Pusa (Bihar)

Fourteen frontline demonstrations were laid out during the year 2016-17 in the village Mukundpur and Panapur of Vaishali districts of Bihar. The demonstrations conducted were on: use of bio-fertilizers-*Azatobactor* and PSB (4), zero-tillage technology (4) and new improved wheat varieties (6). The performance of different demonstrations conducted was very encouraging. A field day was organized on April 12, 2016 in the village Harpur Bochha, the adopted FLDs village. About a hundred farmers gathered and participated in the discussions on the performance of the latest wheat variety and future plans of diffusion. Wheat variety showed an average yield of 4.014 t/ha in FLD.

IARI Outreach Programme

In April 2016, under the IARI Outreach Programme *Kharif, 2016*, paddy seed were distributed among sixteen KVKs of Bihar and one 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 given to 560 farmers. The response of farmers was very encouraging for the scented varieties of paddy, especially for Pusa Sugandh 5. Seed for 140 demonstrations of pigeonpea (var. Pusa 9) was distributed in village of Mukundpur, Panapur, and Mirpur under Vaishali district of Bihar. In Rabi, 2016-17 with a goal to popularize IARI Wheat

varieties among farmers under the IARI Outreach Programme on "Strengthening of wheat Programme in Eastern India", 810 minikits demonstrations of three timely sown wheat varieties HD-2733, HD 2824 and HD 2967 and two late sown wheat varieties HI 1563 and HD 3118 were laid out in 18 districts of Bihar, one in West Bengal, two in Jharkhand, and two NGOs (*Parivartan, Siwan*and *Gramin Vikash Kendra, Nalanda*).

About 540 minikit demonstrations of three wheat varieties were laid out in farmers' fields under the close supervision of KVKs in Bihar, Jharkhand and West Bengal in Rabi 2015-16. In *Kharif* 2016, 560 minikit demonstrations of three varieties of paddy were laid out in farmers' fields in Bihar, Jharkhand and West Bengal, and 30 minikit demonstrations of Pusa 9 variety of pigeonpea were laid out in farmers' fields in Bihar. The results showed as below:

Bihar

Mean Yield:	HD 2733 (3.312 t/ha) HD 2824 (3.14 2t/ha) and HD 2967 (3.264 t/ha)
Yield increase:	41 to 55 per cent against the state average of 2.206 t/ha

West Bengal

Mean Yield:	HD 2733 (3.254 t/ha), HD 2824 (3.025 t/ha) and HD 2967 (3.371 t/ha)
Yield increase:	21.00 to 34.84 per cent against the state average of 2.500 t/ha

Jharkhand

Mean Yield:	HD 2733 (3.254 t/ha) HD 2824 (3.025 t/ha) and HD 2967 (3.371 t/ha)
Yield increase:	50 to 65 percent, against the state average of 2.076 t/ha.

Paddy Demonstrations in *Kharif 2016*

Variety:	Pusa 44
Mean yield:	3.605 t/ha
Variety:	PNR 381
Mean yield:	2.892 t/ha
Variety:	Pusa Sugandha 5
Mean yield:	334.5 kg/ha

Pigeonpea Demonstrations in *Kharif 2016*

Variety:	Pusa-9
Mean yield:	2350 kg/ha

The Station actively participated in three-day *Krishi Unnati Munch* organized by ICAR- Research Complex Patna during May 27-29, 2016 in which varieties of wheat, paddy, and papaya were demonstrated; Agriculture *exhibition-Gramouday se Bharat Uday Abhiyan*on April 23-24, 2016 at Tata Sports Complex Stadium, Jamshedpur district of Jharkhand; *Krishi Pradarshani Evam Kisan Mela* at Parivartan, Siwan on March 2, 2017; and Dr. RPCAU, *Kisan Mela* during December 3-5, 2016

7.3.9.4 Regional Station, Karnal (Haryana)

Seed village programme sponsored by DAC, Ministry of Agriculture, and GOI was continued during *Kharif* 2016 and *Rabi* 2016-17 for farmer-to-farmer horizontal spread of seeds of popular varieties of different crops. In *Kharif* 2016, 40.4 ha area was undertaken for paddy CVs. PB 1121/ PB1509, in *Rabi* 2016-17, 21.2 ha area was taken under wheat HD 3086/ HD 2967/WR544 seed production for increasing the availability of quality seeds in their villages itself. Under Seed Village Programme resource poor farmers and women farmers were given training at the station as well as at farmer's field on various aspects of quality seed production. Other activities performed by the Station are given below:

- *Kisan Pathsala* was organized in Village Badshapur on 24 September, 2016 for quality seed production in which more than sixty women farmers participated.
- *Beej Bikri Diwas* was organized on March 3, 2017. *Pusa Beej* of popular varieties of *basmati* paddy viz., PB 1509, PB 1121 and non-*basmati* variety Pusa 44 of worth ₹10,70,045/- was sold to hundreds of farmers from Haryana, Punjab and Western Uttar Pradesh.

- Participated in "Farmers – Scientists Interactive Workshop and Seed Day" held at ICAR-IIW&BR, Karnal on October 17, 2016; and "*Rabi Kisan Mela*" held at ICAR-CSSRI, Karnal on March 8, 2017 to display the technologies, products and publications of the institute. Stalls exhibited were visited by hundreds of farmers including women farmers. Vegetable kits were also sold to farmers.

Farmers Participatory Seed Production Programme at Village Brass, Karnal

"*Mera Gaon Mera Gaurav*", a mega agricultural development programme, was launched by ICAR-IARI, Regional Station, Karnal in three clusters of five villages each. Scientists of ICAR-IARI, Regional Station, Karnal visited three clusters separately and interacted with the farmers to improve their productivity by adopting latest scientific interventions. The farmers were provided one page write-up in local language of important agricultural activities to be taken care for different crops.

7.3.9.5 Regional Station, Katrain (Kullu Valley) H.P.

Seventy five field demonstrations of the different vegetable were conducted at the farmers' fields. The varieties/hybrids of cucumber, summer squash, brinjal, tomato and French bean showed 10-14 % more yield over check during *Kharif* 2016. Seventy five field demonstrations had been conducted during Rabi 2016-17.

7.3.9.6 Regional Station, Wellington (Tamil Nadu)

Front line demonstrations (FLD's) were conducted on 15 ha area for popularizing wheat cultivation in non- traditional areas of Tamil Nadu and Karnataka for two bread wheat varieties CoW2 and HW 5216 and one *dicoccum* variety HW 1098 in entire *dicoccum growing areas in Maharashtra, Karnataka and Tamil Nadu. The Station conducted two wheat field days at Hosur and Ooty.*

8. EMPOWERMENT OF WOMEN IN AGRICULTURE AND MAINSTREAMING OF GENDER ISSUES

The women are the backbone of agricultural workforce and are a vital part of Indian economy. Over the years, there is a gradual understanding of the key role of women in agricultural development and their contribution in the field of agriculture, food security, horticulture, dairy, nutrition, sericulture, fisheries, and other allied sectors. In addition to contributing to various agriculture processes, women in most regions of the world share responsibility with men and children for caring of animals. With various targeted efforts, their enlightenment is changing the face of rural India. A number of interventions are carried out for mobilizing women into Self Help Groups (SHGs), entrepreneurial development, seed production, vocational trainings etc. for their empowerment.

8.1 CAPACITY BUILDING OF SHGs FOR GENDER EMPOWERMENT

In the year 2015-16, three Self Help Groups (SHGs) from the different villages were formed. The groups were made to start their own enterprises in three different areas. In 2016-17 the groups have widened their reach and selling their products outside Gurgaon also and have drastically increased their income. The details of income of SHGs are as follows:

8.2 VOCATIONAL AND FARM TRAINING FOR TECHNOLOGICAL INTERVENTION

The Institute's KVK at Shikohpur organized various need based self-employment and income generating activities and other extension programmes for creating the awareness about scientific farming and disseminating the technology in wide area. The important programmes and activities organized for rural women during the period (April, 2016 to March, 2017) are as under:

- Vocational training courses for self-employment and income generation.
- Day longs trainings in villages for updating the farm knowledge/skills.
- Exposure visit of rural women to agriculture fairs and exhibitions.
- Front line demonstration 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.

S. No.	Name of SHG	Entrepreneurial Activity Adopted	Duration	Income Generation (Approximate)
1.	Kshitiz	Soy nut, Processed soy and pearl-millet flower, pearl-millet *dalia*, maize *dalia* & flour, pearl-millet biscuits, *laddoo* and other savory snacks from soy bean and pearl-millet.	1 Year	₹ 1,80,443/-
2.	Arzoo	Spices	1 Year	₹ 16,74987/-
3.	Prayas	Preserved products of seasonal fruits and vegetables	1 Year	₹ 50,000/-

Activity wise participation of rural women

S. No.	Name of Activity	Duration	No. of Programmes/ Activity	Number of Beneficiaries
A	**Vocational Trainings**			
1.	Establishment of Nutri-farm	1 week	01	20
2.	Dress designing and tailoring	45 days	02	55
3.	Value addition on soybean and peal-millet	1 week	02	49
4.	Preservation of seasonal fruits and vegetables	1 week	01	18
5.	Participation in other vocational trainings organized	1 week	07	14
	Total	—	**13**	**156**
B	**Agriculture extension and farm advisory**			
1.	Day long trainings (On/off campus)	1 day	24	241
2.	Participation in different field days	1 day	12	147
3.	Jai Kisan Jai Vigyan week	4 days	04	115
4.	Kisan Sammelan	1 days	02	102
	Total		**42**	**605**
	Grand Total (A+B)		**55**	**761**

Soymilk training at Lachoda, Baghpat, U.P.

Vocational training on "Dress Designing and Tailoring"

8.3 WOMENS' PARTICIPATION IN SEED PRODUCTION

Rural women are playing significant role in agricultural development. Women have proven that they can be good managers in any kind of activities. Eleven farm women during *Kharif* 2016 from different villages of Karnal district, Haryana were selected under Seed Village Programme. They were given training on various aspects of quality seed production of Paddy cv. PB 1121 and PB 1509. Through active participation in the trainings, their level of knowledge for importance of quality seed has increased.

8.4 BIOTECHNOLOGY-LED SOCIO-ECONOMIC EMPOWERMENT OF FARM WOMEN

The project is being implemented in collaboration with two non-government organizations, viz., Deen Dayal Research Institute (DRI), Chitrakoot and PRDF, Gorakhpur, UP with lead centre at IARI. During period under report, a bakery unit has been established with necessary baking equipment (bakery oven, dough kneader) and regular trainings on muffins, whole-wheat cookies (*pasta*, almond, pinwheel, tuti-fruity,

choco chips and jam) were being conducted for skill development. The baking technology has improved women's family income. Skill demonstration on preparation and storage of tomato ketchup, mixed pickle, *litti*, *namkeen*, peanut butter, *aonla* candy and carrot *murabba* were conducted.

Through high yielding varieties of wheat, paddy, mustard, mung bean and cotton, farmers got 15-30% higher yield and income. Construction of two low cost polyhouse (one in Hajiyapur and one in Karanpur) with training of seed production is also imparted to the beneficiaries. Healthy seedlings of brinjal, chilli, tomato, bottle gourd, summer squash and melon were raised under protected cultivation. Cultivation of off season vegetable crops helped the farm women get vegetables at household level and they also got income by marketing it during the off season. Varieties of cereals, pulses, oilseeds, vegetables, fodder crops, etc. were also introduced. Carrot was popularized in kitchen garden to show its potential as a commercial crop.

Trainings were conducted on nutritional awareness as well as crop and food diversification, bio-fertilizers, *Trichoderma,* safe grain storage (5), crop cultivation methods (20), fodder production (5), vegetable production (25), balanced nutrition of cattle (4), management of ecto- and endo-parasites in cattle (13), deworming in cattle (7), biogas, nutrient management in crops (15), group mobilization (15), motivational training for entrepreneurship (45), SHGs mobilization (37), credit flow and records maintenance (25), health management practices of milch animals (10), safe and scientific vegetable nursery raising (30), nursery raising for paddy (65), etc.

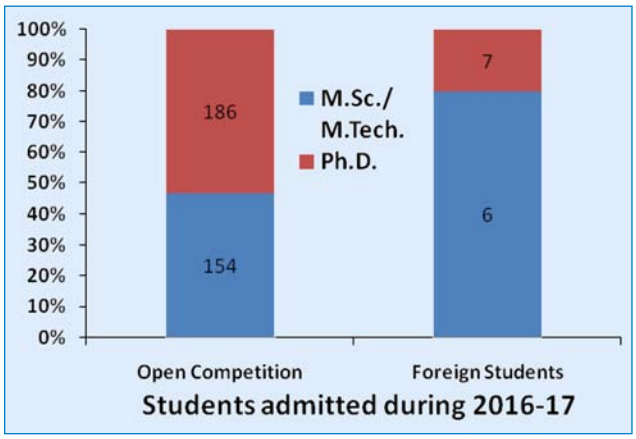
9. POST- GRADUATE EDUCATION AND INFORMATION MANAGEMENT

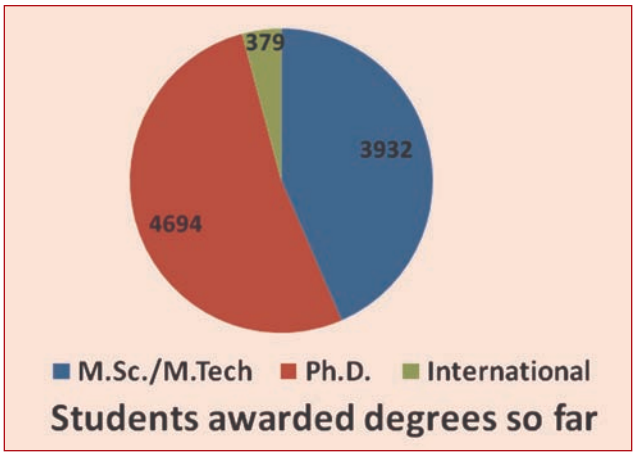
The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence of more than 112 years in research, teaching and extension. The Post Graduate School of IARI continues to provide national and international leadership in Human Resource Development by awarding Post Graduate degrees in 26 disciplines. So far, 3932 M.Sc./M.Tech. and 4694 Ph.D. students have been awarded degrees including 379 international students. The National Assessment and Accreditation Council (NAAC) of UGC has accredited IARI with A+ (3.51/4.00) Grade for five years (2016–2021). Similarly, the National Agricultural Education Accreditation Board (NAEAB), ICAR has granted accreditation to M.Sc., M.Tech. and Ph.D. degrees of all the teaching disciplines of IARI for 2015-2020. Based on Indian Rankings 2017 by the Ministry of Human Resource Development (MHRD), Govt. of India, IARI has been ranked 23rd among overall Institutions of the country.

9.1 POST - GRADUATE EDUCATION

9.1.1 Admission during the Academic Session 2016-17

The PG School continues to be the most sought destination for students seeking admission to 26 PG Courses in all five streams of admission, namely, open competition, faculty up-gradation, ICAR in-service nominees, departmental candidates and foreign students. The admission to the Ph.D. programme is based on the national level entrance examination conducted at different centres of the country, academic track record followed by an interview. While the admissions to the M.Sc. programme is based on an All-India Entrance Test conducted by the Education Division of the Indian Council of Agricultural Research (ICAR). The foreign students are admitted through DARE, Ministry of Agriculture and Farmer's Welfare and are exempted from the written test and interview. During the academic year 2016-17, 160 students (including 4 physically challenged, 2 underprivileged states, and 6 international students) to M.Sc./M.Tech. and 193 students (including 6 physically challenged, 5 ICAR in service, 1 faculty upgradation scheme and 7 international students) to Ph.D. courses were admitted. Eleven students for IARI - Assam and





10 for IARI - Jharkhand were admitted to M.Sc. For PG outreach programme at sister institutes, 9 students for CIAE, Bhopal and 15 students for IIHR, Bengaluru were admitted to Ph.D. programme.

At present, the total number of students on roll is 998 (287 M.Sc., 16 M.Tech. and 695 Ph.D.) including 35 international students representing 13 countries, namely, Afghanistan, Egypt, Ethiopia, Ghana, Guyana, Nepal, Nigeria, Rwanda, Sierra Leone, Sri Lanka, Sudan, Syria and Vietnam.

9.1.2 Convocation

The 55th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 9, 2017 with Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh as the Chief Guest. Dr. T. Mohapatra, Secretary, DARE & Director General, ICAR, former Director Generals of ICAR and former Directors and Deans of IARI graced the function. The Chief Guest presented the degrees, medals and awards to the students and faculty. In his convocation address, the Chief Guest highlighted the government priorities in the field of agricultural research and farmers welfare. He appreciated "*Mera Gaon Mera Gaurav*" programme of IARI, under which the scientists have adopted cluster of villages, as a great success. Dr. Ravinder Kaur, Director (Acting), IARI presented her report on the significant research achievements of the Institute during 2016, while the report of the Dean & Joint Director (Education.), Dr. R.K. Jain highlighted the significant achievements in the field of education and human resource development. The Chief Guest released seven IARI publications and 18 IARI varieties of different crops.

During this Convocation, 231 candidates (112 M.Sc., 8 M.Tech. and 111 Ph.D.) were awarded degrees including 13 (7 M.Sc., 1 M.Tech. and 5 Ph.D.) international students. One student each in M.Sc. (Ms. Priyanka Upreti, Agricultural Economics) and Ph.D. (Ms. Hema Baliwada, Agricultural Extension) were awarded the Best Student of the Year Awards. Five students each in M.Sc. and Ph.D. received IARI Merit Medals. From this year onward, a special IARI Merit Medal for the best Ph.D. student from

A Ph.D. student receiving her degree from Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh at the convocation

the North Eastern Region has been launched to encourage competitiveness, better performance and quality higher Agriculture education. Mr. Sujan Majumdar (Agricultural Chemicals) received this award. Five faculty members of the Institute ,namely, Dr. R. R. Sharma (Post Harvest Technology); Dr. T.K. Das (Agronomy); Dr. Adarsh Kumar (Agricultural Engineering); Dr. R.R. Burman (Agricultural Extension); and Dr. V.S. Raju Dantuluri (Floriculture and Landscape Architecture) received the Best Teacher Award 2016 for their achievements in academics. The XVII Hari Krishna Shastri Memorial Award for the year 2016 was awarded to Dr. B.S. Dwivedi, Head, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi for his outstanding research contribution in the field of Soil Science and Agricultural Chemistry. The XXIV Hooker Award for biennium 2014-15 was awarded to Dr. Gouranga Kar, Principal Scientist, Indian Institute of Water Management, Bhubaneswar for his outstanding research contributions in the area of Water Management.

9.1.3 Special Lectures

Dr. B.P. Pal Memorial Lecture. The 23rd Dr. B.P. Pal Memorial Lecture was delivered by Prof. Ramesh Chand, Member, NITI Aayog on May 26, 2016 on the topic "Addressing Agrarian Distress: Sops Versus Development". Dr. R.S. Paroda, Chairman, Trust for

Prof. Ramesh Chand, Member, NITI Aayog delivering the 23rd Dr. B.P. Pal Memorial Lecture with Dr. R.S. Paroda in Chair

Advancement of Agricultural Sciences, New Delhi, presided over the function.

Teachers' Day Lecture. The Teachers' Day Lecture 2016 was delivered by Dr. N.S. Rathore, DDG (Edn.), ICAR, on September 5, 2016 on "Recent Advances in Agricultural Education in India". Dr. H.S. Gaur, former Vice Chancellor, Sardar Vallabh Bhai Patel University of Agriculture & Technology, Meerut, presided over the function.

Lal Bahadur Shastri Memorial Lecture. The 47th Lal Bahadur Shastri Memorial Lecture was delivered by Dr. Jitendra Singh, Hon'ble Minister of State (Independent Charge) for Development of NER, and MOS for PMO, Govt. of India on February 9, 2017. Hon'ble Minister of State, Ministry of Agriculture and Farmers Welfare, Govt. of India, Shri Parushottam Rupala presided over the function.

9.1.4 International Exposure

The excellence of IARI is recognized internationally. IARI is playing key role in establishing Afghan National University of Agricultural Sciences and Technology (ANASTU), Kandahar, Afghanistan, and Advanced Centre for Agricultural Research and Education (ACARE) at Yezin Agricultural University, Myanmar in collaboration with the Ministry of External Affairs (MEA), Government of India. The Institute imparted the teaching and research guidance to the second batch of 19 students from ANASTU. During their stay at IARI from July 21, 2016 to March 20, 2017, courses like Principles of Crop Production; Soil Fertility and Nutrient Management; Principles and Practices of Weed Management in Field and Horticultural Crops; Principles and Practices of Water Management; Agronomy of Food and Oilseed Crops; Agronomy of Vegetable and Fruit Crops, Protected Cultivation and Precession Farming; Soil Texture, Structure and Health; Soil Testing, Analysis and Nutrient Management; Basic Statistical Methods; and Basic English Literature & Grammar were covered through modular teaching.

9.1.5 Addressing Plagiarism

To maintain academic integrity, 1434 documents in the form of thesis and manuscripts prior to submission were subjected to web based software 'Turnitin' and similarity reports were generated. Realizing its importance some state Agricultural Universities have showed interest in its applications and received training from IARI.

9.2 E-GRANTH AND LIBRARY SERVICES

Prof. M S Swaminathan Library is one of the largest and the finest agro biological libraries in South East Asia housing a total of 3,39,494 publications including books/monographs, journals, reports, bulletins, post graduate theses and other reference materials, etc. The Library has on its role 2000 plus members 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.

9.2.1 Strengthening and Sustainability of E-Granth

In accordance to the ICAR open access policy, it is mandatory to keep a digitized repository of the resources (including thesis) for each Institution. Under the open access policy, an initiative has been

taken to extend this facility to others Institutes/SAUs by generating the Communities in the current instance of Krishikosh and create the permission based moderators to manage the information in repository by providing the current Krishikosh repository facilities hosted at ICAR-IARI. The upgradation of Krishikosh from DSpace version 4.2 to new DSpace version 5.5 version to make use of the improved new features in KrishiKosh, IARI has been also initiated. Currently, this digital repository has about 90 thousand articles including 40,000 M.Sc. and Ph.D. theses. The IARI has developed android based Mobile application with push notification for dissemination of submitted articles in the Krishikosh.

9.2.2 Acquisition Programme

9.2.2.1 Books

During the period under report, the library procured 744 publications which includes 296 in Hindi and 305 in English costing ₹27,54,265/-. The Library also acquired 71 gift publications and 532 theses (399 PG students' theses from IARI and 133 ICAR awarded theses). For the first time, the library purchased 56 e-books, uploaded on IARI server and accessible through IARI Intranet.

9.2.2.2 Serials

The Library procured 2925 journals/serials through subscription, gifts and exchanges. It subscribed to 84 foreign journals, 143 Indian journals, 99 Advances and Annual reviews and 850 newsletters. Exchange relationship was maintained with 65 institutions globally and nationally by sending 125 annual reports, ICAR journals and society publications. One hundred twenty five annual scientific/technical reports of different institutions were received in the Library during the reported period.

9.2.3 Documentation Activities

9.2.3.1 AGRIS project

IARI Library was declared as an input center for National Agricultural Research Database (NARD) under AGRIS Project. The Library was assigned the job of scanning articles from 10 most important Indian journals. The input was done in ISO format using AGRIN methodology.

9.2.3.2 Developmental news in agriculture

Fourteen newspapers were scanned and 1520 news items pertaining to IARI as well as ICAR were sent to the Directorate, Principal Scientist (PME) and CATAT.

9.2.3.3 Document processing

In all, 1166 documents consisting of 258 books, 429 post-graduate IARI theses, 131 ICAR awarded theses, 89 old books, 26 bulletins and 233 Hindi books were processed (classification and cataloguing).

9.2.4 Resource Management

9.2.4.1 Reference, circulation and stack maintenance

Apart from about 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 reported period, 373 new members (52 staff and 321 students) were registered. During the period under report, 1255 publications were issued and 1260 publications returned to its members through "KOHA" library management software. Fine amounting to ₹13,477 was collected for overdue publications. Twelve documents were issued under Inter Library Loan System to various institutions. About 355 no dues certificates were issued. Membership of DELNET (Developing Library Network) was renewed to provide Inter Library loan (reference services) to scientific community.

9.2.5 CD-Rom Workstation

The access of CABI one International prominent Database on Agricultural aspects is available through CeRA. Fifteen terminals were provided to users in CD-ROM workstation of the library. These database is accessible to scientists/students/users of IARI through LAN. In all, 8,500 references were downloaded by the scientists and students of IARI and research scholars from all over India. A revenue of ₹7382 was generated through service of databases and photocopy.

10. PUBLICATIONS

One of the important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications are an integral component of the information system. During the year under report, 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 *adhoc* technical publications both in English and Hindi. The details of these publications are given below:

10.1 PUBLICATIONS AT A GLANCE

1. Research/Symposia Papers		
a)	Research papers (With international impact factor or NAAS rating 6 and above) published in journals	601
b)	Symposia/conference papers	641
2. Books/Chapters in Books		
a)	Books	36
b)	Chapters in books	212
3. Popular Articles		379

10.2 IN-HOUSE PUBLICATIONS

10.2.1 Regular Publications

- IARI Annual Report 2015-16 (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)

- Significant Post Graduate Student's Research Achievements (2007-2016) (ISBN 978-93-83168-24-8)
- A Handbook: Central Government Agricultural Development Schemes (ISBN 978-93-83168-26-2)
- Plant Pathology Research Series Vol. II : Genomics, Race Profile and Characterization of Resistance to Pathogens (ISBN 978-93-83168-27-9)
- Fellow and Innovative Farmers-2017: An Introduction. (ISBN 978-93-83168-28-6)
- Principles and Practices of Weed Management- A Practical Manual (ISBN 978-93-83168-29-3)
- Popular and Recent IARI Vegetable Varieties and Hybrids (TB-ICN: 163/2016)
- Recommendations of Brainstorming Session on Technological Options for Agricultural Water Management (TB –ICN: 164/2016)
- Promising Technologies in Composting (TB-ICN: 165/2016)
- On - Farm Burning of Rice Straw: Problem, Prospect and Policy (TB-ICN: 166/2016)
- Protocol for *Agrobacterium* Mediated Transformation of Soybean (TB-ICN: 167/2016)
- Microbial Technologies for Sustainable Phosphorus Management (TB-ICN: 168/2016)
- Recent Advances in Breeding Approaches and Varietal Development of Perennial Horticultural Crops (TB-ICN: 169/2017)
- Conservation Agriculture for Enhancing Crop Productivity and Resource Use Efficiency (TB-ICN: 170/2017)
- Scientific Weed Management (TB-ICN: 171/2017)
- Layout and Maintenance of Field Experiments and Recording Observations (TB-ICN: 172/2017).

10.2.3 नियमित प्रकाशन (हिन्दी)

- पूसा सुरभि (वार्षिक) (ISSN: 2348-2656)
- वार्षिक रिपोर्ट 2015–16 (ISSN: 0972-7299)
- पूसा समाचार (त्रैमासिक) (ISSN: 0972-7280)
- प्रसार दूत (त्रैमासिक)
- भा.कृ.अ.सं. सामयिकी (मासिक) (केवल संस्थान की वेबसाइट पर उपलब्ध)

10.2.4 तकनीकी प्रकाशन (हिन्दी)

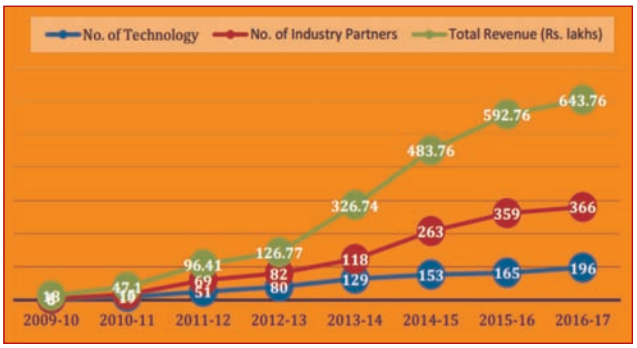
- उन्नत पर्वतीय कृषि हेतु मृदा एवं जल प्रबंधन (ISBN: 978-93-83168-25-5)
- दलहन फसल उत्पादन और मिट्टी के स्वास्थ्य के लिए राइजोबियम टीका प्रौद्योगिकी (ICN: H-156/2016)
- कृषि आयाम : जिज्ञासा एवं समाधान (ICN: H-157/2017)
- गेहूं के रोग एवं उनका प्रबंधन (ICN: H-158/2017)
- धान के रोग एवं उनका प्रबंधन (ICN: H-159/2017)
- गोभीवर्गीय सब्जियां – रोग एवं समेकित प्रबंधन (ICN: H-160/2017)
- दलहनी फसलों में रोग प्रबंधन (ICN: H-161/2017)
- टमाटर के रोगों का समेकित प्रबंधन (ICN: H-162/2017)
- प्रशिक्षण पुस्तिका 'बदलते मौसम के परिवेश में फसलोत्पादन एवं बीजोत्पादन तकनीक (ICN: H-163/2017)
- पॉलीहाउस में खेती की तकनीक (ICN: H-164/2017)

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 COMMERCIALIZATION

During 2016-17, 34 innovative technologies of ICAR-IARI were transferred to 19 industry partners which earned the institute a revenue of ₹ 62,00,000. These innovative technologies included the vegetable varieties of IARI such as beet- Detroit Dark Red (DDR), brinjal - Pusa Anupam, cauliflower - Pusa Sharad, cauliflower - Pusa Snowball K-25, carrot- Pusa Rudhira, knoll khol - White Vienna, lettuce - Great Lakes, mustard - Pusa Sag, okra A-4, *palak* - Pusa Harit, radish - Japanese White, squash - Australian Green, turnip - Purple Top White Globe (PTWG), watermelon - Sugar Baby, ridge gourd - Pusa Nutan, sponge gourd - Pusa Sneha, bottlegourd - Pusa Santushti, bottlegourd - Sandesh, bottlegourd - Pusa Samridhi, bittergourd - Pusa Vishesh, cowpea - Pusa Sukomal, *bathua* - Pusa 1, chilli - Pusa Sada Bahar, muskmelon - Pusa Madhuras, onion - Pusa Riddhi, pumpkin - Pusa Vikas, Amaranthus - Pusa Lal Chaulai. A vegetable basket of 27 vegetable varieties listed above was licensed to M/s Ananya Seeds (P) Ltd.



Technology commercialization from 2009 to 2017

The other innovative technologies licensed to different industry partners this year were entomopathogenic nematode-based *Galleria* Cadaver for Insect Pest Management, STFR meter, wheat variety HD 3086, BGA bio-fertilizer technology, VAM bio-fertilizer technology, compost inoculant bio-fertilizer technology.

11.2 INTELLECTUAL PROPERTY RIGHTS

Three new patent applications filed with 4 renewals of existing patents has been done, along with 7 responses to First Examination Report (FER), 2 hearings and 5 patents granted; One Trade Mark application granted; 1 PPVFRA application filed and 2 PPVFRA's registered; 1 Copyright granted in August 2016 and 1 copyright application filed; 4 NBA Form – III applications submitted and 1 Form – II application submitted. The details are as follows:

S. No.	Name of Innovation/Technology/Process	Application/ Registration No.	Date of Filing/Grant
Patent Application Filed			
1.	Digital Soil Test and Fertilizer Recommendation (STFR) Meter	PCT/IB2016/053174	May 30, 2016
2.	An Apparatus for *in vivo* Mass Production of Entomopathogenic Nematode	IN201711000736	January 7, 2017

3.	A semi-synthetic diet for mass rearing five species of genus *Bactrocera* (Insecta: Diptera: Tephritidae) of agricultural and quarantine significance	IN201711009555	March 20, 2017
Patent Granted			
1.	A Process for Preparation of Polymer Encapsulated Nano-Sulfur Fungicide	IN277235A	November 16, 2016
2.	Process for the preparation of 5 substituted 1-3,4 oxiadiazole – 2 thiols as new urease and nitrification inhibitors	IN279536A	January 27, 2017
3.	Pusa Chickpea Thresher	IN282047A	March 30, 2017
4.	Improved Neem Larvicidal Compositions	IN282129A	March 30, 2017
5.	A Slow or Controlled Release Mosquito Larvicidal Composition and a Process for Preparation Thereof	IN282133A	March 30, 2017
Trade Mark Granted			
1.	"flexiCFF"	2796885	August 11, 2016
Plant Variety Protection Filed			
1.	Pusa Snowball K-25	REG/2016/668	June 2, 2016
Plant Variety Protection Granted			
1.	Pusa Hybrid 20/ DBHL 20 (Brinjal)	274 of 2016	August 26, 2016
2.	Pusa Prachi/ HI 1563 (Wheat)	236 of 2016	August 19, 2016
Copyright Granted			
1.	Decision Support System for Soil Health Assessment	8955/2016-COSW	August, 2016
Copyright Application Filed			
1.	Desin of Micro Irrigation System (DOMS)	--	March 20, 2017

Twenty six varieties were protected under PPV&FR. The details are as follows:

Varieties protected under PPV&FR

S. No.	Variety	Denomination	Registration/ Certificate No.
1.	Cauliflower	Pusa Snowball K 25	REG/2016/668
2.	Cabbage	Pusa Cabbage 1 (KGMR 1)	757 of 2014
3.	*Wheat	HD 2967	647 of 2014
4.	Wheat	HD 2985 (Pusa Basant)	655 of 2014
5.	Wheat	HD 2987 (Pusa Bahar)	643 of 2014
6.	Wheat	Pusa Prachi (HI 1563)	236 of 2016
7.	Brinjal	Pusa Hybrid 20 (DBHL 20)	274 of 2016
8.	Mustard	Pusa Mustard 21	146 of 2014
9.	Mustard	Pusa Agrani	148 of 2014
10.	Mustard	Pusa Vijay	326 of 2014
11.	Mustard	Pusa Mustard 28	327 of 2014
12.	Mustard	Pusa Mustard 22	328 of 2014
13.	Mustard	Pusa Mahak	329 of 2014
14.	Mustard	Pusa EJ-9912-13	330 of 2014
15.	Mustard	Pusa Aditya	331 of 2014
16.	Mustard	Pusa Karishma	332 of 2014
17.	Mustard	Pusa Mustard 25	333 of 2014
18.	Mustard	Pusa Mustard 24	334 of 2014
19.	Mustard	Pusa Swarnim	335 of 2014
20.	Mustard	Pusa Mustard 29	760 of 2014
21.	Mustard	Pusa Mustard 30	797 of 2014
22.	Mustard	Pusa Mustard 27	152 of 2014
23.	Mustard	Pusa Mustard 26	153 of 2014
24.	Wheat	HD 3086, Pusa Gautami	REG/2015/326
25.	Wheat	HD 3059, Pusa Pacheti	REG/2015/1286
26.	Wheat	HD 3090, Pusa Amulya	REG/2015/1287

11.3 AGRIBUSINESS INCUBATION

A. ITMC Meetings and Zonal workshop

During the reported period, four Institute Technology Management Committee (ITMC) meetings were organized by the Unit. A Zonal Workshop was organized on June 9, 2016 and reviewed the activities and progress of their respective Institutes.

A view of ITMC meeting

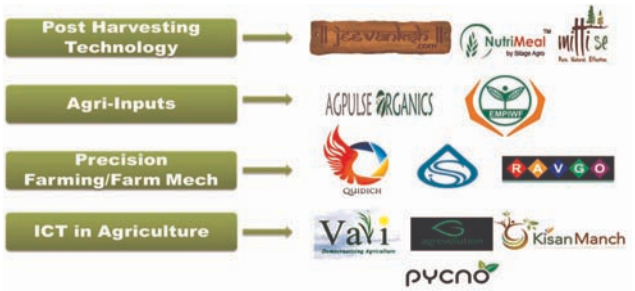
Inauguration of "Arise", Launch Pad for Agri-Startups

B. IP Spectra: Intellectual Property Facilitation Centre for Agro-based MSMEs

IP Spectra an Intellectual Property Facilitation Centre (IPFC) for agro-based Micro, Small and Medium Enterprizes (MSMEs) has been established for providing IP services to agro-based MSMEs with financial support of Ministries of MSME, Govt. of India (www.ipspectra.ztmbpd.iari.res.in). The mission of IP Spectra is to provide complete IP solution services like Drafting and Filing Applications for Patent, Copyright, Trademark, Industrial Design, PPVFR; Pre-grant and Post-grant Services, hand-holding support towards technology commercialization, Advisory Services to agro startup and MSMEs as well as to create awareness about IPR.

C. Arise 2016: Launchpad for Agri-Startups

- An agribusiness incubation acceleration program 'Arise', Launch-pad for Agri Start-ups, was organized from June, 2016 to March, 2017, wherein young entrepreneurs/ideas had been identified at the initial phase itself & provision of necessary skills / mentoring had been made to form a proper business proposal and ultimately a viable business entity.



- Out of 500 plus applications received, 60 potential proposals had been selected to present their business plans in 'Arise' Selection Day Event in front of expert panels from various domains of Agriculture and allied sectors. Twenty two business proposals got selected in the mentioned event yielding a highly diversified incubation portfolio.
- A business incubation workshop from September 18-24, 2016 was organized in order to make them equipped with the basics of business i.e., company formation, financial prepositions, marketing strategy, accounting, tax planning, etc. with a focus on their respective sector.
- To provide, the agri entrepreneurs, a platform to run their market feasibility studies and pilot marketing of their products, stalls have been designed and provided to them free of cost under funding from the project.
- To adhere with the objective of developing successful agri enterprises, special 67 one-to-one mentoring sessions are being run in terms of milestone setting and timely review.
- To acquaint them with the start-up funding ecosystem in the country, organized a Workshop on 'Current Funding Opportunities for Start-ups' on March 1, 2017. Also organized an evaluation meet to review and evaluate the performance of all 22 start-ups by the committee on March 1, 2017.

A view of workshop on "Current Funding Opportunities for Start-ups"

- Finally after continuous mentoring and handholding, 13 proposals have been shortlisted for grant in aid facilitation from MSME and 5 proposals shortlisted for private external funding. Currently they are being mentored on the presentation aspects for pitching in front of investors.
- For Arise participants, a business incubation workshop from September 18–24, 2016 was organized to equip them with the basics of business, marketing in agribusiness and regulatory affairs.
- To adhere with the objective of developing successful agri enterprises, special one-to-one mentoring sessions are being run in terms of milestone setting and timely review. Till date 60 mentoring programs have been organized for the incubatees.

A participant presenting business plan in Arise 2016

Participants in Arise business incubation workshop

11.4 CORPORATE MEMBERSHIP

During the year under report, 83 new corporate members with 78 renewals of existing memberships were registered, generating a revenue of ₹ 7,80,000.

11.5 OTHER ACTIVITIES

A. Agripreneurship Development Program (ADPs)

During 2016-17, 3 agripreneurship development program (ADPs) were organized. (i) two ADPs on soil fertility evaluation and nutrient management for enhancing crop productivity and soil health were organized from November 15-20, 2016 and November 21-26 2016 for Samriddhi team of Mahindra group (44 participants benefitted from the training), and (ii) ADP on unlocking the secrets to create a successful tissue culture enterprise with an objective to empower entrepreneurs on various aspects of plant tissue culture from November 28-December 3, 2016 (11 aspiring agripreneurs participated).

Glimpses of ADPs organized by ZTM & BPD Unit

B. Marketing and Promotion Campaign

During the year 2016-17, 14 e-maketing campaign for 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 rice, wheat and mustard seed varieties developed by IARI has been launched. More than 5800 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 479 cold calls were made to various agro-based companies and corporate members for promotion of new technologies developed by IARI.

C. Marketing and Networking Platform

- During *Krishi Unnati Mela* 2017, ZTM&BPD Unit showcased the ready to commercialize technologies of IARI, services which were of benefit to the farming community as well as other stakeholders of agricultural development. ZTM also showcased the technologies of incubates in order to provide networking and marketing support. The incubates attracted handsome number of people and got their market feasibility studies, sensory studies and sales done. The efforts of the ZTM & BPD unit were highly appreciated from across senior management team and visitors as well as different agencies.

ZTM&BPD stall at *Krishi Unnati Mela* 2017

- ZTM&BPD Unit organized B2B meetings with 242 companies which included participation from Mangalore Chemicals & Fertilizers Ltd., Adani Agri Fresh Ltd, India Glycols Limited, etc. to showcase the potential technologies of IARI.
- ZTM&BPD Unit participated in *Krishi Mela 2016*, Punjab organized in collaboration with M/s. Eco Inputs Pvt. Ltd. to showcase the prospective technologies of IARI to the farmers.

E. Vegetable Field Day

ZTM&BPD Unit organized a vegetable field day on February 15, 2017. The program was attended by breeders and marketing specialists of several seed companies like Syngenta India Limited, Nuziveedu Seeds Limited, Rallis India Limited, Rasi Seeds Pvt Ltd, Sakata Seeds Pvt Ltd, Dayal Seeds Pvt Ltd, Bejo Sheetal, Noble Seeds Pvt Ltd, Ananya Seeds Pvt Ltd,etc. The seed company representatives visited the vegetable field and acknowledged the new varieties of institute.

Glimpses of vegetable field day

12. LINKAGES AND COLLABORATION

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 agricultural sciences 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 the 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 some of the private seed sector having strong R&D base and expertise in seed quality enhancement as well as with the advanced centres of research in other countries.

The Institute has extended liaison with private companies for commercialization of its technologies. Many IARI technologies with private and public enterprises have been commercialized.

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 trials 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 1.4.2016 to 31.3.2017 is given below:

Name of funding agency	No. of projects
Within India DBT, DST, National Committee on Plasticulture Application in Horticulture (NCPAH), Agricultural and Processed Food Products Export Development Authority (APEDA), Ministry of Micro, Small & Medium Enterprises (MSME), CSIR, Department of Agriculture and Cooperation (DAC), Directorate of Horticulture, IMD, Board of Research in Nuclear Sciences (BRNS), NHB, National Mission for Sustainable Agriculture(NMSA), Mission for Integrated Development of Horticulture (MIDH), Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), Space Application Centre, and ICAR	181
Outside India International Centre for Agriculture Research in Dry Areas (ICARDA), CIMMYT, Harvest Plus Consortium-IFPRI, Bill & Melinda Gates Foundation-IRRI, Michigan State University-GCFSI, UNDP, US-India Education Foundation	7
Total	**188**

13. AWARDS AND RECOGNITIONS

- Dr. K. Annapurna, Head, Division of Microbiology awarded DBT Women Leader in Bio-Sciences.
- Dr. Shelly Praveen, Head, Division of Biochemistry awarded ERASMUS MUNDUS, EU Fellowship.
- Dr. Irani Mukherjee, Professor, Division of Agricultural Chemicals was elected NAAS Fellow.
- Dr. V.K. Baranwal, Professor, Division of Plant Pathology was elected NAAS Fellow.
- Dr. Y.S. Shivay, Professor, Division of Agronomy was elected NAAS Fellow.
- Dr. Neeru Bhooshan, Incharge, ZTM & BPD Unit received (i) Certificate for recognition in the mBillionth Award 2016, and (ii) Nari Shakti Award 2017.
- Dr. Sarangi, Principal Scientist, WTC was elected NAAS Fellow.
- Dr. R.R. Sharma, Principal Scientist, Division of Food Science and Postharvest Technology was elected NAAS Fellow.
- Dr. Namita R Das, CESCRA, selected for SERB Indo-US Post-Doctoral Fellowship-2016 by Indo-US Science and Technology Forum (IUSSTF).
- Dr. Debashis Chakraborty, Senior Scientist, Division of Agricultural Physics (i) selected for the ICAR National Fellow Award and (ii) Australia Award Fellowship by Department of Foreign Affairs and Trade, Australia.
- Dr. Gopala Krishnan S., Senior Scientist, Division of Genetics received (i) Lal Bahadur Shastri Outstanding Young Scientist Award 2015 of ICAR for his contribution in the field of Crop and Horticultural Sciences, and (ii) Dr. P. N. Bahl Award in the field of Crop Sciences by the Division of Genetics, IARI, New Delhi.
- Dr. Surender Singh, Scientist, Division of Microbiology received Young Scientist Award 2015-16 of NAAS.
- Dr. Sujit Sarkar, Scientist, IARI Regional Station, Kalimpong received Jawaharlal Nehru Award of ICAR for outstanding PG research in socio-economic aspect of climate change under Social Science group.

In addition, a large number of our scientists received various awards instituted by the professional societies and also 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.) and Revised Estimates (R.E.) for the year 2016-17 under Non- Plan

NON-PLAN **₹ in lakhs**

Sl. No.	Name of the Head	B.E. 2016-17	R.E. 2016-17
1	**2**	**3**	**4**
	Grants for creation of Capital Assets (CAPITAL)		
1	Works		
	(A) Land		
	(B) Building		
	i. Office building		98.60
	ii. Residential building		
	iii. Minors Works		
2	Equipments	65.00	71.50
3	Information & Technology	8.00	
4	Library Books & Journal	7.00	17.05
5	Vehicles & Vessels		
6	Livestock	1.50	1.50
7	Furniture & Fixtures	24.00	35.85
8	Others		
A	**Total- CAPITAL (Grants for creation of Capital Assets)**	**105.50**	**224.50**
	Grants in Aid-Salaries (REVENUE)		
1	**Establishment Expenses**		
	(A) Salary		
	i. Establishment charges	18000.00	16519.98
	ii. Wages		
	iii. Overtime allowance	2.50	1.52
	Total-Establishment Expenses (Grants in Aid-Salaries)	**18002.50**	**16521.50**
	Grants in Aid-General (REVENUE)		
1	Pension & Other Retirement Benefits	12000.00	11518.50
2	Traveling Allowance		
	A. Domestic/Transfer T.A.	40.00	50.00
	B. Foreign T.A		
	Total-Traveling Allowance	**40.00**	**50.00**
3	Research & Operational Expenses		
	A. Research Expenses	252.50	350
	B. Operational Expenses	321.00	350
	Total Res. & Operational Exp.	**573.50**	**700.00**
4	Administrative Expenses		

Sl. No.	Name of the Head	B.E. 2016-17	R.E. 2016-17
	A. Infrastructure	2000.00	5736.70
	B. Communication	50.00	36.10
	C. Repair & Maintenance		
	i. Equipments, Vehicles & Others	200.00	138.00
	ii. Office building	720.00	963.00
	iii. Residential building	450.00	576.30
	iv. Minor Works	250.00	407.50
	D. Others (exc.TA)	700.00	1217.70
	Total-Administrative Expenses	**4370.00**	**9075.30**
5	Miscellaneous Expenses		
	A. HRD	6.00	6.00
	B. Other Items (fellowships)	500.00	450.00
	C. Publicity & Exhibitions	9.50	4.50
	D. Guest House-Maintenance	70.00	90.70
	E. Other Miscellaneous	200.00	235.00
	Total -Miscellaneous Expenses	**785.50**	**786.20**
	Total Grants in Aid-General	**17769.00**	**22130.00**
B	**Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)**	**35771.50**	**38651.50**
	TOTAL (CAPITAL + REVENUE)	**35877.00**	**38876.00**
	(C) Loan & Advances	60.00	65.00
	GRAND TOTAL	**35937.00**	**38941.00**

Statement showing Budget Estimates (B.E.) and Revised Estimates (R.E.) for the year 2016-17 under Plan

PLAN **₹ in lakhs**

Sl. No.	Name of the Head	B.E. 2016-17	R.E. 2016-17
1	**2**	**3**	**4**
	Grants for creation of Capital Assets (CAPITAL)		
1	Works		
	(A) Land		
	(B) Building		
	i. Office building	100.00	300.00
	ii. Residential building		
	iii. Minors Works		
2	Equipments	100.00	100.00
3	Information & Technology		
4	Library Books & Journal	202.00	
5	Vehicles & Vessels		
6	Livestock		
7	Furniture & Fixtures		
8	Others		
A	**Total- CAPITAL (Grants for creation of Capital Assets)**	**402.00**	**400.00**
	Grants in Aid-Salaries (REVENUE)		

Sl. No.	Name of the Head	B.E. 2016-17	R.E. 2016-17
1	Establishment Expenses		
	(A) Salary		
	i. Establishment charges		
	ii. Wages		
	iii. Overtime allowance		
	Total-Establishment Expenses (Grants in Aid-Salaries)	**0.00**	**0.00**
	Grants in Aid-General (REVENUE)		
1	Pension & Other Retirement Benefits	0.00	0.00
2	Traveling Allowance		
	A. Domestic/Transfer T.A.	120.00	70.00
	B. Foreign T.A.		
	Total-Traveling Allowance	**120.00**	**70.00**
3	Research & Operational Expenses		
	A. Research Expenses	615.65	540.00
	B. Operational Expenses	358.35	400.00
	Total Res. & Operational Exp.	**974.00**	**940.00**
4	Administrative Expenses		
	A. Infrastructure	213.00	225.00
	B. Communication	5.00	
	C. Repair & Maintenance		
	i. Equipments, Vehicles & Others	133.00	100.00
	ii. Office building		
	iii. Residential building		
	iv. Minor Works		
	D. Others (exc.TA)	230.00	118.00
	Total-Administrative Expenses	**581.00**	**443.00**
5	Miscellaneous Expenses		
	A. HRD	68.00	60.00
	B. Other Items (fellowships)		
	C. Publicity & Exhibitions		
	D. Guest House-Maintenance		
	E. Other Miscellaneous		
	Total -Miscellaneous Expenses	**68.00**	**60.00**
	Total Grants in Aid-General	**1743.00**	**1513.00**
B	**Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)**	**1743.00**	**1513.00**
	TOTAL (CAPITAL + REVENUE)	**2145.00**	**1913.00**
*	Tribal Sub Plan	125.00	149.00
*	NEH	20.00	15.00
	GRAND TOTAL	**2290.00**	**2077.00**

Statement showing Unified Budget Estimates (U.B.E.) for the year 2017-18

Unified Budget Estimate 2017-18 **₹ in lakhs**

Sl. No.	Name of the Head	U.B.E. 2017-18
	Grants for creation of Capital Assets (CAPITAL)	
1	Works	
	(A) Land	
	(B) Building	
	i. Office building	300.00
	ii. Residential building	170.00
	iii. Minors Works	
2	Equipments	170.00
3	Information & Technology	
4	Library Books & Journal	217.00
5	Vehicles & Vessels	
6	Livestock	1.00
7	Furniture & Fixtures	40.00
8	Others	
A	**Total- CAPITAL (Grants for creation of Capital Assets)**	**898.00**
	Grants in Aid-Salaries (REVENUE)	
1	Establishment Expenses	
	(A) Salary	
	i. Establishment charges	19231.00
	ii. Wages	
	iii. Overtime allowance	2.75
	Total-Establishment Expenses (Grants in Aid-Salaries)	**19233.75**
	Grants in Aid-General (REVENUE)	
1	Pension & Other Retirement Benefits	14231.00
2	Traveling Allowance	
	A. Domestic/Transfer T.A.	85.00
	B. Foreign T.A	
	Total-Traveling Allowance	**85.00**
3	Research & Opeational Expenses	
	A. Research Expenses	150.00
	B. Operational Expenses	260.00
	Total Res. & Operational Exp.	**410.00**
4	Administrative Expenses	
	A. Infrastructure	6000.00
	B. Communication	50.00
	C. Repair & Maintenance	
	i. Equipments, Vehicles & Others	150.00
	ii. Office building	150.00
	iii. Residential building	225.00
	iv. Minor Works	225.00
	D. Others (exc.TA)	645.00
	Total-Administrative Expenses	**7445.00**

Sl. No.	Name of the Head	U.B.E. 2017-18
5	Miscellaneous Expenses	
	A. HRD	35.00
	B. Other Items (fellowships) (OBC)	500.00
	C. Publicity & Exhibitions	2.25
	D. Guest House-Maintenance	30.00
	E. Other Miscellaneous	135.00
	Total -Miscellaneous Expenses	702.25
	Total Grants in Aid-General	**8642.25**
B	**Total Revenue (Grants in Aid-Salaries + Grants in Aid-General)**	**22873.25**
	TOTAL (CAPITAL + REVENUE)	**43005.00**
	Tribal Sub Plan (Capital)	20
*	Tribal Sub Plan (revenue)	10
	NEH (Capital)	
*	NEH (revenue)	40
	GRAND TOTAL	**43075.00**

15. STAFF POSITION

(As on 31.03.2017)

	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	6	3
2)	Principal Scientist	65	39
3)	Senior Scientist/Scientist (S.G.)	170	112
4)	Scientist	337	352*
	Total	**578**	**506**
B.	**TECHNICAL STAFF**		
1)	Category III	20	13
2)	Category II	290	181
3)	Category I	360	277
4)	Auxiliary	1	1
	Total	**671**	**472**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	19	19
2)	Group B	275	189
3)	Group C	163	119
	Total	**457**	**327**
D.	**SKILLED SUPPORT STAFF**	**1301**	**810**

Note: * 15 posts of Senior Scientist have been filled up at the entry level (Scientist).

16. POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLED PERSONS

16.1 POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY ABLED 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 2016-17, 10 physically challenged students (4 M.Sc./M.Tech and 6 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.

17. OFFICIAL LANGUAGE (*RAJ BHASHA)* IMPLEMENTATION

According to Article 343 of the Constitution, Hindi shall be the Offi cial Language (OL) of the Union Government. To implement the objectives in letter 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-offi cial 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 offi cial/research activities and the eff ective implementation of Offi cial Language. To ensure follow up action on the decisions taken in these meetings, sub-committees were also constituted in diff erent Divisions, Regional Stations and the Directorate.

17.1.1 Inspection of Progressive Use of Offi cial Language

To achieve the targets fixed in the annual programme of the Department of Offi cial Language, Ministry of Home Affairs, Govt. of India, and as per the recommendations of the Institute Offi cial Language Implementation Committee (OLIC), an OL Inspection Committee was constituted under the Chairmanship of Dr. Indramani Mishra, Head, Division of Agricultural Engineering. The Committee inspected the progressive use of OL in all the Divisions, Units and sections of the Directorate. The Committee also visited the Regional Station, Kalingpong 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 HINDI WORKSHOPS

In order to motivate the staff members in diff erent categories to do maximum work in Hindi, three Hindi workshops were organized by the Institute head quarter during the year 2016-17.

- First workshop on "*Rajbhasha ke Vividh Aayam evam Sarkari Kamkaj Mein Masaouda Lekhan ka Mahatva*" was organized on June 28-29, 2016 in the Institute for its administrative offi cers. The main purpose of the workshop was to make the administrative staff familiar with diff erent aspects of using Hindi language in offi ces, and to teach them the skill of noting and drafting in Hindi.

A presentation being made by a participant in power point presentation competition

- Second workshop/competition on power point presentation on "*Kisan - Bechara ya Desh ka Sahara*" was held on September 19, 2016 for scientists and technical offi cers of the Institute at CESCRA auditorium, in the presence of Dr. Ravinder Kaur, Director (Acting) and Dr. K.V. Prabhu, Joint Director (Research), IARI. Nineteen scientists and technical offi cers participated in the power point presentation. Dr. Dinesh Kumar Sharma, Principal Scientist, CESCRA, Dr. Atul Kumar, Principal Scientist, Division of Seed Science & Technology, Dr. Brij Bihari Sharma, Scientist, Division of Vegetable Science, Dr. Bhoopindra Singh, Principal Scientist, CESCRA and Dr. Rajesh Kumar, Chief Technical Offi cer, Division of Microbiology were awarded first, second, third, fourth & fifth cash prizes of ₹10,000/-, ₹7000/-, ₹5000/-, ₹3000/- and ₹3000/, respectively, all the participants were given certifi cates.

  Third workshop on "*Rajbhasha Niti and Sarkari Kamkaj Mein Hindi Ka Vyavharik Prayog Va Samadhan Tatha Svatantra Bharat Mein Hindi Mein Kamkaj Ki Anivaryata*" was organized on February 14-15, 2017 for scientists of the Institute. Fifty scientists participated in the workshop.

Dr. K.V. Prabhu, Joint Director (Research) delivering the inaugural address at the Hindi workshop on February 14, 2017

17.3 AWARD SCHEMES/COMPETITIONS

During the year 2016-17, many competitions/ award schemes were also initiated to motivate the employees of the Institute to do their maximum work in Hindi. A large number of offi cers and employees of different categories of staff participated in these activities. The following activities were organized :

17.3.1 Award Scheme for Doing Maximum Offi cial Work in Hindi

This award scheme of the Department of Offi cial Language, Ministry of Home Affairs, Govt. of India was implemented as per the directives of the Department and 9 employees of the Institute were given cash awards for doing their maximum offi cial work in Hindi during the period under report.

17.3.2 *Rajbhasa Patra Vyavahar Pratiyogita*

Rajbhasa Patra Vyavahar Pratiyogita was organized amongst the different Divisions, different sections of Directorate, and Regional Stations of IARI, separately. In the period under report, the Division of Food Science and Post Harvest Technology amongst the Divisions, Joint Director (Research) Personal Section amongst different section of Directorate, and Regional Station, Pune amongst the Regional Stations were given mobile shield for doing maximum work in Hindi.

17.3.3 Awards for Scientific Writing in Different Magzines/Papers

A competition for Popular Scientific Writing was organized for scientists/technical offi cers of the Institute, and winners were awarded first (₹7000/-), second (₹5000/-) and third (₹3000/-) prizes for their published articles in different journals.

17.3.4 Pusa Vishisht Hindi Pravakta Puraskar

Pusa Vishisht Hindi Pravakta Puraskar was given jointly to Dr. Livleen Shukla and Dr. Geeta Singh, Principal Scientists, Division of Microbiology. Evaluation was done on the basis of recommendations of course coordinator and feedback of the trainees. The *Puraskar* carries a cash prize of s ₹10,000/- and a certificate.

17.3.5 Outstanding Nodal Offi cer Puraskar

For better coordination between Hindi Section and each of the Divisions/Sections/Units, and significant

progress in offi cial language in the Institute, one Nodal Offi cer was nominated for each Division/Section/Unit. To motivate the Nodal Offi cers for their outstanding contribution in Offi cial Language Implementation work in their Divisions/Sections/Units, a prize of ₹5000/- was announced. Dr. Jasveer Singh, Chief Technical Offi cer, Division of Plant Pathology received the above prize for the year 2015.

17.4 *HINDI CHETNA MAAS*

The Institute celebrated *Hindi Chetna Maas* from September 1 to 30, 2016. Dr. K.V. Prabhu, Joint Director (Research) inaugurated the *Hindi Chetna Maas* on September 1, 2016. On this occasion, an essay writing competition was also organized. During the *Hindi Chetna Maas*, various other Hindi competitions like noting & drafting, Hindi translation, debate, and quiz, etc. were also organized for all categories of the staff members.

Hindi Week/Hindi Day were also celebrated in different Divisions and Regional Stations of the Institute during this period. Many competitions were organized for promoting the use of Hindi, and participants given prizes.

17.4.1 Hindi Annual Prize Distribution Function

The Institute celebrated its Annual Hindi Prize Distribution Function on November 21, 2016 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 Offi cial Language Implementation Committee gave the welcome address. Shri Keshav Dev, Deputy Director (OL) presented the Institute Offi cial Language Progress Report. Dr. Gurbachan Singh, Chairman, Agricultural Scientists Recruitment Board (ASRB) and Chairman, Town Official Language Implementation Committee, Delhi North was the Chief Guest of the function. The Chief Guest gave away the prizes to the winners of different competitions organized during the year and *Hindi Chetna Maas*.

Dr. K.V. Prabhu, Joint Director (Research) addressing the audience at the *Hindi Chetna Maas* function

Dr. Gurbachan Singh, Chairman, ASRB speaking at the Annual Hindi Prize Distribution Function

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

Name of the training programme	Dates/Month	No. of trainees
Division of Agricultural Chemicals		
Trace Level Analysis of Pesticides, Phytochemicals, Sugars and Organic Acids	January 23-30, 2017	15
Division of Agricultural Engineering		
Training on Precision Agriculture Technologies for Technical staff of ICAR	January 16-21, 2017	20
Operationalization and Maintenance of Complete Animal Feed Block Making Technologies	January 3-10, 2017	2
Division of Agricultural Economics		
Impact Assessment of Agricultural Technology	December 14, 2016- January 3, 2017	25
Division of Agricultural Extension		
International Training on Agricultural Knowledge Management through Innovative Communication Interventions	May 31 - June 20, 2016	7
ICAR short course on Developing Agribusiness Skills among Farmers for Maximizing Income	July 11-20, 2016	21
Enhancing Personal Effectiveness for Job Performance for Skill Supporting Staff	July 21-29, 2016	30
CAFT on Information Communication Technology Mediated Agricultural Extension	August 2-22, 2016	25
CAFT on Enhancing Training and Teaching-Learning Competencies through Innovative Educational Methodologies and Instructional Technologies	November 30 - December 20, 2016	22
Agricultural Knowledge Management Unit		
Workshop on Krishikosh –An Institutional Repository Tool for Dissemination of Agricultural Knowledge at Prof. Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad	September 29, 2016	50
Workshop on Exploring Krishikosh Repository to Disseminate Agricultural Knowledge for the ICAR Institutes/SAUs in Northern and Western region of India at CCS HAU, Hisar, Haryana	December 6-7, 2016	80
Training on ICT Application in Agriculture" for Technical Staff of ICAR Institute	January 9-13, 2017	25
Training cum Sensitization Workshop on Krishikosh Repository –a Tool for Strengthening Agricultural Knowledge	January 27, 2017	150
Strengthening the Krishikosh a Digital Repository at PAU, Ludhiana	March 3, 2017	15
Training on Application of Bioinformatics Tools in Agriculture	March 6-8, 2017	25
Division of Agricultural Physics		
Imaging Spectroscopy and Applications	December 20-24, 2016	150
Eighteenth IIRS Outreach Programme on Basics of Remote Sensing, GIS & GNSS	August 22 - November 18, 2016	31

Name of the training programme	Dates/Month	No. of trainees
Nineteenth IIRS Outreach Programme on Remote Sensing and GIS Application in Carbon Forestry	February 16 - March 10, 2017	45
Division of Agronomy		
Recent Innovations in Management of Organic Production Systems	August 2-25, 2016	25
Recent Innovations in Organic Farming	January 2-9, 2017	25
Good Agricultural Practices (GAPs) for Enhancing Resource-use Efficiency and Farm Productivity	February 14-27, 2017	26
Model Training Course on Conservation agriculture for enhancing crop productivity and resource-use efficiency	February 20-27, 2017	20
ICAR Summer Training on Layout and Maintenance of Field Experiments and Recording Observations	March 18–27, 2017	25
Division of Biochemistry		
Training for Technical staff of ICAR on Extraction, Estimation and Characterization of Biomolecules from Plant Samples	December 3-8, 2016	14
CAFT on Advanced Omics – Techniques and Tools for Crop Improvement	March 8-28, 2017	21
Centre for Environment Science and Climate Resilient Agriculture		
Training on Appropriate Sampling Techniques including Sample Preparation and Preservation of Soil, Water, Plant and Air Samples for Various Analyses for the Technical Staff of ICAR	February 6-11, 2017	25
Centre for Protected Cultivation and Technology		
Water Management	October 2016	15
Hi -Tech Horticulture (Production of Fruit, Flower and Vegetable)	November 2-6, 2016	50
Protected Cultivation	November 7, 2017	50
Protected Cultivation Technologies	November 27-30, 2016	35
Protected Cultivation	December 15-16, 2016	51
More Profit from Protected Cultivation	February 14-15, 2017	30
Division of Entomology		
Identification of Insect Pests/ Vectors/ their Damaging Symptoms and Management	December 1-14, 2016	20
Division of Floriculture & Landscaping		
Commercial Cultivation of Flower Crops	February 24-28, 2017	12
Division of Fruits and Horticultural Technology		
Model Training on Good Agricultural Practices (GAP) for Horticultural Crops	October 19-26, 2016	25
Winter School on Recent Advances in Breeding Approaches and Varietal Development of Perennial Horticultural Crops	January 12 - February 1, 2017	25
Division of Microbiology		
Training on Biofertilizers (VAM Production, Compost Production) for Licensees	2016-2017	8
Division of Plant Physiology		
Training for Technical Staffs of ICAR Institute on Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants	January 16-25, 2017	20
Division of Soil Science and Agricultural Chemistry		
13th Advanced Level Training on Soil Testing, Plant Analysis and Water Quality Assessment	November 29 - December 19, 2016	15
Soil Health Management for Sustaining Crop Production and Farm Profit	December 22-29, 2016	19
Training on Instrumentation Techniques for Analysis of Soil, Plant and Water	February 13-22, 2017	21
Training on Advanced Tools and Techniques for Analysis of Micro- and Secondary Nutrients and Pollutant Elements	March 3-12, 2016	23

Name of the training programme	Dates/Month	No. of trainees
Water Technology Centre		
Training on Soil and Water Management for Afghanistan staff	March 9- April 21, 2016	3
Training on Soil and Water Conservation for Developing Hill Agriculture of Nainital district by ATMA	July 14-16, 2016	25
Training for Technical Staff of ICAR on Fundamental Concepts and Methodologies for Agricultural Water Management	December 19-24, 2016	25
Training on Precision Farming Technologies, Water Management	5 Trainings	207
Farmers Awareness Program on Precision Farming Technologies to Improve Crop Production and Water Use Efficiency	17-Awareness Program	581
Field Day for Farmers	4 Field Day	242
Regional Station, Indore		
Training on Recording of Data in Coordinated Wheat Trials and Nurseries	March 1-2, 2017	19
Crop and Seed Production Technology to Farmers		~4100 farmers
Regional Station, Pusa, Bihar		
Crop and Seed Production Technologies under Changing Climate Scenario	March 23-29, 2017	20
Regional Station, Karnal		
Farmers' Training for Members of *Krishi Vistar avum Mahila Utthan Samiti,* Karnal	August 26, 2016	30
Short Course Training on Advances in Variety Maintenance and Quality Seed Production for Entrepreneurship	February 14-23, 2017	21
Three trainings for farmers under Seed Village Programme during *Kharif* season on different aspects of quality seed production	*Kharif* 2016	51
Regional Station, Katrain		
Farmers Training Programme	December 29-30, 2016	25
Cauliflower Day for Popularization of Cauliflower Hybrids Developed at the Station	February 22, 2017	60
Regional Station, Kalimpong		
Training on Organic Farming and Protected Cultivation of Horticultural Crops, ATMA, Maharashtra	November 22, 2016	30
Multi Cropping, RSETI, Central Bank of India	February 2-8, 2017	30
Advance Organic Farming Technologies and Practices for Sustainable Agriculture, ATMA, Uttar Dinajpur	March 22-26, 2017	60
Production of Organic Fruit and Vegetables, Sonada	March 8-12, 2017	30
Organic Production of Mandarin Orange, Nursery Development, Pokhriabong, PDDUUKSY, ICAR	March 15-19, 2017	30
Commercial Vegetable Seed Production, Mungpoo, PDDUUKSY, ICAR	March 16-20, 2017	30
Organic Production of Large Cardamom, SIRI, Cattle Breeding, Vermicomposting, Sittong, PDDUUKSY, ICAR	March 17-21, 2017	30
Organic Production of Vegetables, Pudung, PDDUUKSY, ICAR	March 18-22, 2017	30
Master Training on Quality Improvement of Large Cardamom and Ginger, Spice Board, Kalimpong	December 7, 2016	25
Zonal Technology Management and Business Planning & Development Unit		
Plant Tissue Culture	November 28-December 3, 2016	11
Agripreneurship Development Programme on Soil Fertility Evaluation and Nutrient Management for Enhancing Crop Productivity and Soil Health	November 15-20 2016, and November 21-26, 2016	44
IMC, Directorate		
MDP Training for Procurement of Goods, Especially in Import of Goods by Indian Institute of Foreign Trade (Deemed University), New Delhi	November 7-9, 2016 & November 16-18, 2016	73

18.1.1 Training Programmes Organized by the Institute's Centre for Agricultural Technology Assessment and Transfer (CATAT)

In all, 21 on-campus training programmes were organized for agriculture officials and progressive farmers from different states. These programmes were attended by 295 participants from Bihar, Gujarat, Assam, Himachal Pradesh, Madhya Pradesh, Jharkhand, West Bengal, Uttarakhand, Rajasthan, UP, Haryana and NCR Delhi. One training programme was also organized by IARI for 15 representatives of VOs and SAUs/ICAR partners of collaborative programme on 'Good Agricultural Practices and Post-Harvest Processing'.

18.1.2 Trainings for Different Target Groups at Institute's *KVK*, Shikohpur, Gurugram

Trainings were organized for different target groups at Institute's *KVK*, Shikohpur, Gurugram 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. A total of 19 skill development trainings were organized for farmers and farm women in which 407 trainees participated. A total of 63 short duration trainings for farmers, farm women and rural youth were organized and 1217 beneficiaries participated in these programmes.

18.1.3 Other Capacity Building Activities

The Institute's CATAT also conducted several capacity building activities i.e., trainings on application of bio-fertilizers, soil testing and nutrient management, household nutrition and hygienic practices, nutrition garden, improved agricultural practices for climate change, soil and water mapping, *Swachh Bharat Abhiyan*, an awareness about stubble burning and agro-advisory campaign at IARI Model Villages and other locations. Besides two hundred & fifty soil health cards were also distributed to the farmers in Rajpur village, Aligarh district (U.P.).

Trainings for different target groups at *KVK*, Shikohpur

Sl. No.	Type of training with target groups	No. of trainings	No. of beneficiaries		
			Male	Female	Total
1.	Vocational trainings for rural youth and girls	19	251	156	407
2.	Day long On/Off campus trainings for practicing farmers and farm women 1. On Campus 2. Off campus	24 39	455 521	22 219	477 740
3.	In-Service (refresher course) trainings for field extension functionaries	8	128	20	148
	Total	**90**	**1355**	**417**	**1772**

19. MISCELLANY

I. Ongoing Projects at IARI as on 31.3.2017

(A)	**In-house Research Projects**	**47**
	School of Crop Improvement	14
	School of Horticultural Sciences	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)	**Flagship Programmes**	**04**

II. Scientific Meetings Organized

a)	Workshops	27
b)	Seminars	21
c)	Summer institutes/Winter school	1
d)	Farmers' day (s)	68
e)	Others	195
	Total	**312**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	377
b)	Scientific meetings	295
c)	Workshops	204
d)	Symposia	165
e)	Others	130
	Total	**1171**

Abroad

a)	Seminars	10
b)	Scientific meetings	9
c)	Workshops	3
d)	Symposia	9
e)	Others	7
	Total	**38**

IV. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel

Academic Council

- Seven new courses such as: (i) Climate Smart Agriculture (ES 511); (ii) International Agriculture (PGS 507); (iii) Advances in Breeding for Stress Resistance in Vegetable Crops (VSC 623); (iv) Advances in Breeding for Quality and Special Traits in Vegetable Crops (VSC 624); (v) Introduction to Emerging Agricultural Techniques (AG Ext 560); (vi) Advances in Instructional Technology (AG Ext 607); and (vii) Quantitative Techniques for Social Research (AG Ext 608) were added to the PG School course curriculum.
- Initiation of Integrated M.Sc./Ph.D. programme initially in Molecular Biology & Biotechnology after seeking approvals from the Council and UGC.

Research Advisory Committee

1. School of Crop Improvement

- More emphasis needs to be laid on strategic research keeping in view the priorities of national and international importance including nutritional quality enhancement in addition to the applied research on technological innovations.
- More efforts are needed to work out the genetic control of the biotic and abiotic stress resistance

for isolation/characterization of the gene(s) or QTLs responsible on priority in crops where successful breeding interventions have not been possible.

2. School of Horticulture

- Modalities should be worked out in consultation with Director (Horticulture) of states for release of state varieties in horticultural crops.
- Edible vegetable seeds such as pumpkin should be analysed for nutritional qualities and processing possibilities be explored for the potential ones. Seed of vegetable as breakfast ingredient must be considered.

3. School of Natural Resource Management

- The mechanism of increased harvest index and other physiological traits by use of Pusa Hydrogel should be worked out under limited irrigation or rainfed conditions.
- The mode of action (physical and biological) and basis of sustainability of waste water treatment plant is not yet worked out, a requirement for it to be commercialized/replicated.
- There is a need to make a water and Nitrogen balance sheet and shift from recommended dose of fertilizer for traditional and conservation agriculture, with an emphasis on water saving strategies and fertilizer placement method.
- To avoid labour and transportation, methods should be devised for degrading crop residues *in situ* i.e., where it falls.

4. School of Crop Protection

- The technologies having potential for commercialization should be highlighted for better visibility and dissemination. We must try to commercialize the technology timely like private sectors commercialize their technologies.
- Need based problems having wider implications like whiteflies and their resistance to many pesticides or nematodes in vegetable crops must be addressed, with an emphasis on developing nematicidal formulations for major crops like direct seeded rice (DSR), rainfed wheat, maize, *bajra*, etc.

5. School of Basic Sciences

- Genotypes which use Nitrogen efficiently should be identified and their metabolic pathways, genomics and physiological adaptations at molecular level involved in nitrogen use efficiency (NUE) should be studied in collaboration with soil scientists.
- Research work on proteomics and transcriptomics to understand the mechanism of flowering in pigeonpea and chickpea should be strengthened for enhancing the pulse productivity.
- Field facility for screening the abiotic stress should be created and validation of the pot culture experiments requires to be done under field condition for all the experiments for getting realistic results.

6. School of Social Sciences

- The impact assessment and technological efficiency of programmes should be studied along with e-marketing related studies on pricing and quality issues.
- Efforts for out scaling of technologies through PPP mode be made so that impact is on larger scale in short time.
- The study of seed chain from research to farmer's field is important. Network on selling of seeds should be established for its strengthening.
- The feedback on the learning from farmers should be collated and published based on farm size (small, medium, large), farming system (sole, mixed, inter cropping), input type (organic, inorganic), resources availability (rich, poor), water (irrigated, rainfed), type of cultivation (open field, protected), crop (field crop, vegetable, flowers, fruits) for better interpretation of results.

7. Post Graduate School Activities

- RAC opined that ICAR should be approached for provision for utilizing HRD funds for Post-

Doctoral fellowship and international visits by scientists, funds for dedicated overseas-associateship programme for faculty upgradation and one time seed grant for newly joined scientists.

- The need of more funds for carrying out practical and better hostel facilities was emphasized.

8. Administrative and Financial Activities

- Changes made in financial management for its betterment during the last year should be presented.
- Tracking/monitoring of files movement should be adhered to. Piecemeal objections should be discouraged.
- Guest lectures by inviting experts from institute like NIFM may be arranged for DDOs, finance and audit personnel.

Extension Council

- A team for utilization of fellow farmers and innovative farmers experience in IARI research and extension programme to be formulated. The team will suggest effective/ meaningful utilization of farmers' resources and methodology of learning exchange by the various Head of Divisions and Regional Stations for strengthening farmers' participation in technology testing and dissemination.
- A meeting of all HODs with Jt. Director (Extension) and Social Science School Coordinator to decide which technology has to go in which type of extension model and to plan and monitor extension interventions by the Divisions.
- Standing committee has to be set up to report success stories/ technologies available and to decide which technology extension system will transfer to social system

V. Resource Generation

1) Consultancy & other services

Consultancy services:	nil
Contract research:	₹22,56,622
Contract service:	₹ 5,42,959
Training:	₹1,75,000
Total (A):	₹29,74,581

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed:	₹4,04,51,089
(b) Commercialization:	₹5,13,151
(c) Prototype manufacturing:	₹7, 22,926
Total (B):	₹4,16,87,166

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 : ₹54,60,395

(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. : ₹72,79,876

(d) Cash transferred from Syndicate Bank to Directors Account No. C-49 (9029.305.17) from sale of Information Bulletin through DD : Nil

(e) 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): ₹1,29,770

Total (C) : ₹128,70,041

Grand Total (A+B+C) : ₹29,74,581 + ₹4,16,87,166 + ₹128,70,041= **₹5,75,31,788**

VI. Infrastructural Development

- Strengthening of Divisional Laboratory of Vegetable Science with new molecular laboratory and environmentally controlled polyhouses and insect-proof net house. Installation of two new tubewells and development of drainage and sub-drainage channels and fencing of vegetable farm area.

- Creation of office cum laboratory building at Amartara Cottage, Shimla and farmers Training Hall at Dhanda Farm of ICAR-IARI Regional Station, Shimla.
- Construction of internal roads in research farm area and residential quarters at ICAR-IARI, Regional Station, Pune.
- Strengthening of Divisional Laboratory and workshop of Agricultural Engineering with instruments and design centre and farm machinery testing facilities.
- Modernization of seminar hall cum meeting room, construction of a high tech green house, renovation of farmers guest house, library and computer lab at ICAR-IARI (RS), Kalimpong.

VII. All India Coordinated Research Projects in Operation during the period April 1, 2016 to March 31, 2017

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 Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
6. All India Coordinated Research Project on Biological Control of Crop Pests and Weeds
7. All India Coordinated Research Project on Soybean
8. All India Coordinated Research Project on Sub-Tropical Fruits
9. All India Coordinated Research Project on N.S.P. (Crops)
10. All India Coordinated Research Project on Mustard
11. All India Coordinated Research Project on Wheat
12. All India Coordinated Research Project on Rice
13. All India Coordinated Research Project on Pulses
14. All India Coordinated Research Project on Vegetable
15. All India Coordinated Research Project on Pearl millet
16. AINP on White grubs and other Soil Arthropods (AINPWOSA)
17. All India Coordinated Wheat & Barley Improvement Project (AICW&BIP)
18. Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)
19. AICRP on Vegetable Crops
20. Adhoc Cooperating Center of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal
21. All India Coordinated Research Project on Ergonomics & Safety in Agriculture (ESA)

VIII. Foreign visitors during the period April 1, 2016 to March 31, 2017

S. No.	Visitor (s)	Date of visit
1.	A delegation led by H.E. Uri Ariel, Agriculture & Rural Development Minister, Israel	6.4.2016
2.	A delegation from Democratic People's Republic of Korea	27.4.2016
3.	Visit of H.E. Gen Candido Pereira Dos Santos Van-Dunem, Minister of Former Combatants & Veterans of the Homeland, Republic of Angola	5.5.2016
4.	A 5- member delegation from Bhutan	17.5.2016
5.	A delegation led by H.E. Afonso Pedro Canga, Minister of Rural Development, Republic of Angola	25.5.2016
6.	A 15- member delegation from BRICS	28.6.2016
7.	A 4- member delegation from Sudan	5.9.2016
8.	A 16- member delegation of the legislative and Executive Arms of the Federal Government of Nigeria	20.10.2016
9.	A 27- member of delegation of Sri Lanka	18.11.2016
10.	A 12- member delegation from Norway	15.2.2017
11.	A 11- member student delegation from Colorado	15.3.2017

A Norwegian delegation interacting with IARI team

A Sudanese delegation interacting with IARI team

Appendix 1

Members of Board of Management of IARI

(As on 31.3.2017)

Chairman

Dr. J.S. Sandhu
Director (Add. Charge), 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

Sh. Alok Kumar Gupta
Chairman/President,
Surabhi Foundation, New Delhi

Shri Ratneswari Prasad Singh
Village Ratnapur, Post Badahrwa
Dist Sitamarhi, Bihar

Dr. B.S. Tomar
Head
Division of Vegetable Science, IARI

Dr. I.M. Mishra
Head
Division of Agricultural Engineering, IARI

Dr. Anjani Kumar
PC, KVK, Shikohpur

Dr. A.K. Singh
Head, Division of Genetics, IARI

Dr. D.K. Yadava
Head
Division of Seed Science and Technology, IARI

Dr. S.K. Sharma
Head
IARI Regional Station, Pune

Dr. Premlata Singh
Head (Acting)
Division of Agricultural Extension, IARI

Dr. S.K. Singh
Head
Division of Fruits and Horticultural Technology, IARI

Dr. M. Premjit Singh
Vice Chancellor
Central Agricultural University, Imphal, Manipur

Agriculture Commissioner
Deptt. of Agril. and Cooperation, Ministry of Agriculture, Krishi Bhawan, New Delhi

Dr. Ajoy Kumar Singh
Vice Chancellor
Bihar Agricultural University, Sabour, Bhagalpur, Bihar

Dr. Chandan Hazarika
Director
PG Studies, Assam Agricultural University, Jorhat, Assam

Shri Ojing Aje
Village-Ngorlung Post Ruksin,
East Siang, Arunachal Pradesh

Smt. Krishna Yadav
Gurugram, Haryana

AS&FA, ICAR or his nominee not below the rank of DD(F)

Development Commissioner
of Delhi Administration

Member - Secretary

Smt. Shashi Prabha Razdan
Registrar & Joint Director (Adm.), IARI

Appendix 2

Members of Research Advisory Committee of IARI

(As on 31.03.2017)

Chairman

Dr. P.L. Gautam
Former Deputy Director General
(Crop Science) & Former
Chairperson, PPV&FRA

Members

Dr. B. Mishra
Former VC
Sher-e- Kashmir University
of Agricultural Sciences and
Technology, Jammu

Dr. S.P. Ghosh
Former Deputy Director General
(Horticulture), ICAR
New Delhi

Dr. C. L. Acharya
Former Director
Indian Institute of Soil Science
(ICAR), Bhopal

Dr. R. Khetarpal
Regional Director (South Asia)
CABI, CG Block, NASC Complex
DPS Marg, New Delhi

Dr. K.R. Koundal
Former Joint Director (Research)
IARI, New Delhi

Dr. P.K. Joshi
Former Director
NCAP & NAARM and Director,
South Asia, IFPRI, South Asia
Regional Office, New Delhi

Dr. J.S. Sandhu
Deputy Director General
(Crop Science), ICAR
Krishi Bhawan, New Delhi

Dr. J.S. Sandhu
Director (Add. Charge)
IARI

Member – Secretary

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

Appendix 3

Members of Academic Council of IARI

(As on 31.03.2017)

Chairman

Dr. J.S. Sandhu
Director (Add. Charge), IARI

Vice-Chairman

Dr. R.K. Jain
Dean & Joint Director (Edn.), IARI

Members

Dr. N.S. Rathore
Deputy Director General
(Education), ICAR

Dr. Kuldeep Singh
Director, NBPGR

Dr. N.K. Singh
Director (Acting), NRCPB

Dr. U.C. Sud
Director, IASRI

Dr. P.K. Mishra
Director, IISWC, Dehradun

Dr. K.K. Singh
Director, CIAE, Bhopal

Dr. M.R. Dinesh
Director, IIHR, Bengaluru

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

Dr. J.P. Sharma
Joint Director (Extn.), IARI

Dr. C. Ramasamy
Former Vice Chancellor, TNAU
9/12, 5th Cross, Ramalingam Nagar
K.K. Pudur, Coimbatore, Tamilnadu

Dr. J.S. Samra
Former CEO, National Rainfed
Area Authority
H. No. 262, First Floor
Sector 33 A, Chandigarh-160020

Dr. H.S. Gaur
Former VC, SVPUAT, Meerut
27/109/4B/1A, Jawala Nagar,
Shahdara, Delhi

Dr. S.K. Datta
Former DDG(CS), ICAR
Flat No. 020302, 1050/1
Sarvey Park, Kolkata

Dr. Man Singh
Project Director (Acting)
Water Technology Centre

Dr. K.M. Manjaiah
Associate Dean, PG School

Dr. (Ms.) Irani Mukherjee
Professor, Agricultural Chemicals

Dr. (Ms.) Alka Singh
Professor, Agricultural Economics

Dr. D.K. Singh
Professor, Agricultural Engineering

Dr. R.N. Padaria
Professor, Agricultural Extension

Dr. V.K. Sehgal
Professor, Agricultural Physics

Dr. (Ms.) Seema Jaggi
Professor, Agricultural Statistics

Dr. Y.S. Shivay
Professor, Agronomy

Dr. (Ms.) Aruna Tyagi
Professor, Biochemistry

Dr. A.R. Rao
Professor, Bioinformatics

Dr. Sudeep Marwaha
Professor, Computer Application

Dr. Subhash Chander
Professor, Entomology

Dr. Soora Naresh Kumar
Professor, Environmental Sciences

Dr. K.P. Singh
Professor, Floriculture and
Landscaping

Dr. S.K. Jha
Professor, Post Harvest Technology

Dr. O.P. Awasthi
Professor, Fruits and Horticultural
Technology

Dr. Vinod
Professor, Genetics

Dr. Sunil Pabbi
Professor, Microbiology

Dr. R.C. Bhattacharya
Professor, Molecular Biology and
Biotechnology

Dr. Anil Sirohi
Professor, Nematology & Master of
Halls of Residences

Dr. (Ms.) Rekha Chaudhury
Professor, Plant Genetic Resources

Dr. V.K. Baranwal
Professor, Plant Pathology

Dr. V.P. Singh
Professor, Plant Physiology

Dr. S.K. Jain
Professor, Seed Science & Technology

Dr. S.P. Datta
Professor, Soil Science & Agricultural Chemistry

Dr. T.K. Behera
Professor, Vegetable Science

Dr. Man Singh
Professor, Water Science & Technology

Mr. Sanchal Bilgrami
Comptroller

Dr. B.S. Tomar
Head, Vegetable Science

Dr. Bhupinder Singh
Principal Scientist, CESCRA

Ms. Usha Khemchandani
Incharge, Prof. M.S. Swaminathan Library

Mr. Bhoopesh Punera
President, PGSSU

Ms. Anu Kumari
Students' Representative to the Academic Council

Member-Secretary

Ms. Shashi Prabha Razdan
Registrar & Joint Director (Admn.)

Appendix 4

Members of Extension Council of IARI

(As on 31.3.2017)

Chairperson

Dr. J.S. Sandhu
Director (Add. Charge)
IARI, New Delhi

Members

Dr. A.K. Singh
DDG (Extension)
ICAR, KAB-I, PUSA, New Delhi

Dr. J.P. Sharma
Joint Director (Extension)
IARI, New Delhi

Dr. K.V. Prabhu
Joint Director (Research)
IARI, New Delhi

Ms. Shashi Prabha Razdan
Joint Director (Admn.)
IARI, New Delhi

Dr. A.K. Singh
Head
Division of Genetics, IARI
New Delhi

Dr. B.S. Tomar
Head
Division of Vegetable Sciences
IARI, New Delhi

Dr. Anupama
Head
Division of Agricultural Chemicals
IARI, New Delhi

Dr. V.K. Singh
Head
Division of Agronomy, IARI
New Delhi

Dr. D.K. Yadava
Head
Division of Seed Sci. & Tech, IARI
New Delhi

Dr. Indramani
Head
Division of Agricultural Engg.
IARI, New Delhi

Dr. B.S. Dwivedi
Head
Division of SS&AC., IARI
New Delhi

Dr. V.K. Baranwal
Professor
Plant Pathology, IARI
New Delhi

Dr. Sanjay Kumar
I/c Seed Production Unit, IARI
New Delhi

Project Director, WTC, IARI
New Delhi

Dr. V.K. Pandita
Head
IARI Regional Station
Karnal-132001

Dr. S.K. Malhotra
Agril. Commissioner, DOAC
MOA, Krishi Bhavan
New Delhi

Mr. A.P. Saini
Jt. Director (Agril.), Delhi
Development Deptt, 11th Floor
MSO Building IP estate, ITO
New Delhi

Mr. P. Sreekanth
Director (Agril. Mktg.) Delhi
Dev. Deptt. 49, Shamnath Marg
Old. Sectt., Delhi

Dr. K. Ponnusamy
Principal Scientist
Dairy Extension Division
NDRI, Karnal-132001

Dr. Shailesh Mishra
Director (FI)
Directorate of Extension,
Krishi Vistar Sadan, Behind Agro.
Division, IARI Campus New Delhi

Member-Secretary

Dr. Premlata Singh
Head
Division of Agricultural Extension
IARI, New Delhi

Appendix 5

Members of Institute Research Council (IRC)

(As on 31.03.2017)

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 6

Members of Institute Joint Staff Council (IJSC)

(As on 31.3.2017)

Chairman

Dr. J.S. Sandhu
Director (Add. Charge), IARI

Members (Official Side)

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

Dr. J.P. Sharma
Joint Director (Extension)

Dr. Alka Singh
Professor, Agricultural Economics

Dr. Anil Sirohi
Professor, Nematology

Mr. Sanchal Bilgrami
Comptroller

Secretary (Official Side)

Ms. Shashi Prabha Razdan
Registrar & Joint Director (Admn.)

Members of the Staff Side (Elected)

Mr. Satyendra Kumar
AAO, Division of Vegetable Science

Mr. Yogesh Kumar
Assistant, Division of Plant Pathology

Mr. Radhey Krishan Thakur
UDC, Directorate, IARI

Mr. Raj Kumar
UDC, Directorate

Mr. Veer Pal Singh
Technical Officer, CPCT

Mr. Ganesh Rai
Technical Assistant
Division of Entomology

Mr. Shrawan Kumar
Technical Assistant, AKMU

Mr. Shiv Kumar Singh
Technical Assistant
Division of Plant Pathology

Mr. Umesh Thakur
Skilled Support Staff
Audit, Directorate

Mr. Raj Pal
Skilled Support Staff, Directorate

Mr. Shashi Kant Kamat
Skilled Support Staff
Seed Production Unit

Secretary (Staff Side)

Mr. Bijender Kumar
Skilled Support Staff
CATAT

Appendix 7

Personnel

(As on 31.03.2017)

Directorate

Director (Add. Charge)
Dr. J.S. Sandhu

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

Dean & Joint Director (Education)
Dr. R.K. Jain

Joint Director (Extension)
Dr. J.P. Sharma

Joint Director (Admn.) & Registrar
Mrs. Shashi Prabha Razdan

Principal Scientist (PME)
Dr. M. Jayanthi

Incharge, Publication Unit
Dr. R.K. Sharma

Comptroller
Mr. Sanchal Bilgrami

Chief Administrative Officers
Mr. Pushpendra Kumar
Mr. M.K. Jain

Agricultural Chemicals

Head
Dr. Anupama

Professor
Dr. Irani Mukherjee

Network Project Coordinator
Dr. K.K. Sharma

Agricultural Economics

Head (Acting)
Dr. Amit Kar

Professor
Dr. Alka Singh

Agricultural Engineering

Head
Dr. Indra Mani

Professor
Dr. D.K. Singh

Agricultural Extension

Head (Acting)
Dr. Prem Lata Singh

Professor
Dr. R.N. Padaria

Agricultural Physics

Head
Dr. P. Krishnan

Professor
Dr. V.K. Sehgal

Agronomy

Head
Dr. V.K. Singh

Professor
Dr. Y.S. Shivay

Biochemistry

Head
Dr. Shelly Praveen

Professor
Dr. Aruna Tyagi

Entomology

Head
Dr. Chitra Srivastava

Professor
Dr. Subhash Chander

National Fellow
Dr. G.K. Mahapatro

Floriculture and Landscaping

Head
Dr. S.S. Sindhu

Professor
Dr. K.P. Singh

Fruits and Horticultural Technology

Head
Dr. S.K. Singh

Professor
Dr. O.P. Awasthi

Genetics

Head
Dr. A.K. Singh

Professor
Dr. Vinod

Microbiology & CCUBGA

Head
Dr. Annapurna K.

Professor
Dr. Sunil Pabbi

Nematology

Head
Dr. Uma Rao

Professor
Dr. Anil Sirohi

Project Coordinator
Dr. Raman Kumar Wallia

Plant Pathology

Head
Dr. Rashmi Aggarwal

Professor
Dr. V.K. Baranwal

Plant Physiology

Head
Dr. C. Viswanathan

Professor
Dr. V.P. Singh

Food Science & Post Harvest Technology

Head (Acting)
Dr. Vidya Ram Sagar

Professor
Dr. S.K. Jha

Seed Science and Technology

Head
Dr. D.K. Yadava

Professor
Dr. S.K. Jain

Soil Science and Agricultural Chemistry

Head (Acting)
Dr. B.S. Dwivedi

Professor
Dr. S.P. Datta

Vegetable Science

Head
Dr. B.S. Tomar

Professor
Dr. T.K. Behera

Centre for Environment Science and Climate Resilient Agriculture (CESCRA)*

Head (Acting)
Dr. S.D. Singh

Professor
Dr. Naresh Kumar

Water Technology Centre

Project Director (Incharge)
Dr. Man Singh

Professor
Dr. Man Singh

Centre for Agricultural Technology Assessment and Transfer

Incharge
Dr. B.K. Singh

Centre for Protected Cultivation Technology

Incharge
Dr. Neelam Patel

Agricultural Knowledge Management Unit (AKMU)

Incharge
Dr. A.K. Mishra

Agricultural Technology Information Centre (ATIC)

Incharge
Dr. N.V. Kumbhare

Farm Operation Service Unit

Incharge
Dr. Manoj Khanna

National Phytotron Facility

Incharge
Dr. Akshay Talukdar

Seed Production Unit

Incharge
Dr. Sanjay Kumar

Zonal Technology Management & Business Planning and Development (ZTM & BPD) Unit

Incharge
Dr. Neeru Bhooshan

IARI Library

Incharge (Library Services)
Ms. Usha Khemchandani

IARI Regional Station, Amartara Cottage, Shimla

Head (Acting)
Dr. K.K. Pramanick

IARI Regional Station, Indore

Head
Dr. S.V. Sai Prasad

IARI Regional Station, Kalimpong

Incharge

Dr. Dwijendra Barman

IARI Regional Station, Karnal

Head

Dr. V.K. Pandita

IARI Regional Station, Katrain

Head

Dr. Raj Kumar

IARI Regional Station, Pune

Head (Acting)

Dr. S.K. Sharma

IARI Regional Station, Pusa

Head (Acting)

Dr. Ashish Kumar Gupta

IARI Regional Station, Wellington (The Nilgiris)

Head

Dr. M. Sivaswamy

IARI Rice Breeding & Genetics Research Centre, Aduthurai

Incharge

Dr. M. Nagarajan

IARI Centre for Improvement of Pulses in South, Dharwad

Incharge

Dr. B.S. Patil

IARI Krishi Vigyan Kendra, Shikohpur, Gurugram

Incharge

Dr. Anjani Kumar

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*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.