ISSN 0972-6136

Annual Report
2017-18

ICAR-Indian Agricultural Research Institute
New Delhi-110012

Annual Report
2017-18

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

Printed : *July, 2018*

Supervision and Guidance

Dr. A.K. Singh
Director (Add. Charge)

Dr. J.P. Sharma
Joint Director (Research) (Add. Charge)

Compilation Committee and Editorial Team

Dr. C.Viswanathan, Dr. Rashmi Aggarwal, Dr. S.K. Singh, Dr. Premlata Singh, Dr.Vinod, Dr. S.P. Datta, Dr. K.M. Manjaiah, Dr. R.K. Sharma, Dr. S.S. Sindhu, Dr. Kehar Singh and Mr. D.K. Parashar

Correct citation: IARI. Annual Report 2017-18, Indian Agricultural Research Institute, New Delhi – 110 012, India.

Copies printed: 1000

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 M. S. Printers, C-108/1 Back Side, Naraina Industrial Area, Phase-1, New Delhi-110024

Mob: 7838075335, 9990785533, 9899355565, Tel.: 011-45104606 E-mail: msprinter1991@gmail.com

PREFACE

The Indian Agricultural Research Institute (IARI) maintained its leadership position in agricultural research, education and extension in India. To address the emerging needs of the farmers and consumers, IARI has developed several economically and environmentally sustainable technologies during this year for enhancing food and nutritional security, agricultural exports and farm profit. During 2017-18, the Institute has developed new crop varieties/hybrids with improved yield, quality and climate resilience, crop and natural resource management technologies and new farm machineries with enhanced input use efficiency and minimal global warming potential. During this year, 31 innovative technologies of IARI were transferred to 14 industry partners.

Crop improvement programme of the wheat employed cutting edge genomics and molecular breeding approaches for development and release of twelve improved varieties of food crops with enhanced yield, quality, and tolerance to biotic and abiotic stresses. High yielding and superior quality wheat varieties one each in bread (HI1612) and durum (HI 8777) wheat were released for commercial cultivation in North Eastern Plains Zone and Peninsular Zone, respectively. HI1612 has a potential yield of 5.05 t/ha and possesses adult plant resistance to leaf and stripe rusts, and moderate resistance to leaf blight, Karnal bunt, *Fusarium* head blight and loose smut. HI 8777 contains higher iron and zinc content in the grain and produces an average yield of 1.85 t/ha. The *Basmati* rice variety Pusa Basmati 1121 developed by the Institute has earned a cumulative value of ₹ 50 lakh crores during 2008-2016, and brought prosperity to millions of farmers. This year, an improved version of Pusa Basmati 1121 named Pusa Basmati 1718 was developed with inbuilt resistance to bacterial blight disease. This variety produces average yield of 4.64 t/ha and matures in 136-138 days.

In maize, the Institute has developed four maize hybrids, namely, Pusa Vivek QPM 9 Improved, Pusa HM 4 Improved, Pusa HM 8 Improved and Pusa HM 9 Improved by using marker-assisted introgression of genes for improved provitamin-A content and protein quality (high tryptophan and lysine). Pusa Vivek QPM 9 Improved, the first provitamin-A rich maize hybrid of the Country. In pearl millet, a dual purpose hybrid, Pusa 1201 ((MH 1849) with resistant to downy mildew and high grain yield (2.81 t/ha) and stover yield (7.20 t/ha) was released. A *desi* chickpea variety BG 3043 was released for timely sown conditions of NEPZ. This variety has an average yield of 1.6 t/ha and potential yield 2.5 t/ha. An extra early maturing (120 days) pigeon pea variety, Pusa Arhar 16, with average seed yield of 1.96 t/ha was released and notified for NCT, Delhi. It is compact semi-erect variety suitable for high density planting and harvesting by combine harvester. A mungbean variety, Pusa 1431 with maturity duration of 66 days was released for NCT Delhi. A lentil variety, L 4727, with an average yield of 1.15 to 1.45 t/ha was released for timely sown, rainfed conditions of Central Zone. The first double zero Indian mustard variety, Pusa Double Zero Mustard 31, which was released for NCT, Delhi during 2015, was released for Zone II (Punjab, Haryana, Delhi, Jammu and northern Rajasthan) this year.

The Institute has released 18 varieties/hybrids in vegetable and flower crops. In vegetable crops, two varieties each in brinjal (Pusa Hara Baingan 1 and Pusa Safed Baingan 1) and muskmelon (Pusa Madhurima & Pusa Sarda), one each in okra (Pusa Bhindi 5), *Chenopodium* (Pusa Green), cucumber (Pusa Seedless Cucumber 6), long melon (Pusa Utkarsh), round melon (Pusa Raunak) and garden pea (Pusa Prabal), and two F_1 hybrids, viz., one in bitter gourd (Pusa Hybrid 4) and one in sponge gourd (Pusa Shrestha) were released by Delhi State Seed Sub-Committee. In flower crops, six varieties were released by the State Seed Sub-Committee for Agriculture & Horticultural Crops, Govt. of NCT, Delhi. These were Pusa Mahak (rose), Pusa Bahar and Pusa Deep (marigold), Pusa Guldasta and Pusa Swet (chrysanthemum), and Pusa Sinduri (gladiolus). These varieties and hybrids are expected to benefit farmers and consumers.

The Crop and Natural Resource Management research at the Institute has developed several technologies for efficient resource management. Crop diversification studies showed that the highest system productivity was obtained from maize-potato-onion cropping system recording 34.7% higher system productivity, while babycorn-mustard cropping system resulted in highest net returns (₹ 106142 ha^{-1}) over traditional rice-wheat cropping system. Integrated farming system in 1.0 ha area was found to give a net return of ₹ 3.78 lakhs ha^{-1} $year^{-1}$. Global warming potential (GWP) of the different cropping systems was quantified and highest GWP were observed in maize-potato-onion system due to higher nitrous oxide emission. Carbon, nitrogen and water footprints of rice crop production under different water management practices were estimated.

Crop Protection has made significant progress in development of diagnostic protocols integrated management technologies for agricultural pests and pathogens of national importance. Weather based prediction model was

developed for *Helicoverpa armigera* in chickpea. Transgenic eggplants with *msp-18* and *msp-20* genes were developed for host-induced gene silencing in nematodes. For control of *Sclerotium rolfsii*, 6-flouro-3-iodo-chromen-4 one was found to the best compound. A new series of biogels and composites based on a natural gum and carboxymethylcellulose cross-linked with prestandardized organic acid were synthesized and characterized using XRD and FTIR.

The basic and strategic research programmes of the Institute has identified genes and mapped QTLs for yield, quality and adaptive traits. To bridge the phenotype-genotype gap, the Institute has established a *state-of-the art* plant phenomics facility. Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated and dedicated the "Nanaji Deshmukh Plant Phenomics Centre (NDPPC)" to the Nation on 11th October, 2017. For development of low phytate soybean, CRISPR-Cas9 technology was used to knockout *GmIPK1* gene and transient assays confirmed 6-7 fold reduction in phytate content in leaf. QTLs for biotic and abiotic stress tolerance were mapped in different crops. Total organic carbon of soil was assessed using AVIRIS-NG (Airborne Visible Infra Red Imaging Spectrometer - Next Generation) for mapping soil organic carbon and location specific model developed were used further for generating soil organic carbon map. Weather based agro-met advisory bulletins were issued in Hindi and English on every Tuesday and Friday. During 2017-18, total 102 agro-advisory bulletins were issued to benefit the farmers.

The Social Sciences and Technology Transfer programmes of the Institute has made significant progress in analyzing the influence of public investments, credit, farm mechanization, total factor productivity and diversification, and dissemination of IARI technologies and development of innovative extension models. Under IARI-Post Office Linkage Extension Model, the quality seeds of improved IARI varieties were disseminated. Under *Mera Gaon Mera Gaurav* programme IARI scientists have visited 600 villages, interacted with farmers and disseminated IARI technologies. Agricultural Technology Information Centers (ATIC) is effectively providing products, technologies, services and information services to the different stakeholders through a '*Single Window Delivery System*'. In ATIC, farm advisory services are also given through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), PusaAgricom 1800-11- 8989, exhibitions, farm literatures and letters. The Institute's *Krishi Vigyan Kendra* at Shikohpur, Gurugram, has conducted several extension activities for the speedy dissemination of technologies.

The National Agricultural Fair, *Krishi Unnati Mela* 2018 with a major theme of "*doubling farmers' income by 2022*" was organized at IARI, New Delhi during March 16-19, 2018 in collaboration with ICAR, DARE and DAC, Ministry of Agriculture and Farmers Welfare. The *mela* was inaugurated by Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh. Hon'ble Prime Minister of India, Shri Narendra Modi who inaugurated the *Jaivik Kheti* portal and laid the foundation stone of 25 KVKs besides launching an e-marketing portal for organic products on March 17, 2018. Hon'ble Prime Minister also gave the *Krishi Karman* Awards and the *Pandit Deen Dayal Upadhyaya Krishi Protsahan Puraskar*s. Over one lakh visitors and 500 public and private exhibitors from across the country participated and gained from the fair.

The Institute received ISO9001:2015 certificate for quality management system. The 56th Convocation of the Post Graduate School of the IARI was held on February 9, 2018. Hon'ble President of India, Shri Ram Nath Kovind graced the function as Chief Guest. During this Convocation, 237 candidates (133 M.Sc., 7 M.Tech. and 97 Ph.D.) were awarded degrees including 14 (12 M.Sc./ M.Tech. and 2 Ph.D.) international students.

I congratulate the scientists and students of the Institute who contributed to advance basic and strategic research, technology development, and received prestigious awards/recognitions and brought laurels to the Institute. The Institute's achievements during this year will have significant impact on increasing the farm income and food security of the Nation.

I express my appreciation to Dr. J.P. Sharma, Joint Director (Extension & Research) and the multidisciplinary editorial team for compiling and bringing out this report in time.

July 6, 2018
New Delhi-110012

(A.K. Singh)
Director

CONTENTS

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.

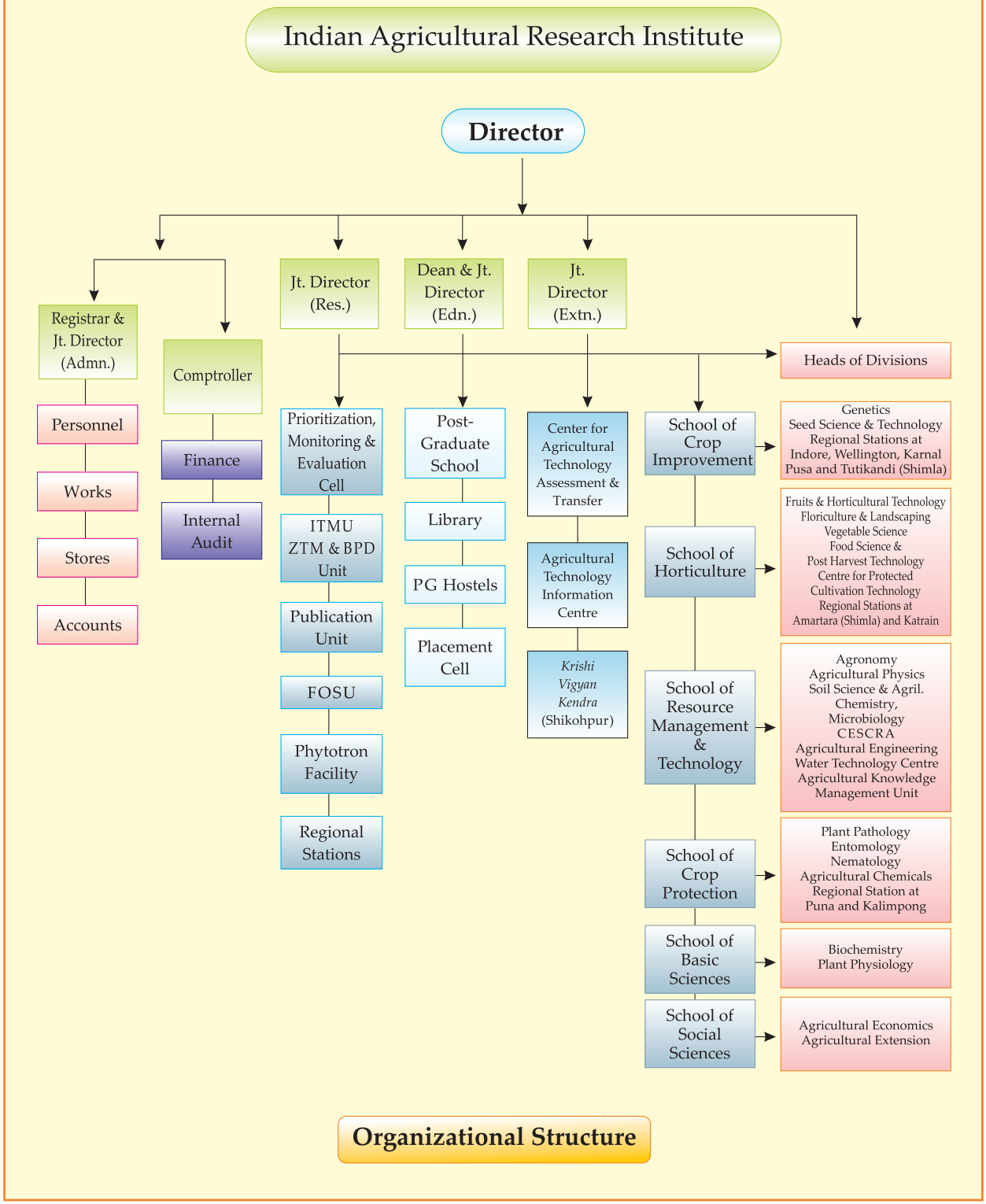
The growth of India's agriculture during the past more than 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout 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 2651 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹ 49729.15 lakh (Unified Budget) for the year 2017-18.



Organizational Structure

EXECUTIVE SUMMARY

The Indian Agricultural Research Institute (IARI) maintained its leadership role in research, education and extension. The Institute has employed cutting edge science to develop new varieties/hybrids, crop protection and management technologies, pest diagnostic methods, farm machineries and post-harvest technologies for enhancing farm income, resource use efficiency, productivity and environmental sustainability. The salient achievements of the Institute during 2017-18 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 2017-18. A bread wheat variety HI1612 with an average yield of 3.78t/ha and potential yield of 5.05 t/ha was released for commercial cultivation under timely sown, restricted irrigation conditions of North Eastern Plains Zone. This variety possesses adult plant resistance to leaf and stripe rusts, and moderate resistance to leaf blight, Karnal bunt, *Fusarium* head blight and loose smut. A durum wheat variety, HI 8777 with higher iron and zinc content and an average yield of 1.85 t/ha was released for timely sown rainfed conditions of Peninsular Zone. It possesses adult plant resistance to leaf and stem rusts, and resistance to Karnal bunt, loose smut, flag smut and foot rot. A *Basmati* rice variety Pusa Basmati 1718, a NIL of Pusa Basmati 1121 introgressed with bacterial blight resistant possessing bacterial blight resistance genes *xa13* and *Xa21*, was released for cultivation in Punjab, Haryana and Delhi. This variety produces average yield of 4.64 t/ha and matures in 136-138 days.

In maize, four hybrids, namely, Pusa Vivek QPM 9 Improved, Pusa HM 4 Improved, Pusa HM 8 Improved and Pusa HM 9 Improved were released for commercial cultivation in different agro-ecological zones. Pusa Vivek QPM 9 Improved, the first provitamin-A rich maize hybrid of the Country, is an improved version of Vivek QPM 9 with *crtRB1* allele. Pusa HM 4 Improved, Pusa HM 8 Improved and Pusa HM 9 Improved are improved versions of hybrids HM 4, HM 8 and HM 9, respectively, and developed through marker-assisted introgression of *opaque2* allele. All these hybrids are improved for protein quality and possess high tryptophan and lysine, as compared with the original hybrids. In pearl millet, a dual purpose hybrid, Pusa 1201 ((MH 1849), resistant to downy mildew was released for NCT of Delhi. The grain yield of this hybrid is about 2.81 t/ha with stover yield of 7.20 t/ha and matures in 80 days.

A *desi* chickpea variety BG 3043 was released for timely sown conditions of NEPZ. This variety has an average yield of 1.6 t/ha and potential yield 2.5 t/ha. It matures in about 130 days and is suitable for rice-chickpea cropping system of eastern India. Another chickpea variety BGD 111-1 was identified for release under rainfed conditions of Karnataka. An extra early maturing (120 days) pigeon pea variety, Pusa Arhar 16, with average seed yield of 1.96 t/ha was released and notified for NCT, Delhi. It is compact semi-erect variety suitable for high density planting and harvesting by combine harvester. A mungbean variety, Pusa 1431 with maturity duration of 66 days was released for NCT Delhi. It showed multiple resistance to mungbean yellow mosaic virus (MYMV), Cercospora leaf spots (CLS), anthracnose and web blight. In lentil, L 4727, with an average yield of 1.15 to 1.45 t/ha was released for cultivation under timely sown, rainfed conditions of Central zone comprising states of Madhya Pradesh, parts of Uttar Pradesh, Rajasthan and Chhattisgarh during *rabi* season.

The first double zero Indian mustard variety, Pusa Double Zero Mustard 31, which was released for NCT, Delhi during 2015, was now released for Zone II (Punjab, Haryana, Delhi, Jammu and northern Rajasthan). Average seed yield of this variety is 2.32 t/ha with 41.6% oil content and matures in 142 days.

A large pool of genetic resources including land races, wild relatives of crops, exotic and indigenous genotypes and many introgression lines are maintained as active germplasm, evaluated for biotic and abiotic stresses and quality parameters in different crops. In rice, a set of 100 different accessions of wild rice *O. rufipogon, O. nivara, O. longistaminata* were evaluated and utilized in wide crossing for introgression of useful traits. In maize, low phytic acid mutants viz., *lpa1* and *lpa2* procured from exotic source were crossed with seven elite inbreds viz., HKI 323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1 and HKI 193-2. F_2 segregants homozygous for *lpa1* and *lpa2* were selected based on foreground selection. A teosinte accession was crossed with 17 elite maize inbreds and F_1 plants with tillering and intermediate characteristics of tassels, ears and plant morphology were developed. A Sikkim Primitive accession with 6-8 ears per plant was crossed with 35 elite maize inbreds and the F_1 with three ears per plant were developed. In pearl millet heat stress tolerant lines were identified. From the ICARDA germplasm, a unique lentil genotype (LIEN33127-E) having up to 6 flowers per peduncle (range: 4-6 flowers per peduncle) was identified. In *Brassica*, 847 germplasm lines from different *Brassica* species were maintained by selfing. In soybean, 328 germplasm lines were screened for terminal drought tolerance.

In horticultural crops, the Institute has released 18 varieties in vegetable and flower crops. In vegetable crops 10 varieties, viz., two each in brinjal (Pusa Hara Baingan 1 and Pusa Safed Baingan 1) and muskmelon (Pusa Madhurima and Pusa Sarda), one each in okra (Pusa Bhindi 5), *Chenopodium* (Pusa Green), cucumber (Pusa Seedless Cucumber 6), long melon (Pusa Utkarsh), round melon (Pusa Raunak) and garden pea (Pusa Prabal), and two F_1 hybrids, viz., one in bitter gourd (Pusa Hybrid 4) and one in sponge gourd (Pusa Shrestha) were released by Delhi State Seed Sub-Committee. In onion Sel. 153-1 was identified for release by the AICRP (VC). In flower crops, six varieties were identified by the Institute Variety Identification Committee, and were further released by the State Seed Sub-Committee for Agriculture & Horticultural Crops, Govt. of NCT Delhi. These were Pusa Mahak (rose), Pusa Bahar and Pusa Deep (marigold), Pusa Guldasta and Pusa Swet (chrysanthemum), and Pusa Sinduri (gladiolus).

Several varieties and hybrids are in advanced stages of development and testing. In cauliflower, one F_1 hybrid (Ogu1A x DH-53-1) using double haploid line was developed at Katrain. One purple cauliflower variety, KTPCF 1 was developed through hybridization followed by recurrent selection. In a snowball cauliflower variety Pusa Snowball K 25, *Or*-gene for β-carotene rich and *Pr*-gene for anthocyanin were introgressed from an exotic collection EC 625883 and an inbred line, KTPCF-1, respectively. High yielding cucumber hybrids DGCH 18 and DGCH 15 with yields of 26.2 and 24.9 t/ha, respectively, were developed. In musk melon, DHM 162 was found promising for cultivation under net house (5.1 t/1000 m^2 with TSS 13.6^{0}Brix). In tomato, advanced segregating lines developed from the interspecific crosses of *S. habrochaites* (LA1777) were found promising for tolerance to ToLCNDV and late blight. At IARI regional station, Katrain, three promising high yielding sweet pepper hybrids, namely, KTCH 5 (38.90 t/ha), KTCH 9 (37.55 t/ha) and KTCH 129 (36.59 t/ha) were identified.

In carrot, three promising lines, viz., IPC 13 red, IPC 98 and IPC Ht-1 were advanced to AVT-I of ICAR-AICRP (VC) trial. In *kharif* onion, genotypes KH 138, KH 141, KH 122, KH184 and KH 118 performed best and produced good quality bulbs. Pusa Soumya (*A. fistulosum* L.) and Red Creole 2 (*A. cepa* L.) were identified as moderately resistant to Stem phylium blight. Among okra hybrids, DOH 1 was found resistant to YVMV, tolerant to leafhopper and recorded 23 t/ha pod yield with smooth dark green attractive pods.

In mango, Hybrid H-11-2 with high maximum fruit weight (267.1 g) was developed. Hybrid 8-11 showed field tolerance to mango malformation. Citrus hybrid rootstocks pummelo (P) × Trifoliate orange (TO) -163, P × Sacaton-164, P × Troyer (T)-181, P × T-206, P × T-211, P×T-212, P × T-216 and P × T-220 were found to be salinity tolerant. Six citrus hybrids were found resistant against *Phytophthora nicotianae.* In grape, four hybrids were identified based on the early maturity and fruit quality traits, viz., Pusa Swarnika (Hur×Cardinal), ER R_2P_{36} (Pearl of Csaba ×Beauty Seedless), 16/2A R_1P_9 and 16/2A R_1P_{14} (Cardinal×Beauty Seedless). Heterosis studies in papaya revealed positive heterosis for fruiting zone in hybrid Red Lady (Self) x Pusa Nanha. Two advance inbred lines, P 9-5 and P 7-9 were found to cold tolerant as compared with *Vasconcellea cundinamarcensis*. Spray of methyl jasmonate (15 mM)

in grape cv. Pusa Navrang significantly enhanced the accumulation of total monomeric anthocyanins (1012.5 mg/kg). The application of 300 ppm ProCa significantly enhanced maximum carotenoids content in juice (305 µg/100 ml) and peel (685 µg/100 ml).

In rose, R-SD-6-201 - a selection from the open-pollinated population of cv. Rose Sherbet; and R-SD-7-2015 - a selection of cv. Pusa Virangana were identified for release. Rose varieties Little Pink, Lalit, Haldighati and Pusa Aditya were identified as salt tolerant. In gladiolus, five promising open pollinated seedlings and mutants, namely, Pink Parassol -Open Seedling, Melody- Open Seedling, Suchitra × Melody, Vidushi (mutant) and Green Pasture × Regency were identified. In Eustoma, five crosses, namely, T11 ×T3, T11 × T7, T12 × T11, T7 × T6 and T12 × T6 were found to be very promising for cut flower production under Kullu valley conditions. In Lilium, crosses between KILH 13 with Prato, Brunello and Navona showed early flowering as compared to their parents.

The Crop and Natural Resource Management research at the Institute focused on development of efficient resource management technologies for enhancing farm productivity and income. Studies on crop diversification indicated that the highest system productivity was obtained from maize-potato-onion cropping system followed by rice-vegetable pea-okra and maize-wheat-mungbean, recording 34.7 and 38.3% higher system productivity, respectively, over traditional rice-wheat cropping system. Further babycorn-mustard cropping system resulted in highest net returns (₹ 106142 ha^{-1}), B:C ratio (2.2), income (₹ 463 ha^{-1} day^{-1}) and water productivity (₹ 149 ha^{-1} mm^{-1}). Real time N management with Nutrient Expert® and Green Seeker helped to achieve overall system productivity (12.7 t ha^{-1}) and additional economic gain (₹ 33,585 ha^{-1}) under maize-wheat system. Adoption of conservation agriculture was found to be climate smart agricultural technique that could reduce greenhouse gas emission and increase C-sequestration, crop yields and profits under long-term rice-wheat cropping system. Integrated farming system in 1.0 ha area involving crops, dairy, fishery, duckery, biogas plant, fruit trees and agro-forestry resulted in net returns of ₹ 3,78,784 ha^{-1} $year^{-1}$ with an employment generation of 628 man-days round the year.

Studies on enrichment, mineralization, stabilization and saturation of carbon in different soil orders and cropping systems showed that among the soil orders, preservation of soil organic carbon (SOC) was highest in Mollisol followed by Vertisol, Alfisol and Inceptisol. Integrated use of enriched compost and biofertilizer with reduced doses of inorganic fertilizers could be followed to improve the yield of rice and reduce the toxicity of aluminium in acidic soil of Assam. Use of waste mica along with organic acid and microbial culture is beneficial in terms of maintaining K supply in soil for crop production. Conjoint application of green manure and metal solubilizing bacteria proved to be the most efficient in enhancing the Zn, Cd and Pb uptake by mustard used for phytoremediation of metal polluted soil. Modified clays and egg shell showed promise for immobilizing metals and metalloid in polluted soil as indicated by a significant reduction in its uptake by rice, spinach and maize.

Drip fertigation with liquid fertilizer like urea ammonium nitrate proved to be advantageous over fertigation with urea and traditional method of broadcasting or soil application in cabbage. Evaluation of soil moisture sensors for irrigation scheduling in wheat and mustard indicated that irrigation water use efficiency was the highest using time domain reflectometry (13.7 kg ha^{-1} mm^{-1}) compared to tensiometer -30 kPa (10.7 kg ha^{-1} mm^{-1}) and gypsum block -30 kPa (10.5 kg ha^{-1} mm^{-1}). The tomato accession number 112, 181, 182, 206 and 304 were found highly suitable for protected cultivation. Vertical soilless structure for growing vegetable crops was designed.

Urea ammonium nitrate applicator was designed to place the fertilizer 2.5 cm beside the seed at a depth of 5 and 10 cm. The three wheel mini tractor type multipurpose equipment was designed to overcome the limitations of power tiller and tractor. A tractor operated raised bed pulse planter was developed for sowing of pigeonpea. A paddy straw collector cum chopper was developed, which cuts the paddy straw stalks in combine harvested field at a height of 2-3 cm from ground level.

Attempts were made to enhance the shelf life and nutritional quality of various food materials such as use of indigenously developed particle films on Kandhari pomegranates, pre-harvest fruit bagging of kinnow mandarin, application of edible coatings and salicylic acid on guava, preparation and packaging of osmo-vac dehydrated *aonla* segments, development of antioxidant rich naturally coloured papaya candy, formulation of gluten-free amaranth pasta, etc.

BGA based composite liquid inoculant was prepared for sustaining crop productivity and soil health. Bioprospecting rhizospheric and endophytic cyanobacterial strains led to the identification of six isolates belonging to *Microchete* sp., *Nostoc* sp. and *Phormidium* sp. capable of solubilizing phosphorus. Inoculation with selected rhizobacteria (NAD 7 and MRD 17) considerably enhanced both root and shoot dry weight under water-deficit stress conditions.

Global warming potential (GWP) of the different cropping systems was quantified and highest GWP were observed in maize-potato-onion system due to higher nitrous oxide emission. Carbon, nitrogen and water footprints of rice crop production under different water management practices were estimated during life cycle of rice up to farm gate. Interactive effect of elevated CO_2 and high temperature on different rice varieties was evaluated. Impact of air pollutants on physical, chemical and biological properties of soil collected from the sites in the vicinity of NTPC, Dadri, UP was assessed. Air pollution tolerance index of *rabi* season crops like wheat, tomato, pea, *methi*, and chickpea were worked out.

The crop protection research at the Institute has made significant advancement in pathogen diversity analysis, diagnostics and development of integrated management technologies for agricultural pests and pathogens of national importance. ITS sequences, chemo-profiling and morphology were used for identification of eleven species of *Stemphylium, Alternaria and Ulocladium*. Seven MLST fragments were sequenced in a panel of 20 *Tilletia indica* isolates. *Trichoderma dumbbelliforme*, isolated from Nagaland, was confirmed as a new species. Three vital protein coding regions of PRSV viz., coat protein (CP), helper component proteinase (HC-pro) and nuclear inclusion protein-a (NIa-pro) from 19 PRSV-P & -W isolates when analyzed. Analysis of 16S rDNA sequence of chickpea stunt phytoplasma isolate showed that it has 99% sequence homology with strains of 16SrVI group phytoplasmas. LAMP based detection assay was developed and validated for *Fusarium graminearum*, *apple chlorotic leaf spot virus* and Huanglongbing or citrus greening disease. Genome of spot blotch pathogen *Bipolaris sorokiniana* was sequenced and assembled in to 10566 scaffolds and 22769 contigs.

Cross infectivity was established for *B. sorokiniana* and *B. oryzae* for infecting both wheat and rice. Genome of *R. solanacearum* Biovar 3, Phylotype I, Race 1 strain UTT-25 was sequenced. A new phytoplasma subgroup 16SrI-X was found to be associated with bottle gourd virescence and phyllody disease in India. Association of GBNV was confirmed through RT-PCR assay using specific primers.

Resistant sources to different insect-pests were identified and efficacy of different chemicals/ biopesticides was tested against various pests in different crops. Weather based prediction model was developed for *Helicoverpa armigera* in chickpea. Khapra beetle *Trogoderma granarium* collected from different 15 localities showed 31.62 fold resistance to phosphine. Analysis of orientation response of male and females *Coccinella transversalis* against both hexane and DCM extracts showed that highest number of beetles moved towards WA extracts. Maximum glutathione S-transferase (GST) activity was observed at 41°C for both mealybug nymphs and parasitoid adults. Radiation doses were optimized for melon fly, *Bactrocera cucurbitae* (Coquillett). Radiation exposure of pupae to 40 and 50 Gy decreased adult emergence (58.67 and 41.67%) and adult fliers (54.18 and 37.12%).

In nematodes, interaction among five esophageal gland genes and cell wall degrading enzymes during infection of *Meloidogyne incognita* was established using RNAi. Host-induced gene silencing strategy was used to generate the transgenic eggplants expressing *msp-18* and *msp-20*, independently. Nine *flp* genes (*flp-1*, *flp-3*, *flp-6*, *flp-7*, *flp-11*, *flp-12*, *flp-14*, *flp-16* and *flp-18*) and a partial neuropeptide receptor gene (*flp-18* GPCR) were characterized from *M. graminicola*. Investigations on *Heterorhabditis-Photorhabdus* host specificity showed that *Hb-clec-78* gene might be involved in modulation of symbiosis with *Photorhabdus* bacteria. An indigenous isolate of *Trichoderma harzianum* ITCC 6888 caused significant mortality in juveniles and egg hatch inhibition in root-knot nematode, *Meloidogyne incognita*. *Pseudomonas fluorescens* (cfu 10^8) @ 80g/sq m was also found effective in controlling *Meloidogyne graminicola* in direct seeded rice. The rice root-knot nematode, *Meloidogyne graminicola* genome was sequenced.

Chemo and bioprospecting for agrochemicals through design, discovery and development of novel processes was undertaken. 6-flouro-3-iodo-chromen-4 one was found to the best compound (EC_{50} - 24.65ppm) against *Sclerotium rolfsii*. Azomethine derivatives were nano sized employing poly ethylene glycol. A new

series of biogels and composites based on a natural gum (BP-1) and carboxymethylcellulose (BP-2) cross-linked with pre standardized organic acid (OA-1) were synthesized and characterized using XRD and FTIR. The method for extraction of seven aflatoxins from the black peppers, cumin, fenugreek, onion seed and coriander was optimized. For effective weed management in different crops, maize, wheat, lentil, gladiolus and onion, efficient control strategies were developed. There was a significant correlation between weed density and nematode density, which indicated that controlling weeds could also suppress nematodes and reduce the cost of nematode control.

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 understanding the regulation of root system architecture (RSA), a root specific drought, osmotic and salt stress inducible *OsMYB TF* gene promoter was cloned from rice. The *OsMYB* promoter::*GUS* reporter transgenics confirmed that the cloned promoter is inducible by multiple stresses and hormones specifically in roots. Towards functional genomics analysis of plant stress hormone ABA receptors (ABARs) in rice, transgenic overexpression and RNAi/CRISPR-Cas9 knock-out was initiated. Rice cv. MTU1010 was transformed with *OsABAR11* under *RD29A* promoter showed higher cold and drought tolerance.

The role of Inositol 1,3,4, tris phosphate 5/6 kinase 2 (*ITPK2*) gene in abiotic stress tolerance was identified besides its previously known function in phytate biosynthesis in soybean. MALDI-TOF/MS analysis heat stress responsive proteome in wheat cv. WR 544, HD 2967, HD 2932 and HD 2285 led to the identification of stress regulation RuBisCO (Rub), RuBisCO activase (Rca) and oxygen evolving enhancer protein (OEEP). By using iTRAQ analysis, the potential involvement of stress associated proteins viz., CDPK, MAPK, HSPS17 and HSP70 in both source-sink pathways were identified. To understand the mechanism of elevated CO_2 (EC)-mediated decline in the protein concentration of wheat grain showed that enhanced NO production under EC negatively regulated the nitrate reductase and high affinity transporters at both transcriptional and post translational levels, and thus poor N assimilation. Analysis of root transcriptome of waterlogging tolerant inbred (HKI 1105) using RNA sequencing revealed 21,364 differentially expressed genes (DEGs) that regulate energy-production, programmed cell death (PCD), aerenchyma formation and ethylene responsiveness under waterlogged stress conditions in maize.

Low phytate soybean crop is required to enhance the bioavailability of phosphate and micronutrients from soybean. To reduce the phytate content in soybean seeds, Inositol pentakisphosphate -2-kinase (IPK1) was targeted for generating genome editing using CRISPR-Cas9 technology. Transient assays showed that CRISPR-Cas9 is effective in knockout of *GmIPK1* gene and reducing phytate content in leaf by 6-7 folds. Epigenetic analysis (DNA 5mC) of genes involved in soybean quality revealed that γ-TMT3 promoter is regulated epigenetically and thus vitamin-E synthesis in soybean. Similarly, isoflavone synthase (*IFS1 & IFS2*) genes were also regulated by gene body methylation. In NRC 37, a high isoflavone variety, the level of total 5-mC in the coding region of *IFS1* and *IFS2* was found to be 85% and 20.51%, respectively, while it was extremely low in NRC 7 (2.5% and 7.89%).

To bridge the phenotype-genotype gap, the Indian Council of Agricultural Research (ICAR) through National Agricultural Science Fund (NASF) established a state-of-the art plant phenomics facility at the Indian Agricultural Research Institute, New Delhi. Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated and dedicated the "Nanaji Deshmukh Plant Phenomics Centre (NDPPC)" to the Nation on 11th October, 2017. Phenomics of diurnal and nocturnal transpiration in rice genotypes were studied in 150 rice genotypes, and genotypes with contrasting transpiration rates were identified. GWAS analysis led to the identification of 18 QTLs for mean day time transpiration and 12 QTLs for mean night time transpiration per unit leaf area were mapped. Similarly, drought tolerance and water use efficiency of a set of 183 wheat genotypes were analyzed at NDPPC, and genotypes with high WUE (>2.5 g grain kg^{-1} water used) were identified. Studies on high night temperature effect on grain quality in rice that GBSS regulates change in amylose content in rice cultivar under high night temperature.

QTLs for biotic and abiotic stress tolerance were mapped in different crops. In wheat, 44 QTLs were mapped in RIL population of GW322 × HI1500 for drought tolerance, and 9 QTLs were mapped in RIL population of WH 730 × HD2733 for heat tolerance. Introgression lines of chickpea were developed harbouring the 'QTL hotspot' for drought tolerance from the donor parent ICC 4958. Pusa 362, an elite *desi* chickpea cultivar was used as recurrent parent. For transfer of rust resistance from wild species, cytologically stable *T. militinae* derived introgression lines (ILs) viz., TMD 6-4, TMD7-5 and TMD11-5 with wide spectrum rust resistance were used for molecular characterization. A dominant gene for leaf rust resistance was mapped to the long arm of chromosome 3B (*LrS2427*) in Selection 2427, a bread wheat introgresed line with *Ae. speltoides* as donor parent.

Two hundred ten RILs were phenotyped for grain iron and zinc content using and QTL for grain iron content was detected on chromosome 3, and for grain zinc content, two QTLs were detected on chromosome 6 and chromosome 7. In lentils, association mapping (AM) led to the identification of three SSRs (PBALC 13, PBALC 206, and GLLC 563) associated with grain Fe concentration explaining 9% to 11% of phenotypic variation and four SSRs (PBALC 353, SSR 317±1, PLC 62, and PBALC 217) associated with grain Zn concentration explaining 14%, to 21% of phenotypic variation.

For transfer of black rot resistance to cauliflower, interspecific hybridization of cauliflower with *Brassica napus*, *B. carinata* and *B. juncea* were made and F1 was obtained by embryo rescue. F1 plants were backcrossed with cauliflower and the backcross generations are being advanced. Marker assisted selection (MAS) backcross breeding was performed for introgression of gynoecious trait (*F* locus) from G 421 (exotic gynoecious line) in to Pusa Uday background, and Improved Pusa Uday (BC_2F_6) with 100% female flowers and quality similar to Pusa Uday was developed.

Total organic carbon of soil was assessed using AVIRIS-NG (Airborne Visible Infra Red Imaging Spectrometer - Next Generation) for mapping soil organic carbon on a regional scale. Soil organic carbon could be estimated with AVIRIS-NG using PLSR model ($R^2 = 0.89$, RMSE = 0.22). Location specific model developed were used further for generating soil organic carbon map using AVIRIS-NG L2 reflectance image. Hyperspectral imaging using nano-hyperspec camera in VNIR range (396-1003nm) was used to map plant nitrogen map of wheat field for high throughput and cost effective estimation of canopy N content of wheat crop. HYDRUS-2D model was calibrated and validated for simulation of soil water dynamics and root water uptake in wheat under different tillage and irrigation management. As sensitivity and uncertainty analyses are critical for identifying the most sensitive parameters of the crop simulation models, Web InfoCrop Wheat model was studied for the sensitivity and uncertainty under water deficit- and high temperature stress conditions for different agro-climatic conditions of India.

Weather based agro-met advisory bulletins were prepared in Hindi and English and issued on every Tuesday and Friday. During 2017-18, total 102 agro-advisory bulletins were prepared in Hindi as well as in English. Farmers are benefited from agro-met advisory as the monsoon, its status and day to day weather conditions which is helping to do proper farm practices at proper time.

The School of Social Sciences and Technology Transfer analyzed the influence of macro-economic variables like public investments, credit, farm mechanization, total factor productivity and diversification. It also focused on developing innovative extension models. The expenditure under *Rashtriya Krishi Vikas Yojana* (RKVY) has increased over the years and was lower in the southern and north-eastern regions, while the same regions have higher project completion percentages (more than 70 %) since the inception of the programme. In contrast, the Northern and Western regions showed higher expenditure per project and lower project completion percentage. The total flow of institutional credit to the agriculture sector was ₹ 7,11,621crores in 2013-14, which is five times more than the credit amount in 2004-05. This may be due to the policy initiative of doubling agricultural credit within three years. Uttar Pradesh received the highest Agricultural Marketing Infrastructure Index value, followed by Maharashtra, Madhya Pradesh and West Bengal. The impact analysis of e-Mandi in Karnataka revealed that the system has helped in faster completion of tender process and the trade transaction leading to faster payment settlement.

Economic impact analysis of IARI *Basmati* variety PB 1121 showed that the total gain due to P B 1121 is ₹ 8,97,904 crores of which Punjab accounts for 49 per cent of the total gain followed by Haryana (34%) and Uttar Pradesh (17 %). Overall the yield increase accounts for 51 per cent of the incremental gain. The IARI wheat variety HD 2967 accounts for 59 per cent of the total gain. Pusa Mustard 30 variety is expected to generate a total surplus of ₹ 12394 million per year. Carrot variety *Pusa Rudhira* gave internal rate of return of 34 per cent which is substantially high.

Under IARI-Post Office Linkage Extension Model, the quality seeds of improved IARI varieties were disseminated. Seed Producers' Association named "*Dev Bhumi Krishi Evam Bahuuddeshiyo Swayat Sahkarita Baswaskheri*" has been promoted at Haridwar district of Uttarakhand for enhancing access to quality seeds. A survey undertaken in Ganjam district of Odisha to analyze the farmers' perception about climate change and adaptation strategies in coastal areas revealed that the major coping strategies adopted by the farmers were line transplanting of paddy (63%) and cultivation of flood-resistant Swarna Sub-1 and drought-resistant Sahabhagi Dhan (59%). Analysis of the efficacy of video extension revealed that the existing extension personnel in the organization had to be trained in video production. Value addition, seed production, protected cultivation of vegetables and flowers, fruit production and primary processing were promoted as entrepreneurial ventures based on the situational assessment. Studies on entrepreneurial adoption behavior of farmers revealed that 48.39 % farmers with low adoption behaviour in respect of specialty and secondary agriculture.

Analysis of National Family Health Survey-4 (2015-16) data for nutritional status of children and adults across the states showed that one per cent increase in food security index would significantly decline the incidence of stunting and underweight by 0.5 and 0.6 % among children, respectively, and about 0.4 % underweight in adults. A study on Behavioral Intentions using Theory of planned behavior for organic food consumption showed that there is a need to enhance knowledge on organic food to change the behavioural intentions of consumers. Training needs on gender mainstreaming and sensitisation study revealed that majority extension personnel followed diverging learning style (53%) followed by accommodator (38%), converger (6%) and assimilator style (3%).

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 program is to provide farmers with required information, knowledge and advisories on regular basis by adopting villages.

During *Rabi* 2016-17, a total number of 373 demonstrations were conducted covering an area of 82.45 ha across 17 locations for wheat, mustard, carrot, cauliflower, pea, spinach and brinjal. Under Participatory Seed production programme, wheat seeds of varieties HD 2967 (90.00 t) and HD 3118 (2.50 t) was produced at PRDF Gorakhpur, and 23.17 tonnes of var. HD 2967 and 38.3 tonnes of HD 3086 were produced at YFAP, Rakhra. During *Kharif* 2017, 12 tonnes of Pusa Basmati 1509, 61.6 tonnes of Pusa 44 and 15.1 tonnes of Pusa Basmati 1121, 14.4 tonnes of Pusa Basmati 1401 seeds of rice were produced at Rakhra.

Agricultural Technology Information Centers (ATIC) is effectively providing products, technologies, services and information services to the different stakeholders through a '*Single Window Delivery System*'. In ATIC, farm advisory services are also given through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600), PusaAgricom 1800-11- 8989, exhibitions, farm literatures and letters. Information and advisory needs of the visitors are also being catered through touch panel *kiosks*, revolving scrollers, LED display boards, information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples, bio-fertilizers displayed, crop *cafeteria* and live demonstrations at the centre.

The Institute's *Krishi Vigyan Kendra* at Shikohpur, Gurugram, conducted seven On-farm trials on different problems, around 2550 agricultural extension activities covering various themes and 200 demonstrations covering 78 ha in various crops for the speedy dissemination of technologies. The IARI regional stations Karnal (Haryana), Pusa (Bihar), Indore (MP), Shimla and Katrain (HP), Wellington and Aduthurai (TN) also significantly contributed to the dissemination of improved IARI varieties and

technologies to the farmers through FLDs and other extension interventions like trainings, exhibitions and farmers' friendly literatures.

The National Agricultural Fair, *Krishi Unnati Mela* 2018 with a major theme of "*doubling farmers' income by 2022*" was organized at IARI, New Delhi during March 16-19, 2018 in collaboration with ICAR, DARE and DAC, Ministry of Agriculture and Farmers Welfare. The *mela* was inaugurated by Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh. Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated the *JaivikKheti* portal and laid the foundation stone of 25 KVKs besides launching an e-marketing portal for organic products on March 17, 2018. Hon'ble Prime Minister also gave the *Krishi Karman* Awards and the *Pandit Deen Dayal Upadhyaya Krishi Protsahan Puraskar*s. Different ICAR institutes, State Agricultural Universities, development agencies, leading companies from public and private sector and Voluntary Organizations participated and displayed their technologies and products. Over one lakh visitors and 500 public and private exhibitors from across the country participated and gained from the fair.

The Institute received ISO9001:2015 certificate during this year for quality management system. The 56th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 9, 2018 with the Hon'ble President of India, Shri Ram Nath Kovind as the Chief Guest. Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh presided over the function. Dr. T. Mohapatra, Secretary, DARE & Director General, ICAR, former Director Generals of ICAR and former Directors and Deans of IARI also graced the function. During this Convocation, 237 candidates (133 M.Sc., 7 M.Tech. and 97 Ph.D.) were awarded degrees including 14 (12 M.Sc./ M.Tech. and 2 Ph.D.) international students.

The Institute brought out 620 quality research publications in scientific peer reviewed research journals with international impact factor or NAAS rating 6 and above. 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 2017-18, 31 innovative technologies of the IARI were transferred to 14 industry partners which earned the institute a revenue of ₹ 48,00,000. One new Patent application has been filed and eight earlier filed applications have been granted. 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 focused at enhancing the productivity and nutritional quality of various field crops with tolerance to biotic and abiotic stresses through judicious use of both conventional and molecular breeding tools. Several improved varieties with higher yield, superior nutritional quality, tolerance to biotic and abiotic stresses and suited to different agro-ecological conditions were 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 complemented by quality seed production and research in other relevant areas of seed science.

1.1 CEREALS

1.1.1 Wheat & Barley

1.1.1.1 Varieties released

HI 1612. A high yielding bread wheat variety with an average yield of 3.78t/ha and potential yield of 5.05t/ha under timely sown, restricted irrigation conditions of North Eastern Plains Zone (NEPZ) was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. It possesses high level of adult plant resistance (APR) to prevalent virulent stripe rust pathotypes (46S119, 78S84, 110S119) and leaf rust pathotypes (77-5, 77-9, 104-2). It also showed resistance to leaf blight, Karnal bunt, *Fusarium* head blight and loose smut. It has high protein (11.5%), iron (41.5 ppm) and zinc (35.5 ppm) content along with high sedimentation value (58 ml). The variety showed excellent score for *chapati* quality (7.64) and biscuit quality (7.39)

A bread wheat variety HI 1612

HI 8777. A *durum* wheat variety with an average yield of 1.85 t/ha and potential yield of 2.88t/ha under timely sown rainfed conditions of Peninsular Zone was released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. It showed APR to prevalent virulent stem rust pathotypes (40A and 117-6) and leaf rust pathotypes (77-5, 104-2 and 77-9). It also showed better resistance to Karnal bunt, loose smut, flag smut and foot rot compared to the checks. It has bold grain (43.27 g/1000-seed) with higher iron (48.7 ppm) and zinc (43.6 ppm) content. It has high overall acceptability (7.0) with 0% yellow berry incidence.

A *durum* wheat variety HI 8777

1.1.1.2 Elite lines under All India Coordinated Wheat & Barley Improvement Programme

A total of sixty-eight genotypes of wheat and eight of barley were contributed and evaluated under the All India Coordinated Research Project on Wheat and Barley trials under various production conditions in six wheat growing zones of the country. Three bread wheat genotypes viz., HD 3226, HD 3237 and HI 1620 are under final stage (AVT-II) of testing. Nineteen entries were tested in AVT-1, including one *dicoccum* , three *durum* and 15 bread wheat genotypes, along with 46 new entries in IVTs. In case of barley, total eight entries including four for timely sown dual purpose i.e., green fodder and grain and, four for timely sown grain purpose were nominated for testing in Northern Hills Zone.

1.1.1.3 Marker-assisted transfer of genes for rust resistance in wheat

Adult plant resistance (APR) genes providing durable resistance to leaf rust were targeted for introgression into two wheat varieties viz., HD 2733 and HD 3059. Molecular validation of targeted genes showed the possible presence of *Lr 68* in HD 3059. Wheat genotype Parula having three APR genes for leaf rust viz., *Lr34, Lr46* and *Lr68* was used as one of the donor parents. For *Lr67* another donor parent, RL6077 was used. In case of HD 3059, the backcrossed lines are in BC_2F_1 stage while in case of HD 2733 it is in BC_1F_1 stage. Leaf rust resistance gene *LrTrk* and stripe rust resistance gene *Yr5* were also targeted to introgress in three wheat varieties, HD 2967, HD 2733 and HD 2932. The materials from these crosses are in BC_2F_1 stage of backcrossing.

1.1.1.4 Development of genotypes with better biscuit making quality

The soft grain, low protein content and weak and extensile flour is ideal for biscuit making which is not available among the indigenous wheat varieties. Earlier, a set of 30 genotypes was screened for *PinA*, *Glu-1* and *Glu-3* alleles to identify candidate Indian wheat varieties for biscuit making quality. HS 490, DBW 14 and HI 1563 were found to possess some of the characteristics (HMWs, LMWs, low to medium SDS- sedimentation value, low farinographic number (FQN)) close to those in the Australian biscuit quality lines Barham and Longreach Orion. The alleles for grain texture in DBW 14 and HI 1563 were found to be *Pina-D1b* and *Pina-D1a* (*'ba'*), whereas, the desired allelic combination is *PinaD1a* and *PinbD1a (*'*aa'*). Therefore, transfer of *PinaD1a* allele was undertaken in these two varieties through MABB using Barham as the donor of *Pin a* allele. Simultaneously, *Lr3/Yr17* segment introgressed in Barham was also targeted for transfer. Foreground selection for *PinaD1a* and *Lr37/Yr17* in DBW 14 and *PinaD1a, GluA3c, GluB3b* and *GluD3c* in HI 1563 and background selection (in BC_1F_1) with 173 SSR primers covering most of the chromosomes was carried out. Simultaneously, phenotypic selection in the field was carried out to reject plants visibly different from DBW 14 or HI 1563. BC_2F_2 plants homozygous for *PinaD1a* and *Lr37*, BC_3F_1 plants heterozygous for *PinaD1a* and *Lr 37* genes for DBW 14 and BC_3F_1 plants of HI1563 carrying *PinaD1a* and *GluA3c, GluB3b*a and *GlueD3c* have been identified.

1.1.1.5 Development of soft grained wheat genotypes for use as donors in quality breeding

Genetic improvement to produce soft grained wheat suited for biscuit quality is a priority for wheat quality breeders. IARI has developed a new genotype QBP12-11 (Wbll1*2/Kkts*2/3/*T.dicoccom* PI272533/ *Ae. squarrosa* (458)//Cmh81a.1261/Vee#10-7) with a high level of grain softness (GHI=18). QBP 12-11, a selection of a CIMMYT material recorded lowest GHI (17.7) among bread wheat genotypes tested during three years under Coordinated Quality Component Screening Nursery at 12 locations. QBP 12-11 will be used as a donor for marker based transfer of grain softness in new elite materials to develop soft grained genotypes suitable for biscuit quality breeding using molecular markers for grain softness

1.1.1.6 Exploring synthetic wheat for finding traits of adaptability to conservation agriculture

Fifty-five synthetic lines along with 20 released varieties of wheat were evaluated under field conditions

for phenological traits and also under hydroponics conditions to study traits related to root architecture. The 'D' genome in synthetic wheat contributes better emergence, larger seeds, greater early vigor and deeper roots. Data on coleoptile length, coleoptile thickness, early vigor, flowering, growth habit and reaction to rust were recorded. The synthetic lines will be genotyped for *Rht* genes viz., *Rht* 4, *Rht* 5, *Rht* 8, *Rht* 11, *Rht* 12 and *Rht* 13.

1.1.2 Rice

1.1.2.1 Variety released and notified

Pusa Basmati 1718. Pusa Basmati 1718 (IET 24565) was released and notified for cultivation in Punjab, Haryana and Delhi. It is a MAS derived bacterial blight

Pusa Basmati 1718

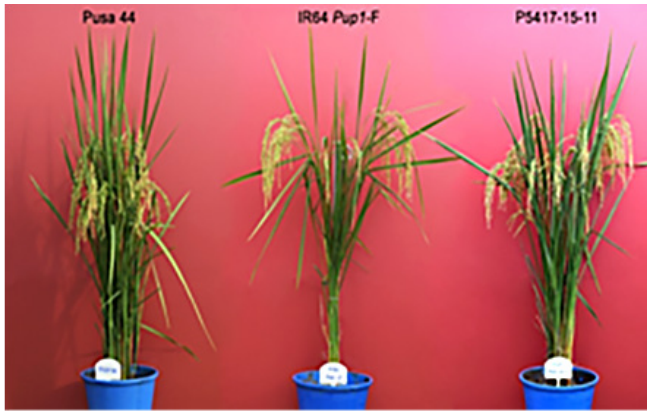
resistant NIL of Basmati rice variety PB 1121 possessing two genes viz., *xa13* and *Xa21* governing resistance to bacterial blight with seed to seed maturity of 136-138 days and average yield of 4.64 t/ha. Its reaction to other major diseases and pests was comparable to recurrent parent with lesser incidence of neck blast disease. It also possesses long slender grains, very good kernel length after cooking, intermediate amylose content (22.2 %) and strong aroma.

1.1.2.2 Elite lines contributed in All India Coordinated Research Project on Rice

A total of 16 genotypes were nominated in different stages of testing in the AICRP on Rice trials during *Kharif* 2017. It includes 4 entries (Pusa 1847-12-1-13, Pusa 1692-10-20-1-1-1, Pusa 1925-13-168-3 and one *Basmati* hybrid, Pusa RH51) in IVT-BT; 3 entries (Pusa 2050-19, Pusa 2050-20 and Pusa 2049-23) in IVT-IME; 2 entries (Pusa 5000-1-1-1 and Pusa 5173-9-1-1-1-1) in IVT-IM, one entry (Pusa 5001-8-3-4) in IVT-MS; 2 entries (Pusa NPT-16-15 and Pusa NPT-16-12) in IVT-NPT and 4 hybrids including Pusa RH 47, Pusa RH 54 in IHRT-E and Pusa RH 52, Pusa RH 53 in IHRT-ME.

1.1.2.3 Developing phosphorus starvation tolerant lines of Pusa 44

Marker assisted backcross breeding was adopted to incorporate the *Pup1*-QTLs governing phosphorus starvation tolerance, in the genetic background of Pusa



Promising line Pusa 5417-15-11 Carrying the QTL, *Pub1* along (Pusa 44) and the donor parent (IR64 *Pub1*-F)

44. *Pup1* contains *OsPSTOL1*, a serine threonine protein kinase gene, responsible for improved root system under P deficient conditions. There are twelve promising families in the pipeline. These lines show improved root system architecture than the donor Pusa 44.

1.1.2.4 Marker assisted identification of restorer lines from *indica-japonica* derivatives and their potential in hybrid rice improvement

A set of 310 *indica-japonica* derivatives were developed by crossing *indica* genotypes with tropical *japonica* lines, and marker assisted selection was adopted for identifying potential restorers for wild abortive male sterility system for their utility in hybrid

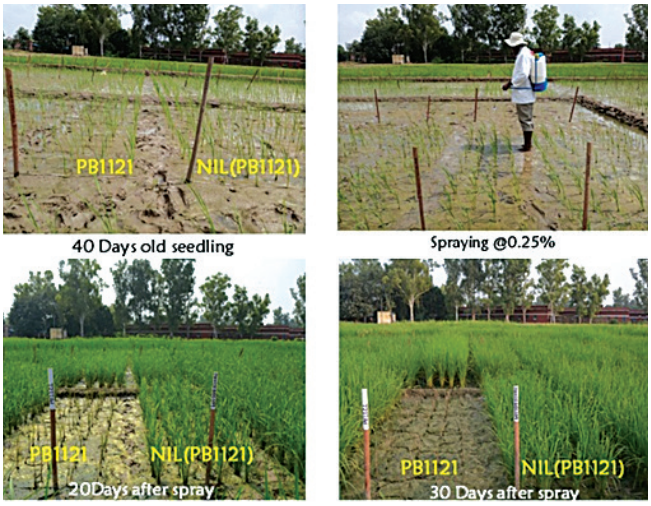
rice breeding. The derived lines were screened for the presence of two fertility restorer genes viz., *Rf3* and *Rf4* using a candidate gene based marker (DRRM-RF3-10) and a gene linked marker (RM6100), respectively. Based on allelic status with these markers, 36 genotypes were found to possess *Rf3* gene, while 45 genotypes were found to possess *Rf4* gene. Seven genotypes were

Tropical Japonica derived lines evaluated during *Kharif* 2017

found to possess both *Rf3* and *Rf4* genes. The potential restorers identified were used further to develop 54 test crosses using Pusa 6A as female and hybrids were tested in three diverse agro climatic locations during *Kharif* 2017. Validation of their fertility restoration as well as heterotic potential with the CMS line will help in improving the extent of heterosis in rice.

1.1.2.5 Marker aided introgression of herbicide tolerance trait into Pusa Basmati 1121

Marker assisted backcross breeding was employed to transfer herbicide tolerance gene (*Als)* from a donor parent HTM-N22 (Imazethapyr tolerant EMS induced mutant of Nagina 22) into popular rice variety, PB 1121. Foreground selection was carried out using the gene linked marker RM6844 and background selection was carried out using 110 polymorphic SSRs uniformly spanning the entire rice genome. Based on grain and cooking quality traits and genome recovery towards recurrent parent PB 1121, 22 superior BC_2F_4 families were selected and evaluated in both sprayed (Imazethapyr) as well as un-sprayed conditions.



Phenotypic screening of NILs in the background of PB 1121 for herbicide tolerance

1.1.3 Maize

1.1.3.1 Hybrids released and notified

Pusa Vivek QPM9 Improved. It is an improved version of Vivek QPM9, and was developed through marker-assisted introgression of *crtRB1* allele. It has been released and notified for Northern Hills Zone [Jammu & Kashmir, Himachal Pradesh, Uttarakhand (Hills) & North Eastern states] and Peninsular Zone [Maharashtra, Karnataka, Andhra Pradesh, Telangana & Tamil Nadu]. Its average grain yield is 5.59 t/ha (NHZ) and 5.92 t/ha (PZ), with a potential grain yield of 7.97 t/ha (NHZ) and 9.37 t/ha (PZ). It is improved for provitamin-A (8.15 ppm) compared to 2.26 ppm in Vivek QPM9. It is country's first provitamin-A

Pusa Vivek QP M9 Improved

rich maize hybrid. Due to presence of *opaque2*, it also contains high tryptophan (0.74%) and lysine (2.67%) in protein, and thus is a multi-nutrient maize hybrid. It is an early maturing hybrid which attains 75% dry husk at 93 days (NHZ) and 83 days (PZ) after sowing.

Pusa HM4 Improved. It is an improved version of HM4, and was developed through marker-assisted

Pusa HM4 Improved

introgression of *opaque2* allele. It has been released and notified for North Western Plains Zone [Punjab, Haryana, Delhi, Uttarakhand (plains) & western Uttar Pradesh]. Its average grain yield is 6.42 t/ha, with a potential grain yield of 8.57 t/ha. It is improved for protein quality and possesses high tryptophan (0.91%) and lysine (3.62%) in protein, compared to 0.58% tryptophan and 2.26% lysine observed in HM4. It is a medium maturing hybrid, and attains 75% dry husk at 87 days after sowing.

Pusa HM8 Improved. It is an improved version

Pusa HM8 Improved

of HM8, and was developed through marker-assisted introgression of *opaque2* allele. It has been released and notified for Peninsular Zone [Maharashtra, Karnataka, Andhra Pradesh, Telangana & Tamil Nadu]. Its average grain yield is 6.26 t/ha, with a potential grain yield of 9.26 t/ha. It is improved for protein quality and possesses high tryptophan (1.06%) and lysine (4.18%) in protein, compared to 0.59% tryptophan and 2.37% lysine in HM8. It is a medium maturing hybrid, and attains 75% dry husk at 95 days after sowing.

Pusa HM9 Improved. It is an improved version of HM9, and was developed through marker-assisted introgression of *opaque2* allele. It has been released

Pusa HM9 Improved

and notified for North Eastern Plains Zone [Bihar, Jharkhand, Odisha, West Bengal, & Eastern Uttar Pradesh]. Its average grain yield is 5.20 t/ha, with a potential grain yield of 7.41 t/ha. It is improved for protein quality and possesses high tryptophan (0.68%) and lysine (2.97%) in protein, compared to 0.28% tryptophan and 1.78% lysine in HM9. It is a medium maturing hybrid, and attains 75% dry husk at 89 days after sowing.

1.1.3.2 Performance of hybrids in AICRP trials

A medium maturing hybrid, AH 1601 evaluated in AICRP trial in *Kharif* 2016 showed an average yield of 7442 kg/ha based on which it was nominated for testing under State maize trials at Madhya Pradesh conducted by JNKVV in *Kharif* 2017. The identification proposal has been submitted to the MP State Variety

Identification Committee. Further, one baby corn (AH 7043) and three provitamin-A (APH 27, APQH 5 and APQH 7) were promoted to AVT-II. Besides, four hybrids (one early AH 7080, two medium AH 1606 and AH 7067R, and one late maturing AH 8183), one rainfed adapted (ADH 1620) and one provitamin-A rich hybrid (APH 1) were promoted from NIVT to AVT-1.

1.1.3.3 Performance of experimental hybrids in station / multi-environment trials

A total 574 newly developed single cross hybrids (270 late and 304 early to medium in maturity) were evaluated at IARI, Delhi; PAU Ludhiana and JNKVV Chhindwara during *Kharif* 2017. Of these, 30 (10 each in different maturity groups) were selected based on their superiority in yield over the best check/s.

1.1.3.4 Identification of potential inbred lines for hybrid development

A set of 50 lines developed using diverse source germplasm viz., hybrids, pools and populations, was evaluated for *per se* performance in *kharif* 2017. PML46, PML107, PML102, AI143 and AI36 with grain yield ranging between 3.5-3.8 t /ha were selected for breeding medium to late maturing hybrids.

1.1.3.5 Marker-assisted introgression of *lpa1* and *lpa2* mutant in elite inbreds

Seven elite inbreds viz., QPM version of HKI323Q, HKI1105Q, HKI1128Q; and QPM + provitamin A version of HKI161, HKI163, HKI193-1 and HKI193-2, which are the parents of nine hybrids (HM4, HM8, HM9, HM10, HM11, HQPM1, HQPM4, HQPM5 and HQPM7) were targeted for introgression of *lpa1* and *lpa2* alleles separately. Fifty five BC_2F_2 progeny with homozygosity for *lpa1* and *lpa2* (individually) were selected for grain quality analyses.

Star indicates improved version of the original inbreds

1.1.3.6 Development of vitamin-E enriched inbreds

QPM and provitamin A version of four elite hybrids viz., HQPM1, HQPM4, HQPM5 and HQPM7 were targeted for marker-assisted introgression of *VTE4* allele. The α-tocopherol in the BC_2F_3 progenies (with *opaque2*, *crtRB1*, *lcyE* and *VTE4*) increased up to 21.7 ppm compared to 6-10 ppm in the original inbreds.

1.1.3.7 Development of biofortified sweet corn genotypes

ASKH1 (SWT016 × SWT017) and ASKH2 (SWT016 × SWT018), promising sweet corn hybrids developed at IARI, New Delhi were targeted for enrichment of lysine, tryptophan, provitamin-A and vitamin-E by introgressing *opaque2*, *crtRB1* and *VTE4* alleles in different combinations. Progenies homozygous for i) *shrunken2*, *opaque2* and *crtRB1*, and ii) *shrunken2*, *VTE4* and *crtRB1* were developed in SWT016, SWT017 and SWT018 genetic background. Further, inbreds in the genetic background of HKI 161, HKI 163, HKI 193-1 and HKI 193-2 having *shrunken2*, *crtRB1* and *opaque2* have been developed.

1.1.3.8 Combining *opaque2* and *opaque16* in white maize for enhancement of protein quality

Parental lines of white grained hybrids viz, HM5 (HKI1344 × HK1348-6-2) and HM12 (HKI1344 × HKI1378) were targeted for marker-assisted introgression of both *opaque2* and *opaque16*. BC_1F_1 populations were genotyped using *o2* (gene based SSR; *phi057* and *phi1066*) and *o16* (linked SSRs: *umc1141* and *umc1149*) specific markers, and segregants heterozygous for both the genes having high background recovery and phenotypic similarity with the original lines were advanced to generate BC_2F_1.

1.1.3.9 Introgression of *teosinte branched-1* from Sikkim Primitive

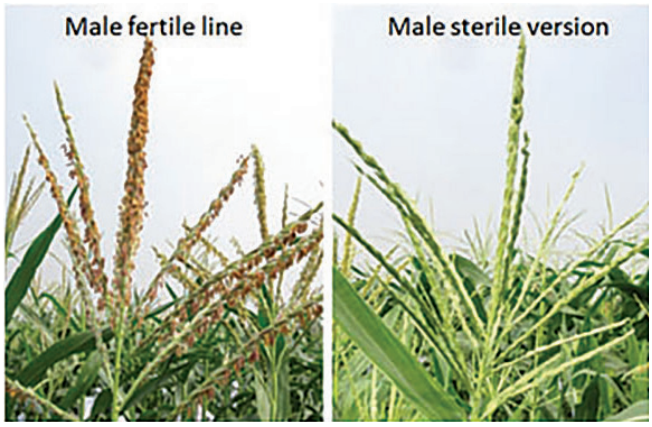
Sikkim primitive has been identified as one of the unique landrace accessions in India as it bears 6-8 ears/plant compared to 1-2 ears/plant observed in conventional maize germplasm. *Teosinte branched-1* (*tb1*) gene has been advocated as the primary reason for prolificacy in maize. Nine elite inbreds (HKI323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1 and HKI 193-2, CM 150Q and CM 151Q) which are parents of ten hybrids were targeted for marker-assisted introgression of *tb1* allele. BC_1F_1 and BC_2F_1 populations were genotyped using *tb1*-specific marker, and foreground positive plants with high background recovery and phenotypic similarity were selected and advanced to generate BC_2F_2 populations.

1.1.3.10 Development of high amylopectin maize

High amylopectin/waxy maize is a popular choice in North-Eastern states. It contains 95-100% amylopectin, in contrast to 70-75% in normal maize. Recessive *waxy1* (*wx1*) allele enhances amylopectin. Two hybrids viz., Pusa waxy-1 and Pusa waxy-2 developed from waxy inbreds developed at IARI, New Delhi were identified as the most promising. Further, *wx1* has been targeted for introgression in seven elite inbreds (HKI 323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1 and HKI 193-2) that are the parents of nine popular hybrids. BC_1F_1 and BC_2F_1 generations were genotyped and segregants heterozygous for *wx1* with high recovery of background genome recovery and phenotypic similarity were selected and advanced to generate BC_2F_2 populations.

1.1.3.11 Development of male sterile baby corn

Male sterile baby corn possesses significant advantage as it does not require manual detasseling which is a laborious and time consuming operation, and increases the cost of the cultivation. Donor with cytoplasmic male sterile cytoplasm has been crossed in elite inbreds viz., HKI 323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1, HKI 193-2, V335PV, V345PV, CM150Q, CM151Q, SWT016, SWT017, SWT020 and



Tassel characteristics of male fertile (HKI193-1) and its male sterile version

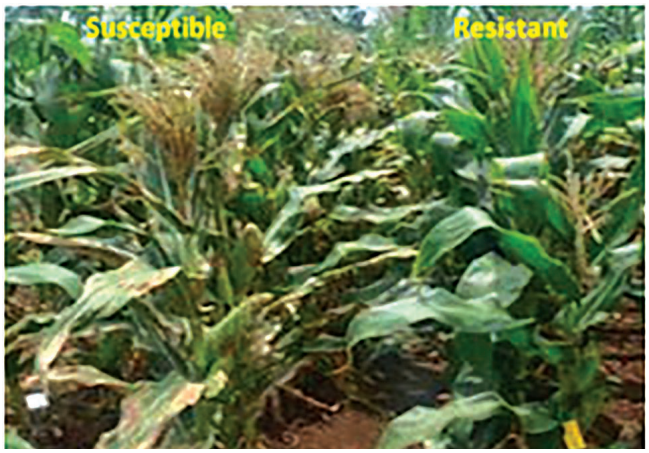
SWT021. Backcross progenies with male sterility and similarity with the original inbreds for plant-, ear- and grain- characteristics were selected for detailed characterization.

1.1.3.12 Hybrids with tolerance to TLB

Five hundred experimental hybrids were screened for turcicum leaf blight (TLB) under natural epiphytotic conditions. Fifty potential hybrids with mean disease score less than 2.0 were selected. H 7363, H 7583R, H 8245 in late, and H 7556R, H 7582, H 8622 in medium category displayed >20% heterosis over best checks.

1.1.3.13 Inbreds with tolerance to foliar diseases

A set of 100 newly developed inbreds were screened against Turcicum Leaf Blight (TLB), Maydis Leaf Blight (MLB) and Curvularia Leaf Spot (CLS).



TLB resistant line PDM-4641

CDM 1345, DIM 302, PDM 188, CDM 1308, PDM 4641 were resistant for TLB. Whereas, CDM 1306, DIM 302, CDM 1345 and PDM 4131 were resistant to MLB; and DIM 335, PDM 4131, CDM 1306 possessed resistance to CLS. PDM 188 and CDM 1305 with multiple disease resistance (MLB, TLB and CLS) were identified for augmenting resistance breeding programme. Preliminary screening indicated DIM-301 and DIM-313 with shoot borer tolerance.

1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Hybrid released and notified

Pusa 1201 (MH 1849). A dual purpose pearl millet hybrid with high grain and stover yields was released and notified for NCT of Delhi**.** Average grain yield of this hybrid is 2.81 t/ha with stover yield of 7.20 t/ha. It matures in 80 days (78-83 days in zone A). It is highly resistant to downy mildew. Based on the average of six locations, grain iron and zinc content of Pusa 1201 is 55 ppm and 48 ppm, respectively.

Pusa 1201

1.2.1.2 Performance of hybrids in coordinated trials

In Advanced Hybrid Trial- Medium, sixteen entries including five checks were evaluated during *Kharif* 2017 at 21 locations. Pusa 1601 (MH 2235) out yielded best check MPMH 17 by a margin of 3.44% and 86M01 by a margin of 9.35%. Three hybrids viz., Pusa 1701 (MH 2313), Pusa 1709 (MH 2314) and Pusa 1712 (MH 2315) were tested at 18 locations in Initial Hybrid Trial-M in zone A. Out of thirty nine hybrids tested in this trial, hybrid MH 2314 ranked at number four with an average yield of 3.61 t/ha followed by MH 2315 (rank 6) with an average yield of 3.40 t/ha and MH 2313 (rank 9) 3.34 t/ha. Hybrids MH 2314 and MH 2345 out yielded the best check by a margin of 7.92 and 1.67%, respectively.

1.2.1.3 Hybrid development and evaluation

Three hundred two new test hybrids were developed involving high yielding, downy mildew resistant, blast resistant and high iron and zinc enriched parents belonging to early and medium maturity group. Sixty three hybrids based on A_4 cytoplasm were tested in Intermediate Station Trial. Twelve hybrid combinations were found promising. Thirty four hybrids based on A_4 cytoplasm were tested in Initial Station Trial. Four hybrid combinations were found promising. Thirty seven hybrids developed by crossing iron enriched parents were tested in Intermediate Station Trial. Twelve hybrid combinations were found promising. Eighteen hybrids developed by crossing of iron enriched parents were tested in Initial Station Trial of which two hybrid combinations were found promising.

1.2.1.4 Promotion of entries in coordinated trials

Population trial in Zone A was conducted at 10 locations and two varieties, Pusa Composite 712 (MP 577) and Pusa Composite 714 (MP 579) recorded higher grain yield 2.34 t/ha and 2.31 t/ha, respectively, than best check JBV 2 (2.28 t/ha) and were promoted. Three genotypes, 411A, 411B and PPMI 1002 were nominated to Pearl Millet Downy Mildew Virulence Nursery (PMDMVN)-2017. Based on 11 location data, genotype PPMI 1002 was found highly resistant at 30 DAS (1.9 %) and 60 DAS (1.8%).

1.2.1.5 Maintenance breeding of cytoplasmic male sterile lines

Forty CMS lines were maintained by attempting 1560 paired crosses. Nucleus seed multiplication of 19

promising CMS lines (411A/411B, 431A/431B, ICMA 843-22/ICMB 843-22, ICMA 841A/B, ICMA 92777A/B, 576A/B, ICMA 96222/B, ICMA 96666 /B, ICMA 97111/B, ICMA 98444/B, ICMA 99111/B, ICMA 99444/B, ICMA 01222/B, ICMA 01555/B, ICMA 04111/B, ICMA 04999/B, ICMA 08666/B, ICMA 11222/B, and ICMA 13222/B) was undertaken.

1.2.1.6 Maintenance breeding of restores/inbreds

Total 367 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 content.

1.2.1.7 Evaluation of newly introduced CMS and high Fe and Zn lines

Seventy four A/B pairs and 43 restorer lines selected at ICRISAT during field day were evaluated for their suitability to early maturity, disease resistance, spike thickness, compactness and overall agronomic performance during 2017. Twenty nine high Fe and Zn lines selected at ICRISAT were also evaluated during *Kharif* 2017.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Variety released and notified

BG 3043. A *desi* chickpea variety BG 3043 was released and notified for timely sown conditions of NEPZ (eastern Uttar Pradesh, Bihar, West Bengal, Jharkhand, and Assam). Its average yield is 1.6 t/ha and has a potential yield of 2.5 t/ha. Its 100-seeds weight is 21-22 g. It matures in about 130 days and is suitable for rice-chickpea cropping system of eastern India. It has profuse branching and as a result produces more number of pods per plant.

BG 3043

1.3.1.2 Variety identified

BGD 111-1. A high yielding chickpea variety BGD 111-1 was identified for release in rainfed conditions of Karnataka. It has average grain yield of 1.9 t/ha with a 100-seed weight of 25 g. It matures in 96-98 days. It is suitable for moisture stress conditions of short season environment.

Grain characteristics of BGD 111-1

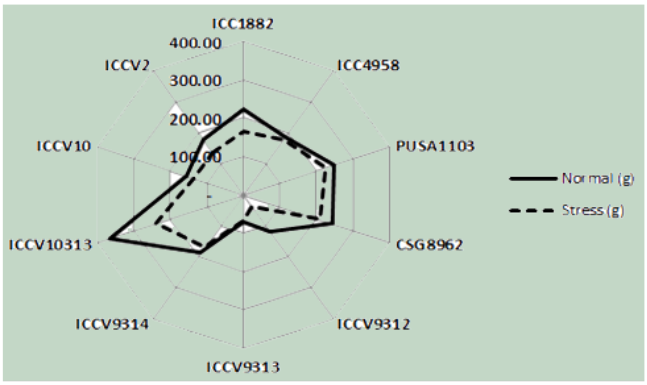
1.3.1.3 Promising chickpea entries in AICRP

Three *desi* chickpea entries were promoted to AVT 1 (BG 3075 and BG 3076 in AVT 1-*desi* and BG 3062 in AVT 1-MH) during 2017-18. Two drought tolerant introgression lines (BG 3097 and BG 3098) were entered in AVT 1-DTIL. Eleven promising genotypes were entered in IVTs (BG 3087 and BG 3088 in IVT- *desi*, BG 3089, BG 3090 and BGD 139 in IVT-Rainfed, BG 3091 and BG 3092 in IVT-Late sown, BG 3093 and BG 3094 in IVT-MH and BG 3095 and BG 3096 in IVT-*Kabuli*).

1.3.1.4 Identification of selection indices to discern response of chickpea to drought stress

Chickpea responds to drought stress with an array of biochemical and physiological mechanisms which include reduced cell growth and decreased leaf area,

biomass and yield. Since growth and photosynthesis are the two main processes affected by drought stress, maximum reduction was seen in plant height, yield and biomass. Genotypes viz., ICC 4958, Pusa 1103, CSG 8962, ICCV 10313, and ICCV 10 showing minimum reduction in growth parameters and low drought susceptibility index under stress conditions were identified for use in breeding programme to develop drought tolerant lines.



Star Micro plot of yield under normal and drought stress

1.3.2 Pigeon pea

1.3.2.1 Variety released and notified

Pusa Arhar 16. Pusa Arhar 16 was released and notified for NCT, Delhi. Its average seed yield in station trials, large scale demonstrations and crop cutting experiments is 1.96 t/ha in Delhi over four years. It is an extra early maturing (120 days) variety with compact semi-erect plant type and is suitable for high density planting and harvesting by combine harvester. Due to its semi-dwarf stature, spraying is easy and efficient with knapsack sprayer.

Pusa Arhar 16

1.3.3 Mungbean

1.3.3.1 Variety released and notified

Pusa 1431. Pusa 1431 was released and notified for NCT Delhi. Its average seed yield is 1.30 -1.38 t/ha at IARI New Delhi. It matures in 66 days and 100-seed weight is 4.7g. It showed multiple resistance to mungbean yellow mosaic virus (MYMV), Cercospora leaf spots (CLS), anthracnose and web blight.

Pusa 1431

1.3.4 Lentil

1.3.4.1 Variety released and notified

L 4727. L 4727 was released and notified for cultivation under timely sown, rainfed conditions of central zone comprising states of Madhya Pradesh, parts of Uttar Pradesh Rajasthan and Chhattisgarh during *Rabi* season. Average yield of this variety is 1.15 to 1.45 t/ha.

L 4727

1.4 OILSEED CROPS

1.4.1 Mustard

1.4.1.1 Variety released and notified

Pusa Double Zero Mustard 31. First double zero Indian mustard variety, initially released for NCT, Delhi during 2015, has now been released for Zone II (Punjab, Haryana, Delhi, Jammu and Northern Rajasthan). Average seed yield of this variety is 2.32 t/ha. It is a yellow and small (3.68g/1000-seeds) seeded variety with 41.6% oil content. Its oil contains <2% erucic acid and defatted seed meal cake contains <30 PPM glucosinolates. It matures in 142 days.

Pusa Double Zero Mustard 31

1.4.1.2 Elite lines/hybrids contributed to AICRP-RM trials

During 2017-18, 20 entries were contributed for evaluation under AICRP-RM trials. Out of these two hybrids (Pusa MH 8 and Pusa MH 9) based on *Diplotaxis berthautii* were contributed for the first time from IARI, New Delhi for evaluation in Initial Hybrid trial. NPJ 203 and LES 54 were evaluated in AVT-1 Timely Sown and AVT-1 Quality trials. The rest of the entries were evaluated in their respective trials viz., IVT Early (NPJ 209, NPJ 210), IVT Timely Sown Irrigated (NPJ 211, NPJ 212), IVT Timely Sown Rainfed (NPJ 213, NPJ 214), IVT Quality [LES 56 (0), LES 57 (0), PDZ 9 (00), PDZ 10 (00)] and IVT Late Sown (NPJ 215, NPJ 216), IHT (Pusa MH 8 and Pusa MH 9). Four entries viz., NPJ 217, NPJ 218, NPJ 219 and NPJ 220 were evaluated under National Disease Screening Nursery.

1.4.1.3 Elite lines/hybrids evaluated in station trials

One hundred twenty four advance lines and 20 CGMS based hybrids were evaluated in seven station trials viz., MST (Early Sown), MST (Timely Sown Irrigated), MST (Timely Sown Rainfed), MST (Quality), MST (Hybrid) and MST (Late Sown).

1.4.1.4 Breeding for high temperature tolerance

Eighty advance genotypes including station trial entries were evaluated for juvenile and post-reproductive stage heat stress. To elucidate the genetics of high temperature tolerance, 15 F_2 populations involving tolerant (PM 26, Bio 902 and EJ 20) and susceptible (PM 21, EC 597325 and NPJ 119) parents were raised under timely and late sown conditions.

1.4.1.5 Phenotyping for identification of '0' and '00' genotypes

For identifying low erucic acid and double low genotypes in segregating generations and maintenance of double/ single low varieties and advance lines, a large number of single plants and bulks were phenotyped through biochemical analysis. For low erucic acid, 7025 single plants/bulks were analyzed of which 6308 were having <2% erucic acid. Total 2128 single plants/bulks from double low quality breeding material were also analyzed for total glucosinolates content, of which 1034 plants/bulks were possessing <30ppm glucosinolates.

1.4.1.6 MAS for white rust and quality traits

Molecular markers linked to white rust and oil quality traits were screened in thirty backcross populations (BC_1F_1, BC_2F_1 and BC_3F_1) generated for introgression of white rust resistance alongwith low erucic acid and/or glucosinolates 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 genotypic data, 31 backcrosses were attempted with the respective recipient parents.

1.4.1.7 Breeding for white rust resistance

Well adapted genotypes were crossed with white rust resistance donors like Bio-YSR, BEC-144, BEC-286, Heera and EC-399299 and 255 progenies in F_7, BC_1F_6, F_3, BC_2F_1 and F_2 generations were raised at IARI RS, Wellington, and 17 entries were bulked and 303 single plants were selected. Bulked entries were evaluated in the main season in station trial. Progenies of the resistant plants (F_8, BC_1F_7, F_4, BC_2F_2 and F_3 generations) were evaluated and 40 single plants were selected for white rust and agronomic traits at New Delhi during 2017-18.

1.4.1.8 Hybridization and pre-breeding

Total 229 trait based crosses were attempted for various objectives. In addition, to transfer white rust resistance in 0/00 genotypes, 59 crosses were attempted with the genotyped plants. To infuse genetic variability and improve agronomic traits, other *brassica* species are being utilized. Introgression lines derived from *B. juncea* x *B. carinata* (179 progenies of BC_4, BC_1F_3 and three way crosses) were raised under rainfed conditions and 224 single plants were selected. Crosses (54 F_1s) attempted with *eru-rapa* derived *B. juncea* introgression lines and resynthesised *B. juncea* lines with improved *B. juncea* genotypes, were raised and further crossed to improved backgrounds to eliminate linkage drags.

1.4.1.9 Cytoplasm diversification and CMS line development

To transfer nuclear genome from 22 genetic backgrounds to different sterility inducing cytoplasms viz., *Moricandia arvensis* (*mori*), *Diplotaxis erucoides* (*eru*) and *Diplotaxis berthautii* (*ber*), 52 backcrosses (BC_4-BC_{11}) were attempted in three pairs each with pollen tested plants. Many of these fixed CMS lines were used for hybrid seed production.

1.4.1.10 Restorer development and maintenance

Backcrosses (BC_3-BC_5) were attempted to transfer *Rf* gene, which restores fertility in *mori*, *eru* and *ber* sterile cytoplasms, to 46 nuclear backgrounds. Homozygous dominant plants of restorers (in BC_4F_5 and BC_5F_4 generations) developed through MABB for transferring *Rf* gene to 5 genetic backgrounds (142 progenies), were evaluated and selfed for their further utilization. Twenty six restorers developed through pedigree selection and tested for presence of *Rf* gene were maintained by raising 77 progenies. One hundred one progenies of 31 restorers used as one of the parent in test hybrids, were evaluated and maintained.

1.4.1.11 Hybrid evaluation and seed multiplication

Forty hybrids were evaluated in different Hybrid trials viz., Station Trials (20); multilocation trials under CRP Hybrid Technology (20) [CRPMLT1 Short Duration - (5); CRPMLT 2 Medium Duration – (5), CRPMLT 3 Short Duration- (10)]. Open pollinated seed of 30 hybrids was multiplied in isolation through raising A and R lines alternatively in a row ratio of 5:1. Two restorers viz., Pusa RP 7-3-1-14 and Pusa RP 10-2-1-10 were shared with all the three cooperating centers under CRPHT project.

1.4.1.12 Breeding material evaluated and advanced

Out of the 1152 segregating progenies raised, 77 bulks (Early sown-14, Timely sown-20 and Late sown -23) and 1166 single plants (Early sown-143, Timely sown-363, Quality (0/00)-516 and Late sown -144) were selected and advanced to generations. Fifty F_1s raised for identification of good combiners have also been evaluated. Out of the 114 multiple crosses raised, 112 single plants were selected.

1.4.2 Soybean

Entries in Coordinated trial. DS 3108 was promoted to AVT-I (North Eastern Hills Zone), while DS 3105 (North Eastern Hills Zone) and DS 3106 (North Plains Zone) were advanced to AVT-II.

1.5 SEED SCIENCE AND TECHNOLOGY

1.5.1 Studies on Seed Quality Traits

1.5.1.1 Superoxide content and axis length during seed germination in different types of Indian mustard

Studied changes in content of superoxide anion and explored its possible role in increasing radicle length during germination; which could substantiate the vigour differences in various Indian mustard genotypes. The results showed that the superoxide anion was positively correlated with radicle length which in turn was positively correlated with seed vigour index-I. The single zero and conventional genotypes of Indian mustard had higher content of superoxide anion during 36 hours of germination when radicle length was more than 2 mm. In case of double zero type of Indian mustard, both radicle length and superoxide anion content were significantly lower. Thus, the lower content of superoxide anion could be considered as a possible reason for insignificant increase in radicle length in double zero type of Indian mustard which further may be the cause for their lower seed vigour index-I in comparison to conventional and single zero genotypes of Indian mustard.

1.5.1.2 Seed quality evaluation under storage in specialty maize

Scanning Electron Microscopic (SEM) observations on internal morphology showed differences in starch granules (size, distribution, structure). Hard kernelled types (dent and popcorn) had distinct starch granule arrangement than soft kernelled types (QPM, sweet corn and flint corn). Storage studies under ambient and 20°C for 12 months showed variation among genotypes for germination, vigour, enzymatic activities and seed internal morphology. Among different groups; sweet corn (sugary and double recessive types) and QPM genotypes showed lowest (up to 6-8 months) germination and popcorn and waxy types (up to 12 months) the highest germination and storability among genotypes studied. Seed storability was better under 20°C as compared to ambient storage. During storage, decrease in seed quality was more pronounced between 6 to 12 months under ambient storage conditions. Decline in seed quality was more in parental lines as compared to hybrids and male lines showed poor storability as compared to their female counterparts. Seed stored under ambient condition deteriorated faster due to higher production of superoxide (O^{2-}), hydrogen peroxide (H_2O_2) and free radicals with poor free radical quenching mechanism (lower activity of antioxidant enzymes; SOD and POX). The study concluded that maize compositional groups varied in internal morphology, chemical composition, physiological and biochemical behaviour with differential storage potential.

1.5.1.3 Antioxidant enzymatic activity in pigeonpea primed seeds

The enzyme Ascorbate peroxidase in pigeonpea was found to be significantly negative correlated with Vigour index I but Dehydroascorbic acid enzyme did not show any correlation with any of the seed quality parameters. Glutathione Reductase(GR) with the variety and Monodehydroascorbate Reductase (MDHAR) with age of the seed and vigour index I was found to be highly correlated. Highest activity of MDHAR was observed in seeds exposed at 40°C for 24 h where as it was lowest in osmo-primed (11h at 25°C in 60% PEG-6000 solution) seeds. However, the enzymatic activity was at par with the control.

1.5.1.4 Ascorbate-Glutathione cycle in various recombinant inbred lines (RILs) of soybean

The antioxidant enzymes involved in Ascorbate-Glutathione cycle viz., APX, DHAR, MDHAR, and GR were studied in 46 RILs of Soybean. It was found that the ascorbate recycling enzymes monodehydroascorbate reductase (MDHAR) was significantly negatively correlated (-0.3182) with dehydroascorbate reductase (DHAR) enzyme and was significantly positively correlated (0.4285) with GR enzyme. Moreover, GR was positively correlated with seed viability and

1000 - seed weight indicating that GR could be one of the probable enzyme for seed vigour determination.

1.5.1.5 Selection of best responding varieties through various priming treatments

In order to identify the soybean varieties that respond well in case of hydro-primimg, osmo-priming and thermo-primimg treatments, seven varieties of soybean viz., JS 9752, SKF-NRC 7, SKF-JS 335, SKF 6029, VL-Soya 47, VL-Soya 59 and P 1247 were selected. These varieties were subjected to hydro-priming with W/V of distilled water at 25°C for 4h; osmo-priming with W/V of PEG6000 (60%) at 25°C, thermo-priming by exposing the seeds at 40°C for1h followed with untreated seed as control. JS 9752 and SKF-NRC 7 showed highest germination percentage in all the treatments compared to control. Out of the various treatments, seeds responded well to the thermo-priming treatment in terms of germination percentage, seedling length, seedling dry weight and seedling vigour index-I and II followed by osmo-priming.

1.5.1.6 Effect of priming treatments on field parameters and storage in pigeonpea

Field emergence and speed of germination were significantly affected by variety, sowing time and treatments. Highest emergence of 65.2% was observed in Pusa 991 and it was 75.1% when sown on June 6, 2017 which was significantly higher than the rest of the two sowings done later at 15 days interval. The exposure of seed at 40°C for 24 h was found to be significantly better for both field emergence (79.8%) and speed of germination (13.5). The plant height, primary branches and number of pods on main shoot were also found significantly affected by variety, sowing time and treatments, whereas the biological yield and seed yield were influenced by sowing time. In the first sowing, significantly higher seed yield per plant (74.5g) was recorded, however, the priming treatment with 3% Na_2HPO_4 recorded significantly higher per plant yield of 84.1g over all other treatments. All the seed quality parameters were found significantly better in primed seed stored for one month which declined subsequently after two and three months of storage. Significantly higher germination (81%) was recorded after one month which declined to 71.2% after 3 months of storage. The germination (85.5%) in seeds treated with Thiram @ 3g/kg + Rhizobium was found to be the best among all the priming treatments which was followed by exposure of seed at 40°C for 24 h. However, it was at par with control (80%). The seed vigor index I and II were also found to be significantly better with Thiram @ 3g/kg + Rhizobium treatment. All seed quality parameters had significant negative correlation with storage period.

1.5.1.7 Effect of priming treatments on field parameters and storage in soybean

Field emergence and speed of germination was found significantly affected by variety and sowing time while treatments were found to be non-significant for both. Highest speed of emergence (13.7) and field emergence (82%) was observed in halo-primed (Salt solution of 4EC for 4h) seeds of variety JS 9752 sown on July 11. The plant height was higher (43.3cm) in Metalaxil @ 2.5ml/kg+Imidachloprid 600 FS @ 8.75 ml/kg seed followed by Thiram @ 3g/kg + Rhizobium with non-significant difference over control (41.9cm). Number of nodes and primary branches were found higher in primed seeds (0.2% Potassium nitrate). No- significant differences were observed for yield in all treatments. The variety JS 9752 was found to be significantly superior for all the field parameters. Delayed sowing showed negative effect on plant architecture and yield attributing traits. Yield was found to be significantly correlated with plant height, number of nodes and primary branches. Significantly higher germination was observed in seeds exposed at 40°C for 1 h (72.3%) than control (61.1%). The exposure of seed at 40°C for 24 h and hydropriming (4h at 25°C) treatments also showed significantly higher vigour index II than control. Germination after one month of storage was significantly higher (71.9%) than seed stored for two months (67.2%) and three months (38.8%). Similar trends were observed for all other seed quality parameters in primed seed stored for three months. There were significant differences in storage behaviour of treated seeds of different varieties.

1.5.1.8 Variation in seed physical parameters in mungbean varieties in different growing seasons

Presence of hard seeds in seed lots lead to non-uniform and lowered plant population and uneven maturity. The occurrence and variation of hard seededness has been studied in 51 mungbean genotypes by growing in the field during summer and *Kharif*, 2016. Hard seededness among the genotypes ranged from 2% to 11% and 3% to 46% in summer and *Kharif* seasons grown seed lots, respectively. In the seed lots of genotypes grown in *Kharif* season the seed size of selected hard seed genotypes ranged from 3.69/2.90mm (L/W) to 4.58/3.31mm (L/W) and in selected non-hard seed genotypes it ranged from 4.01/2.46mm (L/W) to 4.83/3.48mm (L/W). The 100- seed mass in selected hard and non-hard seed genotypes ranged from 2.69 to 4.13g and 2.39 to 3.94g, respectively, in *Kharif* season grown seed lots. In summer season it ranged from 3.57 to 4.75g and 3.05 to 5.58g in selected hard seeded and non-hard seeded genotypes, respectively. A higher seed density of hard seeded genotypes was recorded in comparison to that of non-hard seeded genotypes. The SEM images indicated that the hard seeds had a compact outer cell layer with low surface deposition and depression on the seed coat while the non-hard seeds had loose cells and cracks in the seed coat with high depression and surface deposition. A relatively larger seed size in genotypes grown in summer season showing lower occurrence of hard seeds suggest that the summer season is the desired season for production of quality seeds of identified hard seeded mungbean genotypes.

1.5.1.9 Potential of bio-agents in enhancing seed quality of onion during storage

Freshly harvested (2015-16) and carry over seeds (2014-15) of onion cultivar, Pusa Red and Pusa Riddhi were subjected to seed treatments with the formulations/ cultures of different bio-agents, viz., *Trichoderma harzianum*, *Pseudomonas flourescens*, *Bacillus pumilus* and *Bacillus subtilis* and fungicidal seed treatments viz., Thiram and Bavistin as per the recommended dosage, packaged in cloth bags and aluminium foil packets and stored for a period of 6 months. The samples were drawn at an interval of 2 months each and evaluated for different seed quality parameters viz., seed moisture content, speed of germination, mean germination time, germination percentage, vigour indices and seed health. All the seed treatments were effective in enhancing the seed quality, except *Trichoderma harzianum;* seed treatment with *Pseudomonas flourescens* was effective up to two months of storage only. The plant growth promoting rhizobacteria (PGPRs) viz., *B. pumilis* and *B. subtilis* were found effective in enhancing the germination, field emergence and vigour of onion seeds, which was at par with the chemical seed treatments (Thiram, Thiram + Bavistin). Aluminium foil packaging was better to cloth bags, as the later recorded higher seed moisture content during storage, resulting in faster rate of seed deterioration. Amongst varieties, Pusa Red exhibited better seed storability as compared to Pusa Riddhi. Hence, these PGPRs can be recommended as an alternative to chemical seed treatments for enhancing the planting value and longevity of onion seeds.

1.5.2 Seed Production in CMS Lines of Rice

Rice CMS lines showing differences in flowering time were studied with seeding interval and GA_3 application for seed production. IR79156A/B, RTN 13A/B showed 3-4 days difference in onset of flowering. Seeding interval of 5 days was followed between the parental lines and GA_3 @100g/ha was applied. The results indicated that the parental lines matched for first and mid-flowering time between the parental lines considerably well that lead to an increase of about 7% seed set as compared to that in same day seeding of the parental lines. In another experiment GA_3 was applied at 50,100,150, 200g/ha at appropriate stages in the parental lines (IR79156A/B, IR64608A/B). The results indicated that the parental lines responded positively with increasing doses of GA_3. With the application of GA_3 @200g/ha, the maximum seed set achieved was 47% (control: 27%) in IR79156A and 53% (control: 35%) for IR64608A.

1.5.3 Synchronization of Flowering of Parental Lines of Maize

Hybrid seed production potential of pipeline sweet corn hybrids; ASKH 1 and ASKH 6 was evaluated under Delhi conditions. Parental lines of ASKH 1

and ASKH 6 showed non-synchrony in flowering ranging from 2-3 and 5-7 days, receptively, in *Kharif* season. Non-synchronization up to 2-3 days could be bridged by good pollen shedding in male parent and long stigma receptivity (6-8 days) in female parental lines of potential sweet corn hybrids. However, non-synchronization of 5-7 days was managed by soil application of nitrogenous fertilizers (DAP, urea), foliar application of growth regulators (IAA, GA_3, NAA) and fertilizers (urea, DAP). The results showed that application of NAA@ 500ppm thrice at 2 days interval before anthesis in late parent reduced duration of non-synchronization of flowering by 5 days and also improved vegetative growth in the parental lines.

1.5.4 Effect of Controlled Pollination Methods for Seed Yield and Quality Parameters in Pigeonpea

The seed of four varieties of pigeon pea viz., Pusa 991, Pusa 992, Pusa 2001 and Pusa 2002 planted during *Kharif* 2017 to evaluate the comparative efficacy of pollination control methods using different types of selfing nets/ bags viz., large nets (5m x 3m x 3m) and net bags (86 cm x 46 cm, 50 cm x 28 cm, 1m x 1m x 1.65 m) in influencing seed yield and quality parameters in pigeon pea. The plants were covered with nets/ net bags after bud initiation, but prior to flowering. The uncovered plants/ plot were used as control (open pollination). Twenty plants/branches were tagged with three replications in each treatment and observations on plant height, days to flowering, number of branches/ plant, number of pods/plant, seed yield/plant, 100- seed weight, seed germination and vigour indices were recorded. The seed yield and quality parameters were significantly influenced by the size of the net bags. The larger nets were effective in maintaining seed yield as well as quality and were comparable to control plots. However, the smaller net bags (86 cm x 46 cm and 50 cm x 28 cm) exhibited poor seed setting and seed quality. The experiment was conducted for two years. Therefore, large nets (5m x 3m x 3m) and net bags (1m x 1m x 1.65 m) can be used for maintenance of plot and individual plants, respectively,of pigeonpea varieties.

1.5.5 Seed Health

1.5.5.1 Management of sheath rot of paddy

Seed treatment with Carbendazim 12% WP + Mancozeb 63% WP @3 g/kg seed was found at par with Carboxin 37.5% and Thiram 37.5% WS @2.5 g/ kg seed. These seed treatments in combination with seedling dip in suspension of *Pseudomonas flourescens* @ 10g/ litre followed by one spray Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/liter water at 50 days after transplanting was found most effective. This was validated in *Kharif* 2017 and can be advocated to the farmers.

1.5.5.2 Management strategy against multiple diseases in wheat using combination approach

In management trial using HD 3059 as test variety, seed treatment with Carboxin 37.5% + Thiram 37.5 % WS @ 2.5g/kg seed + two foliar sprays of Propiconazole 25% EC @ 0.1 % at boot leaf stage and 20 days after 1st spray gave best result in reducing the spot blotch of wheat as well as increasing the 1000 - grain weight and grain yield of wheat. Only two foliar sprays of Propiconazole 25% EC @ 0.1% at boot leaf stage and 20 days after 1st spray also gave good result in reducing the spot blotch of wheat. This also took care of yellow rust which was observed in unsprayed plot but was not observed in plots with two sprays of propiconazole.

1.5.5.3 Understanding the seed borne nature and mechanism of seed transmission of soybean yellow mottle mosaic virus (SYMMV)

Mungbean cv. Pusa Vishal and COGG 912 showing mottling and mosaic symptoms under field conditions were collected along with healthy plant samples and were tested for the presence of virus in the groups of one, two, three, five and ten seeds for the whole seed, seed coat, cotyledons and embryo through direct antigen coated enzyme linked immunosorbent assay (DAC-ELISA). DAC-ELISA result revealed the presence of virus mainly in the seed coat and cotyledonary portions with less presence in the embryo. Grow out test for infected seeds did not show any symptoms and did not react positively with SYMMV antiserum in DAC-ELISA detection technique. In the experimental host

(French bean cv. Pusa Parvati and mungbean cv. Pusa Vishal), the virus was detected successfully through DAC-ELISA in the inoculated, systemic leaves, flower (Sepals, petals, stamen and stigma), pod, whole seed, seed coat and cotyledonary portions.

1.5.5.4 Management of bruchid infested seed of lentil cv. L 4076 through mechanical processing

Lentil seed, cultivar L 4076, grown at ICAR-IARI, Regional Station, Karnal during *Rabi* 2013-14 and stored under ambient storage conditions up to *Rabi* 2016-17 having 9.76% bruchid infestation was taken for the study. The seed was passed through air machines (air blowers) which reduced the bruchid infestation to 6.59% only by eliminating only the completely hollow seeds but were unable to eliminate the infested seed with dead insects inside them. This material did not meet the IMSC standard of 1.0% insect damage in legumes and 98% physical purity. Therefore, the infested seed lot was reprocessed on specific gravity separator (SGS). A total of 12 treatment combinations, comprising of three deck slopes (S_1- 2.5^0, S_2- 2.0^0, S_3- 1.5^0), two feedings (F_1- 8kg, F_2- 11kg per minute) and two air volumes from four air blowers (A1 - 50, 50, 50, 50%; A2 - 50, 100, 50, 100%) blowing through the porous deck of SGS, were studied.

Minimum infestation in the final product (0.73%), which is below the IMSC standards, maximum healthy seed recovery (9.32kg/minute) with 93.9% recovery efficiency was obtained by treatment $S_3F_2A_2$. Of the three slopes studied, 1.5^0 slope of the deck gave minimum bruchid infestation in final output (0.98%), maximum final output of healthy seed per minute (7.53kg) and maximum recovery efficiency of 87.17%. With increase in slope of the deck, infestation in the final output increased but final output per minute and recovery efficiency decreased. On the other hand, increased feeding and air volume to specific gravity separator led to significant increase in final output of healthy seed per minute and recovery efficiency. Thus, mechanical processing reduced bruchid infested lentil seed by more than 90%, and improved seed quality i.e. physical purity by 5.53% and seed germination by 10.3%.

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	5.64	161.15	191.52	**358.31**
Pulses	-	6.90	15.36	**22.26**
Oilseeds	-	2.435	10.492	**12.927**
Regional Station, Karnal				
Cereals	4.38	204.83	260.44	**469.65**
Pulses	0.07	0.86	1.07	**2.00**
Forages	0.04	0.60	-	**0.64**
Oilseeds	0.02	1.35	2.38	**3.75**
Others	-	-	0.38	**0.38**
Regional Station, Indore				
Cereals	-	170.60	-	**170.6**
Regional Station, Pusa, Bihar				
Cereals	-	92.83	56.41	**149.24**
Pulses	-	-	4.289	**4.289**
Oilseeds	-	-	1.44	**1.44**
Others	-	-	0.454	**0.454**
Total	**10.15**	**641.555**	**544.235**	**1195.94**

2. HORTICULTURAL SCIENCE

The School of Horticultural Sciences of IARI focused its attention to technological innovations in the form of genetic enhancement, efficient production and resource management strategies. Pre-breeding for creation of desired genetic stocks was targeted by integrating genes from diverse genetic resources for resistance to diseases and insect pests, abiotic stresses and nutrients in vegetable and flower crops. Breeding in perennial fruit crops was aimed for achieving better quality and higher productivity, short stature canopy, input efficient, 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 Delhi State Seed Sub-Committee on Notification and Release of Varieties of different Horticultural Crops, All India Coordinated Research Projects, besides Institute's committee during the year. Several new promising lines/hybrids were also evolved for further evaluation.

2.1 VEGETABLE CROPS

Varieties/F_1 hybrids released. Twelve varieties, viz. two each in brinjal and muskmelon, one each in okra, chenopodium, cucumber, long melon, round melon and garden pea whereas two F_1 hybrids, viz. one in bitter gourd and one in sponge gourd released by Delhi State Seed Sub-committee in the meeting held on December 19, 2017 at IARI, New Delhi.

Cucumber: Pusa Seedless Cucumber 6: It is an extra-early improved variety of parthenocarpic gynoecious cucumber suitable for cultivation in protected conditions. Fruits are attractive, uniform, dark green, glossy, straight, non-hairy with crispy flesh. It becomes ready for first harvest in 40-45 DAS. Average fruit weight is 105 g and average yield is 126.0 t/ha (1260 kg/100 m^2) during winter season under low cost polyhouse.

Pusa Seedless Cucumber 6

Sponge gourd: Pusa Shrestha: It is a first early (45-50 days for first fruit harvest) hybrid with uniform size, suitable for spring summer season cultivation in north Indian plains. Fruits are attractive, uniform, green, elongated & cylindrical, with superficial ribs, smooth texture, white flesh, thick skin and suitable for long distance transportation. Its average fruit length is 27 cm, girth 13 cm, fruit weight 120 g and average yield 19.5 t/ha.

Pusa Shrestha

Long melon: Pusa Utkarsh: It is an early maturing variety suitable for spring-summer season cultivation in north Indian plains. Fruits become ready for first harvesting in 45-50 DAS in spring summer season. Fruits are slightly curved, medium long (length 52 cm), thin (diameter 2.4 cm), attractive light green, having smooth non-prominent ridges, shiny with tender skin,

crispy flesh, and free from bitterness. The average fruit weight is 130-145 g at marketable stage and fruit yield is 29.0 t/ha.

Pusa Utkarsh

Round melon: Pusa Raunak: It is an early maturing variety of round melon for spring-summer season cultivation in north Indian plains. Fruits become ready for first harvest in 55-60 days after sowing in spring summer season. It produces 8-10 fruits per vine. Fruits are attractive green, shiny, uniform, flattish round in shape, 5.0 cm in diameter and covered with soft hair. Average fruit weight is 60 g and fruit yield is 7.5 t/ha.

Pusa Raunak

Bitter gourd: Pusa Hybrid 4: It is first gynoecious hybrid with high female: male flower ratio (2:1) compared to Pusa Do Mausami (1:9). Fruits are dark green, medium long and medium thick with 5-6 discontinuous narrow ridges. Fruits are first harvested after 45-50 days of sowing. The average fruit weight is 60 g and average yield is 22.20 t/ha during spring summer season.

Pusa Hybrid 4

Muskmelon: Pusa Madhurima: This is a unique shaped muskmelon variety having peduncle end is deeply pointed and blossom end is roundish. Its fruit is ovate to obovate shape with average weight is 750-800 g. Fruit surface is grooved with moderate netting, rind colour is creamish-yellow with prominent green sutures. Fruit flesh is thick, green, juicy crispy and sweet with medium musky flavour. Fruits get ready for harvest in about 80 days after sowing. The TSS is 12^0Brix and average yield is 22.5 t/ha.

Pusa Madhurima

Muskmelon: Pusa Sarda (Pusa Sunehari): This is a first variety of Sarda type melon with roundish to elongated globe fruit shape. The rind colour is golden yellow and fruit surface is smooth. The fruit flesh is thick, greenish white, very crispy with no musky flavor and high sweetness (TSS 13.6°Brix). Fruit is ready for harvest in about 85-90 days after sowing. The average fruit weight is 1.0 kg with yield potential of 5.4 t/1000m^2 under net house.

Pusa Sarda

Okra: Pusa Bhindi 5: This variety is **resistant to** *Bhendi yellow vein mosaic virus* (YVMV) disease of okra under field conditions. The pods are attractive dark green colour with 5 ridges and medium in length (10-12 cm). Pods are ready for first harvest in 40-45 days after sowing. It is recommended for growing in *Kharif* as well as spring summer under north Indian condition. The average fruit yield is 18.0 t/ha.

Pusa Bhindi 5

Garden Pea: Pusa Prabal: It is medium maturity variety having powdery mildew and *Fusarium* wilt resistance. It is suitable for early, normal and late sowing under irrigated conditions. Pods become ready to first harvest in 80-85 days after sowing. Long dark green coloured pods have 7-9 seeds/pod with 52% shelling. It has an average pod yield of 10-13 t/ha.

Pusa Prabal

***Chenopodium*: Pusa Green:** It is a multi-cut variety with large size and green leaves. Leaves are smooth and attractive dark green in colour with medium lobing and lamina serration. It is suitable for both direct sowing in October and/ or transplanting in November. It is late bolting in nature and less attacked by diseases and insects. It has high total carotenoids (91.31 mg/100 g) and iron content (7.6 mg/100 g). The average leaf yield in multiple cuttings is 37 t/ha.

Pusa Green

Brinjal: Pusa Hara Baingan 1: It is a green coloured oval fruited variety suitable for *kharif* season under north Indian condition. Fruits are oval green. Each fruit weighing 210-220 g having green non-spiny calyx. First picking starts 55-60 days after transplanting. The average yield is 40-45 t/ha. It contains high total phenols (31.21 mg GAE/ 100 g) with high antioxidant activity (3.41 CUPRAC μmol trolox/g, 3.07 FRAP μmol trolox /g).

Pusa Hara Baingan 1

Brinjal: Pusa Safed Baingan 1: It is a white coloured oval round fruited tyoe suitable for *kharif* season under north Indian plains. Fruits are oval round weighing 50-60 g with green calyx. It is an early variety and ready for first picking from 50-55 days after transplanting.

The average yield is 35 t/ha. It has high total phenols content with high antioxidant activity.

Pusa Safed Baingan 1

Variety Identified.An Onion variety Sel. 153-1 was identified for release for Zone II (Delhi, Rajasthan, Haryana, J&K, Jammu and Punjab) for *rabi* season. The bulbs are compact, globular, creamish-yellow in colour. Average equatorial bulb diameter ranges from 5.0 to 6.2 cm, polar diameter from 5.2-6.5 cm and single bulb weight from 70.0 to 135.0 g.

Sel. 153-1

2.1.1 Cole Crops

2.1.1.1 Cauliflower

Development of new promising lines. A total of 80 F_1 hybrids (59 CMS based, 21 SI based) of early group cauliflower were evaluated and promising were: DCEH 1467 (29.8 t/ha), DCEH 31503 (27.5 t/ha), DCEH 1371(27.2 t/ha) and DCEH 137 (26.4 t/ha). In mid-early group, 45 CMS based F_1 hybrids were evaluated and DC 1025 (36.7 t/h), DCMEH 1093 (36.2 t/ha), DCMEH 2225 (34.9 t/ha) and DCMEH 940 (34.1 t/ha) were promising. Among 20 CMS based F_1 hybrids the DCMLH 1544 (38.0 t/ha), DCMLH-4015 (36.7 t/ha), DCMLH-1476 (36.5 t/ha) and 1404 (36.1 t/ha) were promising for December end to January first week maturity. Six hybrids in early group, namely, DCH 4198, 167, 2398, 9867, 1523 and 988 and five in mid-maturity group, viz., DCMEH 2325, 1033, 1009, 4976 and 1476 have been advanced in AVT-I trial and two hybrids DCH 9325 and DCH 9309 to AVT-II in AICRP (VC).

A promising hybrid in early group, DCEH 1467

Breeding for black rot resistance and Alternaria leaf spot. In cauliflower, F_2 population was generated between black rot susceptible (Pusa Meghna, Pusa Sharad) and resistant lines (BR-161, Lawyana). In total, 251 advance breeding lines were screened through artificial inoculation against *Xanthomonas compestris* pv. *compestris* and identified five new moderate resistant (score 3) sources, namely, xx-2-6-1, DC-85, DC-73-7 (race-1, 4, 6) and Alwari-1 (race 1, 6). A total of 130 lines were screened against *Alternaria brassicicola* (Schwein.) Wiltshire and identified resistant sources in early group (Sel-9, Sel-23000, vv-17; PDI <5.0%), mid group (AL-15, 2.8%; PNI, 8.0%) and snowball group (Kt-17, Kt-2; <1.0%). In overall, the PDI ranged from 0.0-83.3% and mean value of 31.9%.

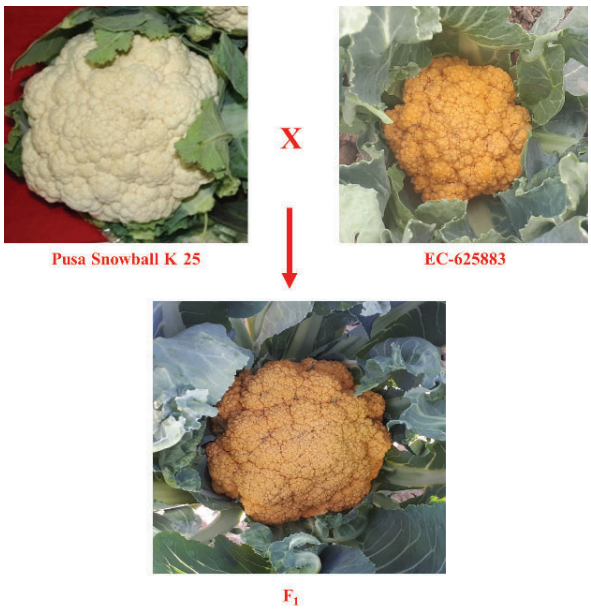
Development of doubled haploid lines and hybrids. A total of 150 F_1 hybrids developed using DH lines were evaluated for 14 important horticultural traits. Among them 5 hybrids were found promising based on their evaluation in different locations. Proposal of one F_1 hybrid, Ogu1A × DH 53-1 was submitted to IARI variety release committee for its identification.

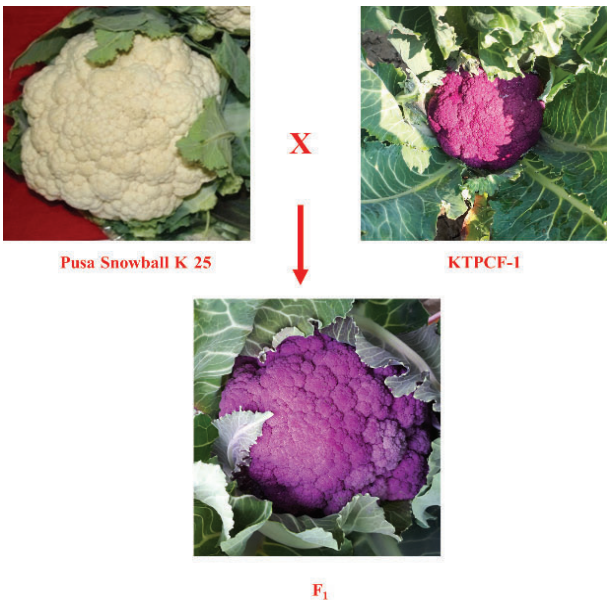
Doubled haploid based cauliflower hybrid, KTH-DH-1 (Ogu1A x DH 53-1)

Purple cauliflower variety, KTPCF-1 with very high concentration of anthocyanin

Development of anthocyanin rich cauliflower. One purple cauliflower variety, KTPCF 1 was developed through hybridization followed by recurrent selection. This genotype was recorded with very high anthocyanin content (43.7 mg/100 g fr. wt.) along with average curd weight of 0.765 kg.

Introgression of β-carotene rich 'Or' and anthocyanin rich 'Pr' genes into cauliflower. In a snowball cauliflower variety, i.e., Pusa Snowball K 25, β-carotene rich (*Or*-gene) and anthocyanin rich (*Pr*-gene) genes were introgressed through hybridization with an exotic collection EC-625883 (β-carotene rich) and an inbred line, KTPCF 1 (anthocyanin rich), respectively. Quality analysis of parental lines and their hybrids revealed that amount of β-carotene increased 22 times in F_1 hybrid (3.85 mg/100 g), while anthocyanin content elevated more than 200 times in F_1 hybrid (38.12 mg/100 g) as compared to its recurrent parent, Pusa Snowball K 25 (β-carotene- 0.17 mg/100 g and anthocyanin 0.19 mg/100 g).





2.1.1.2 Cabbage

Development of CMS and SI systems based cabbage hybrids. Eighty three CMS and SI system based F_1 hybrids of white cabbage were evaluated for their performance for yield and horticultural traits along with 3 standard checks, viz., Alisha, Dollar and Pusa Cabbage Hybrid-1. Among the hybrids, 208A × KTCB 52, 6A × KTCB 25, 6A × KTCB 8 and 5A × KTCB

524 had yield potential of 70.2, 67.3, 67.1 and 65.5 t/ha, respectively, compared to the best commercial check, Dollar (63.2 t/ha). Of the 40 SI based hybrids, S-681 × KTCB 22 (60.6 t/ha), S-681 × KTCB-52 (58.4 t/ha), S 645 × KTCB 22 (56.7 t/ha) and S 208 × KTCB 58 (55.9 t/ha) were superior over the check, Pusa Cabbage Hybrid 1 (44.7 t/ha).

Development of crosses using DH lines and new CMS systems. Six selected DH lines were used to produce 36 crosses with 6 CMS lines. The best cross combinations observed were 6A x 51-19 (59.7 t/ha), 6A x 50-1 (55.0 t/ha), 5A x 51-17 (49.1 t/ha) and 831A x 50-3 (44.6 t/ha). While, following embryo rescue technique, the BC_3 and BC_4 generations with *Trachystoma ballii* and *Diplotaxis catholica* male sterile cytoplasms are being backcrossed with variety Golden Acre as recurrent parent.

Introgression of β-carotene rich 'Or' gene into Cabbage and Broccoli. Crosses of cabbage and sprouting broccoli were made with orange coloured cauliflower exotic collection (EC-625883) with the objective of introgression of β-carotene rich 'Or' gene. The β-carotene content in a cross between Pusa Broccoli KTS-1 x EC 625883) was found to be increased by 10 times (2.74 mg/100 g) as compared to its recurrent parent, Pusa Broccoli KTS-1 (0.25 mg/100 g), while an elevation of 7 times was observed in the cabbage F_1 cross S-83-1 x EC 625883 (3.28 mg/100 g) as compared to its recurrent parent, S-83-1(0.44 mg/100 g).

Comparison of SI and CMS based hybrids for nutritional traits. Four lines each of SI and CMS system of cabbage were crossed with four common testers to develop 32 hybrids (16 SI based and 16 CMS based) and analyzed for different quality traits. The SI system was found superior on the basis of mean performance and expression of heterosis for chlorophyll-a (1.07 mg/g f.w.), chlorophyll-b (1.45 mg/g f.w.), total chlorophyll (1.33 mg/g f.w.), CUPRAC (5.04 µ mol trolox/g), lycopene (1.92 mg/100 g), total carotenoids (2.34 mg/100 g), β-carotene (2.10 mg/100 g), ascorbic acid (20.93 mg/100 g) and anthocyanin content (0.68 mg/100 g), while CMS system excelled only for two traits, *viz*., FRAP (1.43 µ mol trolox/g) and phenolics (557.81 µg gallic acid/g fresh weight). Three hybrids, KTCB-S-691 × KTCB-52, KTCB-S-691 × KTCB-22, KTCB-S-691 × KTCB-26 and one CMS based hybrid, *viz*., KTCB-208A × KTCB-26 were found superior for different quality traits.

Introgreassion of fertility restorer gene (Rfo) into Brassica oleracea through inter-specific hybridization. For the first time in India, fertility restorer gene (Rfo) was introgressed form *Brassica napus* L. to cytoplasmic male sterile genotypes of *Brassica oleracea* L. (cabbage and cauliflower) through interspecific hybridization, embryo rescue and marker-assisted crossing. The different crosses were attempted between cabbage and cauliflower genotypes with fertility restorer (*Rfo*) doner lines, viz., Teri Garima, Shyamali and Phaguni. The embryos of different crosses were rescued and cultured.

2.1.2 Cucurbitaceous Crops

2.1.2.1 Bitter gourd

Promising genotypes. Two previously developed high yielding early maturing hybrids, namely, BBGH 12 and DBGH 542 were included in IET trials of AICRP-VC. Ninety two hybrids were evaluated for yield and related traits. Three best performing F_1 hybrids for yield were: DBGH 232 (26.70 t/ha), DBGH 2359 (25.40 t/ha) and DBGH 2352 (24.75 t/ha). Similarly, two promising selections DBGS 32-1 and DBGS 57 were found promising under polyhouse growing conditions and produced fruit yield of 3.84 and 3.77 t/1000 m^2 with individual fruit weight of 108 g and 122 g, respectively.

2.1.2.2 Cucumber

Promising genotypes. A total of 187 germplasm/advance breeding lines including 24 new collections and 12 gynoecious lines were evaluated and maintained. Out of 25 selections evaluated, DC 83 and DC 22 yielded 18.3 and 17.1 t/ha showing an increase of 23.6% and 15.5% over national check Pant Khira 1 (14.8 t/ha), respectively.

Out of 59 F_1 hybrids evaluated, hybrids DGCH 18 and DGCH 15 yielded 26.2 and 24.9 t/ha, which were

32.3 and 25.8% higher than the check Pant Sankar Khira 1 (19.8 t/ha), respectively. Two new gynoecious hybrids DGCH 31 and DGCH 40 yielded 26.4 and 27.2 t/ha, respectively as compared to national check Pant Sankar Khira 1 (19.8 t/ha) were advanced to at AVT-I of AICRP (VC) trial. A new hybrid DGCH 56 having large size fruit and high yield (27.8 t/ha) was got entered to IET of AICRP (VC) trial.

Promising cucurbit genotypes for protected cultivation. Pusa Seedless Cucumber-6 gave the best performance yielding 1420 kg per 100 m^2 under polyhouse during winter season (off-season). Out of twelve parthenocarpic gynoecious gherkin lines evaluated, DG-8 and DG-3 were found most promising recording average yield of 761.5 and 708.3 kg in 100 m^2 polyhouse, which was significantly higher than check Annaxo (718.2 kg).

2.1.2.3 Luffa

Promising genotype. In sponge gourd, a total of 57 germplasm including 3 accessions of wild species *Luffa echinata*, 4 accessions of *Luffa graveolens* and 18 accessions of *Luffa hermophrodita* (*satputia*) were evaluated and maintained. Out of 16 selections during spring summer season, DSG 43 (13.6 t/ha), and DSG 33 (14.1 t/ha) were found very promising along with superior fruit quality showing yield increase of 20.4% and 24.8%, respectively over the check Kalyanpur Hari Chikni (11.3 t/ha). Out of 30 F_1 hybrids evaluated, DSGH 52 (15.6 t/ha) and DSGH 34 (15.9 t/ha) were found to be most promising showing an increase of 38.1 and 40.7%, respectively over check Kalyanpur Hari Chikni (11.3 t/ ha).

In ridge gourd, out of 16 selections, DRG 7 was found to be very promising showing an yield of 17.6 t/ha as compared to Pusa Nutan 16.5 t/ha. DRG 7 was entered in IET of AICRP (VC) trial. Eight gynoecious lines isolated from the crosses of Pusa Nutan and Satputia DSat 63 were evaluated on the basis of colour, shape and size. DRGGL 8 showing light green attractive colour, long fruit (20-25 cm) and true gynoecious trait was found to be 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 17.8 t/ha and 19.8 t/ ha, respectively as compared to Pusa Nutan (16.5 t/ ha). DRGH 4 was also entered in IET of AICRP (VC) trial.

2.1.2.4 Pumpkin

Promising genotypes. Sixty genotypes were evaluated for yield related traits. In small fruited and semi-vigorous vine segment, the genotypes DPU 41, DPU 43 and DPU 45 were found promising for fruit and fruit yield of 2, 2.2 & 2.6 kg and 20, 21.0 & 21.3 t/ha, respectively. In the medium fruit size (4.5 kg) segment, the genotypes DPU 26 and DPU 80 were found promising. The total carotenoids in the genotypes ranged from 43.5 to 415.5 µg/ g FW. The genotype DPU 43 showed the field resistance against viruses. Twenty one F_1 hybrids were developed and evaluated for yield and related traits in the spring-summer season. TSS content in the hybrids ranged from 6.10 to 10.20°Brix. Two best performing F_1 hybrids were DPU 41 × DPU 45 (av. fruit weight 2.8 kg, flesh thickness 3 cm, TSS 6.50°Brix) and DPU 41 × Narendra Amrit (av. fruit wt. 3.0 kg, flesh thickness 3.45 cm and TSS (6.55°Brix).

Screening for virus resistance. Forty germplasm/ advanced breeding pumpkin lines were planted

DPU 43

during *Kharif* 2017 for field screening against viral disease(es). Except three genotypes (DPU-43, DPU-41, Narendra Upkar), all the others are severely affected by yellow mosaic, leaf curl and mottling & leaf distortion diseases. Those three genotypes were tested at ACPV, Division of Plant Pathology through electron

microscopy to ascertain the possible association of any viruses. DPU-43 was found associated with a negligible number of rigid rod shaped virus particles.

2.1.2.5 Muskmelon

Promising genotypes. Among 29 genotypes evaluated in station trial during summer for open field cultivation, the most promising genotype (C. *melo* var. *cantalupensis*) was DM 154 (23.6 t/ha) with green flesh and TSS 12.1^{0}Brix followed by DM-159 (23.2 t/ha, TSS 12.0^{0}Brix). Genotype, DHM 162 (C. *melo* var. *inodorous*) was found promising for cultivation under net house (5.1 t/1000 m^2 with TSS 13.6^{0}Brix), DHM 159 (4.9 t/1000 m^2 with TSS 13.9^{0}Brix) and shelf-life was 10-15 days better than other *cantalupensis* genotypes.

Promising hybrids. Two hybrids, namely, DMH 5 (24.8 t/ha, TSS 11.6^{0B}rix) and DMH 11 (24.5 t/ha, TSS11.8^{o}Brix) from C. *melo* var. *cantalupensis* group were identified as superior for imparting higher fruit yield with quality. This has been entered in the IET Hybrid Trial of AICRP (VC).

2.1.2.6 Watermelon

Screening of germplasm for resistance against Watermelon bud necrosis virus. Sixty four genotypes from *C. lanatus* var. *citroid*, *C. lanatus* var. *lanatus* and *C. colocynthis* were evaluated under open field as well as net house conditions. Three lines from *C. colocynthis* line DWM 210 showed resistance against *Watermelon bud necrosis virus*.

2.1.3 Solanaceous Crops

2.1.3.1 Brinjal

Promising lines. Among the round fruited lines, DBR 43 (round purple, 43.85 t/ha), DBR 23 (round purple, 42.89 t/ha), DBR 92 (shiny purple, 41.96 t/ha,), DBR 9 (purple, 37.45 t/ha) and DBSR 94 (small oval purple, 30.68 t/ha) were found very promising for fruit yield. In long fruited lines, DB 9 (dark purple, 38.5 t/ha), DBGL 225-2-5-17 (green, 31.5 t/ha), DBL 92 (purple, 35.6 t/ha), DBPL 185 (shiny pink, 41.2 t/ha), DBWL 22-1-11 (white long, 41.2 t/ha) were found promising.

Promising hybrids. Ten round fruited hybrid combinations were evaluated for yield. Hybrids DBHR 25 (black purple, 65.89 t/ha), DBHR 129 (purple, 60.58 t/ha), DBHR 1011 (purple, 56.84 t/ha), DBHR 91 (54.25 t/ha), and DBHR 2340 (purple, 50.84 t/ha) were found to be superior over the check Navina (49.30 t/ha) and Pusa Hybrid-6 (44.25 t/ha).

Screening for heat tolerance. Seventy three breeding lines including commercial varieties were screened horticultural traits (No. of flowers/ plant, No. of fruits/ plant, yield/plant) under hot summer condition (March-June). Among these, DBSR 44 (1.65 kg/ plant), DB 9 (2.65 kg/ plant), DBL 21 (3.68 kg/ plant) and DB 144 (2.12 kg/ plant) were found promising.

Genotype resistance to Phomopsis blight. *In-vitro* screening of 39 genotypes were carried out using artificial inoculation with the conidial suspension of *Phomopsis vexans* (10^{-5} conidia/ml) and the lines DB 31, DB 131, DB 175, and DB 43 were found to be resistant.

Resistance to root knot nematode. Fifteen wild accessions were evaluated against root knot nematode with second stage juvenile (J2) in pot conditions. Out of these wild accessions (*S. indicum* and *S. sisymbriifolium*) were preliminarily identified as resistant to the nematode species.

Pre-breeding and inter-specific hybridization. Out of the 150 crosses attempted between Pusa Shyamla and the wild species, maximum fruit set was observed in the cross combinations of Pusa Shyamla x *Solanum xanthocarpum* (75%). A total of 141 cross combinations were made between Pusa Uttam and the wild accessions, out of which 33% fruit set was observed

in Pusa Uttam x *Solanum unduatum* followed by Pusa Uttam x *Solanum incanum* (20%).

2.1.3.2 Tomato

Screening promising genotypes and hybrids for protected cultivation. Ten purelines and 20 F_1 cross combinations were raised under net house and low cost polyhouse in October. Hybrid-DTPH-60 was found highly suitable for low cost polyhouse and net house with average fruit weight of 125 g. Under protected condition, TSS was recorded 3.3 to 7.9% (cherry red), lycopene content from 1.2 to 8.6 mg/100 g and fruit pH 4.5 to 5.5. The ascorbic acid content was recorded 13 to 40 mg/100 g and acidity 0.34 to 0.46%. The line Sel. 5 having unique capsicum type fruits have thick pulp with average fruit weight of 105 g. Among 8 cherry advance lines developed through reverse breeding, genotype Cherry Sel. 2 recorded 7.5% TSS, attractive fruits, 18 fruits/ cluster with average fruit weight of 11 g.

Cherry Sel. 2 under low cost polyhouse

Sel. 5 fruits with high pulp content

Screening for virus resistance. A total of 250 breeding lines, including germplasm (55), F_1 (120), F_2 populations (15), F_3 populations (8) along with parental lines were screened for ToLCV resistance under field conditions. Thirty five accessions of wild species *Solanum pimpinellifolium* and *S. peruvianum* were also screened for ToLCV resistance. The breeding lines used, were carrying various resistance gene (s)/ combinations, *i.e.* Ty-2, Ty-3, Ty-2+Ty-3, Ty-3a, Ty-2 + ty-5, ty-5, ty-5+ Ty-6, (Ty-2 +Ty-3) + (ty5 + Ty-6). Eight breeding lines carrying multiple disease resistance genes for ToLCV, late blight and bacterial wilt, were also screened. Advanced segregating lines developed from the interspecific crosses of *S. habrochaites* (LA1777) were found promising for tolerance to ToLCNDV and late blight. The selected lines were advanced to F_4 generation. The embryo rescue in interspecific hybrids of *S. lycopersicum* and *S. peruvianum* was adopted. The *S. peruvianum* line IIHR 1940 has been found promising for *Pea-bud necrosis virus* (PBNV) resistance.

2.1.3.3 Chilli

Screening genotypes for high temperature tolerance. Selfed lines of heat tolerant lines (HT-Sel 1, HT-Sel 2 & HT-Sel 3) identified last year were evaluated again this year. Good fruit set under high temperatures (av. max. temp of 43 ^{0}C; min. 28 ^{0}C during May and June) was recorded in these tolerant lines.

Analysis of the segregation for fertility restoration. Analysis of the segregation for fertility restoration in two crosses, namely, KTCA 5 × KTCR 15 (sweet pepper × sweet pepper) and KTCA 10 × KTCR 15 (hot pepper × sweet pepper) showed the goodness of fit to 3:1 and 1:1 (fertility: sterility) ratio in F_2 and backcross populations, respectively which indicated that the CMS-fertility restoration is controlled by single dominant gene.

Bulk segregant analysis (BSA) of F_2 population. Bulk segregant analysis (BSA) of F_2 population generated from the cross KTCA 5 × KTCR 15 was carried out using 357 markers. A new SSR marker (SSR189) was identified, which was found putatively linked to fertility restoration gene in sweet pepper.

Linkage analysis indicated that SSR189 and CRF-SCAR were linked to fertility restorer gene at a distance of 13.7 and 7.3 cM, respectively.

Promising hybrids. A total of 130 experimental hybrids were evaluated for fruit yield and its contributing traits under open field conditions at Katrain. The hybrid KTCH 5 (38.90 t/ha) gave the highest marketable fruit yield per plant followed by KTCH-9 (37.55 t/ha) and KTCH 129 (36.59 t/ha) along with desirable fruit shape, size and colour as per the consumer preference. Further, 30 station hybrids were evaluated for fruit yield and its contributing traits under polyhouse conditions. The hybrids KTCH 13-Y, KTCH 155 and KTCH 17 were found promising with good yield potential (10.50, 8.25 and 7.50 q/100 m^2, respectively) under polyhouse conditions. The hybrids KTCH 13-Y and KTCH 155 performed consistently better over three years under polyhouse conditions. Amongst 20 new selections, KT Sel-6 (1.40 kg/plant), KT Sel-3 (1.38 kg/plant) and KT Sel-2 (1.32 kg/plant) were found promising for cultivation under polyhouse conditions with respect to yield and other parameters.

2.1.4 Root and Bulbous Crops

2.1.4.1 Carrot

Promising genotypes. Twenty nine genotypes/ breeding lines of August end sowing were evaluated for quantitative and quality traits. Root length, root diameter, root weight, core diameter and TSS ranged from 14.6 cm (IPC 1) to 23.75 cm (IPC 13 red), 2.96 cm (IPC 76) to 4.91 cm (IPC 13 red), 90 g (IPC 39, IPC 104 red) to 185 g (IPC 35), 5.89 mm (IPC 92) to 14.08 mm (IPC 13 red) and 6.7°Brix (Pusa Meghali) to 10.3°Brix (IPC 126). Based on the root quality, root shape, surface, external & internal colour and appearance, the genotypes IPC 7, IPC 35 and IPC 39 were found most promising.

Under normal season, the promising genotypes identified were IPC 6, IPC 13 red, IPC 16, IPC 37, IPC 85, IPC 92 and IPC 98. Three promising lines, viz. IPC 13 red, IPC 98 and IPC Ht-1 were advanced to AVT-I of ICAR-AICRP (VC) trial.

Promising hybrids. Ninety 3-way hybrids were assessed for quantitative and quality traits from August end sowing. Root length, root diameter, root weight, core diameter and TSS ranged from 10 cm [(7 x 85) x 34] to 26 cm [(7 x 122) x 35], 3.55 cm [(7 x 39) x 131] to 5.56 cm [(7 x 116) x 76], 83.33 g [(7 x 4) x 92] to 300 g [(7 x 104 red) x 13 red], 11.14 mm [(7 x 16 red) x 126] to 24.81 mm [(7 x 98) x Ht-1] and 5.1°Brix [(Ht-2 x 131) x 11 red] to 9.6°Brix [(7 x 39) x Ht-1]. Based on the quality for root shape, surface, external & internal colour and external appearance, the seven promising genotypes were [(7 x 35) x 11 red], [(7 x 85) x Ht-2], [(7 x 116) x 35], [(7 x 126) x Ht-1], [(7 x 123) x 104 red], [(7 x 123) x 124] and [(7 x 39) x 131].

Seventy CMS based F_1 hybrids of tropical-subtropical carrot genotypes were assessed for quantitative and quality traits. Based on the quality for root shape, surface, external & internal colour and external appearance, the promising F_1 hybrids were DCatH 9813, DCatH 1122, DCatH 534, DCatH 5104, DCatH 74 and DCatH 754. In temperate group, while of the 13 F_1 hybrids from Katrain station Kt 7002 x NK, Kt 10 x KS 59 and Kt 28 x NK were found promising. Similarly, 100 CMS based station hybrids were evaluated for root and its related traits in temperate carrot at Katrain. The best performing hybrids were KTCH 4NJ (39.5 t/ha.), KTCH 822 (38.2 t/ha) and KTCH 10NK (37.9 t/ha.) compared to Pusa Nayanjyoti (37.5 t/ha). These hybrids have good marketable root shape, size and colour.

2.1.4.2 Onion and garlic

Breeding for higher yield in Onion and Garlic during Rabi season. In onion, 54 accessions were analyzed for yield and other horticultural traits of which Sel. 153-1 recorded the highest yield (40 t/ha) followed by ALR and Pusa Ratna. In garlic, 26 accessions were evaluated for yield and other horticultural traits. Genotype PGS 206 recorded significantly higher yield (16.3 t/ha) but was at par with PGS 203 (15.2 t/ha) and PGS 204 (14.4 t/ha). Bhima Omkar recorded the lowest yield (2.8 t/ha).

Breeding for kharif season. During *kharif* season, 117 first generation inbred seedlings of were evaluated for evaluated for their bulbing potential. Genotypes KH 138, KH 141, KH 122, KH 184 and KH 118 performed best and produced good quality bulbs. Out of 31 genotypes raised through onion sets, Bhima Super performed best in terms of yield, plant stand and vigour.

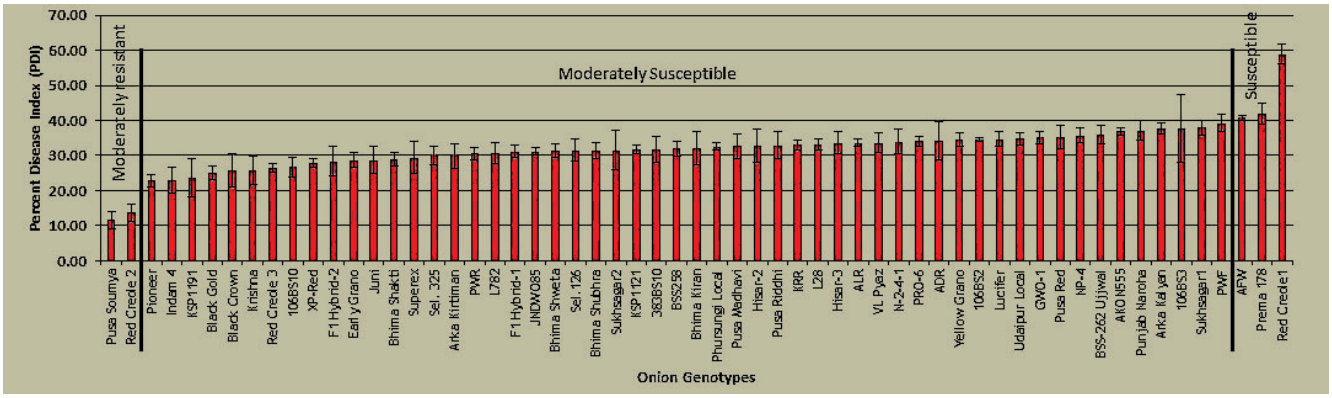
Breeding for bolting tolerance. Seventy onion accessions were planted early in November to screen for bolting resistant genotype. The genotypes AKON 67, AKON7 6, AKON 82 and AKON 83 exhibited negligible bolting.

Breeding for Stemphylium blight resistance. Fifty nine onion accessions were screened for stemphylium blight resistance. Pusa Soumya (*A. fistulosum* L.) and Red Creole 2 (*A. cepa* L.) were identified as moderately resistant and Red Creole1 as susceptible. Significant variation in foliage weight, gross yield, marketable yield, dry matter, total soluble solids, total phenolics and pyruvic acid contents were recorded between non-inoculated and inoculated field trials.

2.1.5 Leguminous Crop

2.1.5.1 Garden pea

Screening for heat tolerance and Disease resistance. Forty genotypes were screened for high temperature tolerance by delayed sowing in mid January to extend the cropping period of pea beyond February-March in north Indian plains. About 10 genotypes GP 55, PP, GP473, GP 912, VP 438-2, GP 904, and GP 1105 were found to be promising for pod setting at high temperature during last week of March or early April. In another study, inheritance of powdery mildew resistance was studied using F_1, F_2, B_1 and B_2 progenies of five crosses, viz., Arkel × GP 6, VRP 6 × GP 6, Arkel × VP 233, AP 3 × GP-6, AP 3 × GP 473. Chi-square analysis showed F_1 and backcross progenies to the susceptible parents segregated in the ratio 1:0, while the F_2 progenies segregated in the ratio of 3:1 and



Reaction of onion genotypes to infection caused by Stemphylium blight under New Delhi conditions (PDI values)

backcross progenies to the resistant parent segregated in the ratio of 1:1. I was confirmed that the resistance to powdery mildew in GP 6, VP 233 and GP 473 genotype was governed by monogenic recessive gene.

2.1.6 Malvaceous Crop

2.1.6.1 Okra

New genetic material. Twenty five parental lines, 22 advance lines, 41 F_{1s} and 24 new collections of okra from NBPGR, Trissur were evaluated for yield, quality traits and biotic stress during *kharif* 2017. Genotype DOV 92 was found resistant to *Bhendi yellow vein mosaic virus* (YVMV) disease and had tolerance to leaf hopper and mites. It recorded average yield of 19.5 t/ha having dark green attractive pods. Among hybrids, DOH 1 was found resistant to YVMV, tolerant to leafhopper and recorded 23 t/ha pod yield with smooth dark green attractive pods. Two short fruited advance lines (DOV 77 and DOV 88) were also found resistant to YVMV along with dark green, small fruits (5.5 cm). Selection was made for red fruited okra from segregating lines of IC-685583 x IC-1610753 and TRN.

Pre-breeding in okra. Forty one wild germplasm (parents, F_1s and advance populations) were evaluated for fruit yield, quality traits and YVMV resistance. The advance lines, C 2-50, Mizo 20, Mizo 8, A 4 x IC-401446 were found 100% free from YVMV symptoms. One BC_1F_1 Plant of Pusa A-4 x *A. moschatus* was found resistant to YVMV disease with desirable fruit quality. Resistant plants from crosses of cultivated and *A. tetraphyllus* and *A. caillei* were selected for further generation advancement.

Okra hybrid (DOH 1): resistance to YVMV disease

DOV 77 and DOV 88: Dark green, export quality small fruited pods of okra

2.1.7 Lettuce

Promising genotypes identified. Thirty eight genotypes were evaluated for yield and yield attributing characters. The promising selections identified were DL 13 (40 t/ha), DL 11 (39.17 t/ha) and EC 687387 (38 t/ha).

2.2 FRUIT CROPS

2.2.1 Fruit Breeding

2.2.1.1 Mango

Mango breeding. During March 2018, seven cross combinations were attempted. Total 557 panicles having 5,302 flowers were crossed employing Amrapali as female parent and Sensation, Vanraj, Tommy Atkins,

Kensington, Pusa Arunima, Illaichi and Bhadauran as male donor parents. From previous year crosses, 182 hybrid stones were obtained and raised in the nursery. Finally, 162 stones germinated and 149 hybrid plants are ready for transplanting in evaluation block. In rootstock breeding, a total of 220 flowers on 87 panicles were crossed using Olour, Kurukkan and Amrapali as parents.

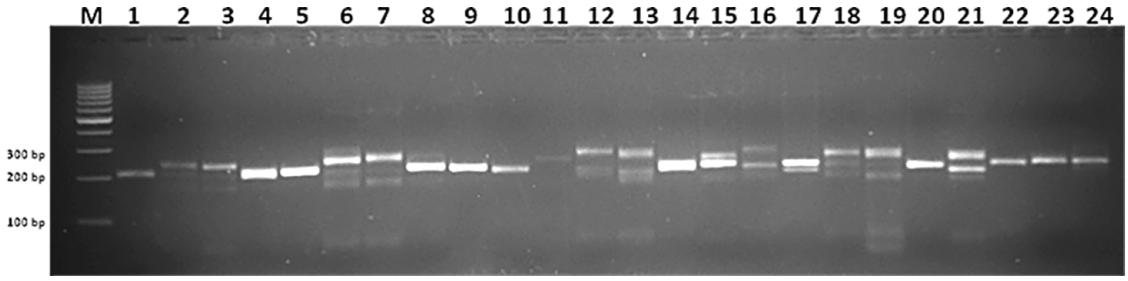
Evaluation of hybrids. Over 80 genotypes were evaluated for different physico-chemical traits. Among hybrids, H 1-5, H 1-11, H 2-14, H 3-2, H 8-11, H 11-2, NH 7-2, and NH 4-1 had more than 200 g fruit weight. The maximum fruit weight was noted in H 11-2 (267.1 g) followed by NH 7-2 (239.48 g). Hybrid NH 7-2 had bright yellow-apricot coloured oblong fruits with bright orange pulp, moderate peel thickness (1.71 mm) and high total soluble solids (23.87°Brix). The fruits of hybrids H 11-2, H 12 5, H 3-2, and H 4-2 had red colouration on fruit shoulder. The maximum TSS was noted in NH8-5 (26.4°Brix) followed by NH-7-2 (24.87°Brix).

Phenotyping of germplasm. Forty mango genotypes were phenotyped for different physico-chemical parameters including total phenolics, total carotenoids and flavonoids contents in peel, pulp and seed. The total phenolics content in seed ranged from 62 mg/100 g in Amrapali to 297.3 mg/100 g in Illaichi. In peel, phenolics content ranged from 194.57 mg/ 100 g in Extrema to 468.37 mg/100 g in Kurukkan. Whereas in pulp, the minimum phenolics content was noted in Hybrid 8-11 (22.65 mg/100 g), while it was maximum in Langra (148.25 mg/100 g). The total flavonoids contents ranged from 7.8 mg/100 in Sensation to 24.57 mg/100 g in Kurukkan.

Diversity analyses using Nobel Hyper Variable SSRs. A genome wide set of 100 hyper variable mango SSRs (HvSSR) with repeat lengths of >50 bp were validated on a set of 24 diverse mango genotypes comprising of exotic, indigenous and hybrids. The HMSSRs were found to be very useful in diversity analysis of mango germplasm due to their abundance, high degree of polymorphism and simple assays.

Fruits of mango hybrid NH 7-2

Fruits of mango Hybrid H 8-11



Validation of Mango SSR58 on 24 diverse mango germplasm. M- Marker, Lane 1-24: 1- Ratna, 2- Ratoul, 3- Khasul Khas, 4- Langra, 5- Lucknow Safeda, 6- Zill, 7- Mallika, 8-Totapari, 9-Swarnrekha, 10-Eturba, 11-Kurrakan, 12-Olour, 13-Neelum, 14-Alphonso, 15- Kalepad, 16-Amrapali, 17-Chausa, 18-Dashehari, 19-Tommy Atkins 20-Fernandin, 21-Maya, 22-Kesar, 23-Manjeera and 24-Sindhu

2.2.1.2 Citrus

Clonal selection in sweet orange. Six accessions, namely, MS 3, MS 7, MS 9, MS 10, MS 20 and MS 21 performed consistently better. Fruit weight varied from 191.15 g in MS 3 to 316.16 g in MS 10 as compared to that of Pusa Sharad (232.12 g), Pusa Round (261.53 g) and Jaffa (211.53 g). Furthermore, significantly higher juice content was in MS 20 (56.90%), MS 7 (55.90%), MS 3 (54.37%) and MS 9 (54.48%) as compared to Jaffa (48.765). TSS/acid ratio was found to be highest in MS 7 (20.31), and ascorbic acid in MS 3 (61.78 mg/100 ml). The highest yield per tree (24.68 kg/tree) was found in MS 7.

Clonal selection in acid lime. Thirty nine clones and three varieties were evaluated. Among clones, 11 were found consistently better than others in terms of yield and fruit composition. Yield per tree (36.72 kg) was higher in ALC 101 followed by ALC 66 (29.33 kg), however it was highest in Pusa Abhinav (41.42 kg). Fruit weight was highest in ALC 70 (45.59 g) as compared to Pusa Udit (36.96 g) and Pusa Abhinav (38.10 g). Higher juice recovery was recorded in ALC 103, ALC-5, ALC 66, ALC 70, ALC 87 and ALC 101 (>50%) as compared to Pusa Udit (44.35%) and Pusa Abhinav (44.52%).

Clonal Selection in lemon (C. limon). The clone LS 5 had the highest fruit weight (63.74 g), while LS 6 had the minimum peel thickness (1.43 mm). Clones LS 4, LS 5 and LS 6 had the minimum seed number (13.6-17.4/ fruit) and the highest juice content was recorded in LS-5 (42.48%) followed by LS 6 and LS 1. LS 1 had the highest TSS (8.22°B) and ascorbic acid (44.27 mg/100 ml juice) contents, while LS 6 and LS 1 had high acid content (5.66-6.06%) compared to Kagzi Kalan.

Evaluation of Tangerine cultivars. Murcott proved 38 and 41 days earlier to harvest compared to Dancy and Kinnow, respectively. It was most productive (75.16 kg tree^{-1}), with highest fruit weight (235.44 g), juice (50.44%) and TSS (11.18ºB) contents, though statistically on par with Kinnow for TSS. However, Dancy had the highest ascorbic acid content (42.27 mg 100^{-1} ml juice) with lowest acid content (0.44%).

Fruiting in new Scion hybrids. During 2017-18, seven citrus hybrids (Pummelo x sweet orange) have come into maiden bearing. The highest fruit weight (551.15 g) was found in CSH 11-13 followed by CSH 11-

Acid lime clone ALC 63 **Acid lime clone ALC 87**

19 and CSH 15-20 (501.47 g). Juice recovery was highest in CSH 7-19 (50.41%), while ascorbic acid content was highest in CSH 11-13 (75.38 mg/100 ml juice).

Rootstock hybrids tolerant to salinity and Phytophthora rot. Of the 60 hybrid citrus rootstocks evaluated against NaCl induced salinity ($EC_{(1:2)}$ 5.10 mS/m), hybrids, namely, Pummelo (P) × trifoliate orange (TO) 163, P × Sacaton 164, P × Troyer (T) 181, P × T 206, P × T 211, P × T 212, P × T 216 and P × T 220 were found tolerant. Of the 30 citrus hybrids, six hybrids, viz., P × TO 103, P × TO 112, P × S 117, P × S 119, P × T 125 and P x T 130 were found resistant against *P. nicotianae* on the basis of lesion length (nil or <2.5 cm). The resistance of identified hybrids against *P. nicotianae* was also evidenced by low ROS generation and ELWL, with high RWC and leaf nutrient status over other hybrids.

Mutagenesis in Kinnow and sweet orange**.** Evaluation of bearing Kinnow mutants revealed significantly higher plant height (3.7 m) in the mutants M 10-4 & M 15-7, while it minimum (1.9 m) in Col-0.02%-1 followed by Col-0.1%-2 (2.2 m). Heaviest fruits (332.25 g) were found in mutant M 15-6. The number of seeds/ fruit varied significantly from 07 in M 35-4, EMS 0.2%-5 and EMS-0.5%-1 to 33 seeds/ fruit in M 35-6. Juice recovery was maximum in mutant EMS 0.5%-4 and EMS-0.5%-5 (59.43%). TSS: acid ratio on 15th December, 2017 was maximum (15:1) in EMS-0.1%-1, while it was minimum (6:1) in M 15-6 which however, attained the TSS:acid ratio of 14.1 during last week of January, thus exhibiting delayed maturity. Average fruit yield was highest (60.00 kg/plant) in M 20-8.

Ploidy manipulation in Kinnow mandarin and sweet orange. Colchiploids of Mosambi (48) and Kinnow (25) were planted in the field for detailed evaluation. Flowering was observed in all Mosambi colchiploids and three colchiploids of Kinnow. The flowering was induced in the same year of grafting, indicating non-juvenility in the multiplied plants. Based on leaf characteristics and internodal length, 23 colchiploids of Kinnow mandarin and 14 of Mosambi were identified.

Identification of superior Darjeeling mandarin genotypes. Twenty genotypes from different parts of Darjeeling hills were collected. The highest fruit weight was recorded in DC 2 (120.45 g) and juice content (63.20 ml). Total soluble solids (TSS) was found to be in MG 1 (11.42ºBrix) and lowest in M-5 (7.06 ºBrix). Minimum acidity was observed in MG 2, MG 4 and MG 5 (0.10%). Flavonoid contents ranged from 2554.6 µg/ml (M 4) to 454.53 µg/ml (DR 2).

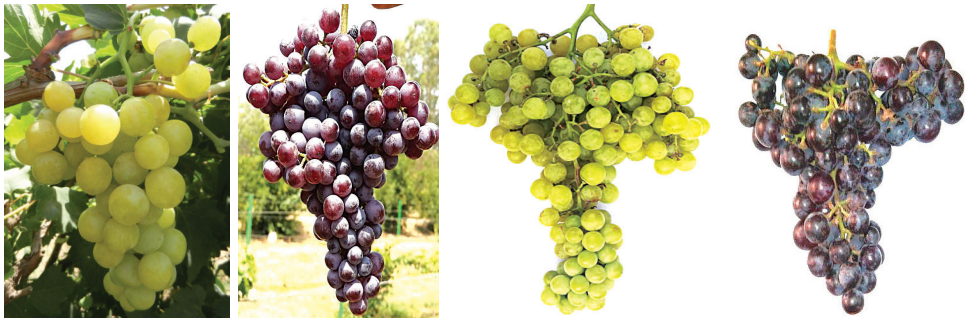
2.2.1.3 Grape

Identification of early maturing hybrids. Four hybrids were identified based on the early maturity and fruit quality traits, viz., Pusa Swarnika (Hur × Cardinal), Hy. ER R_2P_{36} (Pearl of Csaba × Beauty Seedless), Hy. 16/2A R_1P_9 and Hy. 16/2A R_1P_{14} (Cardinal × Beauty Seedless). Based on comparative performance of the hybrids, 'Pusa Swarnika' was released during Convocation 2018. It matures early with large berry, which are round golden-yellow colour with firm pulp. Berries are very sweet. It has natural loose bunches with natural bold berries. The clusters are medium in size. The fruits are ready for harvest before onset of monsoon. Normally fruit yields from the mature vineyard of 6-8-yr-old may be obtained 6-8 tonnes/ ha on head system. The hybrid is tolerant to anthracnose and powdery mildew. It has also desirable traits for table use, juice making and *Munnakka* preparation.

Brief characteristics of some promising grape hybrids.

Parameter	Pusa Swarnika	Hy. ER R_2P_{36}	Hy. 16/2A R_1P_9	Hy. 16/2A R_1P_{14}
Days to maturity (DAFB)	83	70	75	78
Bunch wt. (g).	254.20	218.75	421.32	289.25
Wt. of 100 berries (g)	468.25	201.00	293.32	450.21
Bunch length (cm)	17.25	17.25	24.00	13.00
Berry dia. (mm)	20.25	14.26	16.25	18.20

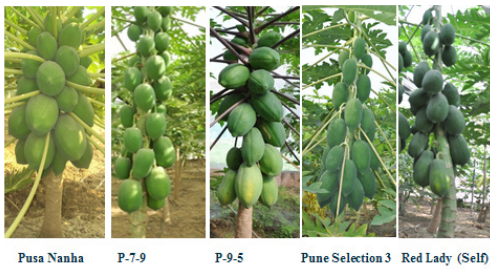
Berry colour	Golden yellow	Purple	Greenish-yellow	Purple
Juice recovery (%)	64.09	68.48	70.61	76.15
Seedlessness	Seeded		Seeded	Seeded
No.of seeds per berry	2-3	NIL	2-3	2-3
Bunch compactness	Loose	Semi compact	Loose	Semi compact
TSS (°Brix)	21.15	21.25	18.5	19.5
Acidity (%)	0.65	0.68	0.82	0.86
Ascorbic acid content (mg/100 g juice)	4.24	3.38	3.25	5.34
Juice pH	3.70	3.90	3.10	3.98
Juice colour	Colourless	Slightly coloured	Colourless	Slightly coloured
Total monomeric anthocyanin content (C3GE, mg k^{-1})	Not detected	166.60	Not detected	387.59
Total phenolics (GAE, mg /100 g)	92.75	108.55	72.00	128.50



Bunches of Pusa Swarnika,Hy. ER R2P36, Hy. 16/2A R1P9 and Hy. 16/2A R1P14

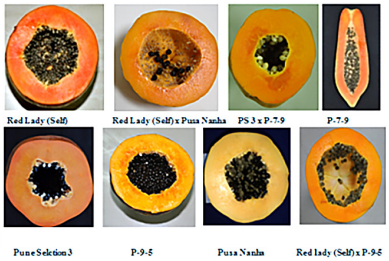
2.2.1.4 Papaya

Evaluation of hybrids and parents. Five parents and three hybrids, namely, Red Lady (selfed), Pusa Nanha, P 9-5, Pune Selection 3 (PS 3), P 7-9, Red Lady (selfed) × Pusa Nanha, Red Lady (selfed) × P 9-5 and Pune Selection 3 × P 7-9 were evaluated on different horticultural traits. Plant height at initiation of first flower was maximum in P 7-9 (96.50 cm), which was on par to Red Lady (selfed) × P 9-5 hybrid. Whereas, shortest plant (63.75 cm) was recorded in Pusa Nanha. Fruiting length was maximum (129.75 cm) in parent PS 3 followed by Red Lady (self), P 9-5, P 7-9 and hybrid PS 3 × P 7-, which were statistically at par. The number of fruits per plant, minimum fruit weight, fruit cavity index and maximum fruit firmness was in the hybrid PS 3 x P-7-9. The hybrid Red Lady (self) × P 9-5 had the maximum shelf-life (8.25 days) at room temperature. The total carotenoids ranged from 3.52 (Pusa Nanha) to 6.09 mg/100 g (P 7-9), which was at par with hybrid Red Lady (self) × Pusa Nanha.



Fruiting view of 5 parent genotypes of papaya

Fruiting view of 3 hybrid genotypes of papaya



View of central cavity and colour of the parent and hybrids papaya fruits

Characterization of Pune Selections in papaya. The intensity of PRSV Infection was very low in all lines. Maximum yield was obtained in PS 3 (44 kg/ plant). However, per unit area productivity was the highest in PS 2 (48 t/ha). Average fruit weight was the lowest in PS 1 (1194 g). Pulp thickness (3.16 cm) and TSS (9^0 Brix) were highest in PS 3. In gynodioecious types, maximum plant height (202 cm) was observed in PS 5-1, and the stem girth (46 cm) was observed in PS 5. The intensity of PRSV infection was nil in all lines while Red Lady had 6% intensity. Maximum yield was obtained in PS 3-1 (28 kg/plant or 49 t/ ha). Average fruit weight was the lowest in PS 2-1 (661 g). Pulp thickness was maximum in PS 2-1 (3.67 cm), and TSS (9.75^0 Brix) was highest in PS-3-1. Per plant fruit yield was 32% less in gynodioecious lines.

Evaluation for cold stress tolerance. Six genotypes (Red Lady, Pusa Nanha, P 7-15, P 7-9 and P 9-5) and a wild relative (*Vasconcellea cundinamarcensis*) were studied to determine the changes in different morphological, physiological and biochemical parameters on exposure to low temperature stress under controlled Phytotron conditions. The decline in photosynthesis rate (*A*) was recorded the highest in Red Lady (82.10%), compared to the lowest in P 7-9 (24.26%). The highest decrease in leaf RWC was noted in Red Lady (18.21%), while it was lowest in *V. cundinamarcensis* (6.10%). The genotypes Pusa Nanha (14.55%) and P 9-5 (17.05%) had the minimum change in MSI under the low temperature exposure. The decline in chlorophyll content was most pronounced in Red Lady (10.99%), while it was least in P 9-5 (4.97%). Genotype *V. cundinamarcensis* accumulated the minimum malondialdehyde content (26.62 µmol g^{-1}FW) followed by P 9-5 (36.02 µmol g^{-1}FW). In general, the maximum increase in antioxidant enzymes activities was in *V. cundinamarcensis*. The maximum increase in catalase activity (207.40%) was noted in P 7-9 at $20^o/10^oC$ (day/ night) temperature regime. Amongst the cultivated papaya types, inbreds P 9-5 and P 7-9 were found more cold tolerant compared to others.

Mutation breeding. The seeds of the papaya P 7-2 were treated with gamma rays 0.1, 0.15, 0.2, 0.25 and 0.3 kGy. Dwarf and precocious lines were selected and selfed for raising M_3 population. Minimum height at first flower initiation (99.8 cm), plant girth (70.65 mm), days to flower initiation (78.28), length of middle internode (3.5 cm), plant spread in east-west direction (141.6 cm), nodes to first flowering (32.20) and petiole length (44.20 cm), maximum fruiting length (86.40 cm), number of fruits (54.8), fruit weight (1.361 kg) and fruit yield (54.26 kg/ plant) were noted in treatment 0.1 kGy.

2.2.2 Orchard Management

Performance of semi-vigorous mango varieties on polyembryonic rootstocks. Pusa Arunima trees were significantly taller (3.64 m) on Olour and had non-significant difference with rootstocks K-3 (3.48 m) and Kurakkan (3.25 m). Pusa Arunima and Pusa Surya was extremely dwarf (2.38 and 1.48 m) on K-2 rootstock. Yield /tree were higher on Olour (22.39 kg/ tree), Kurakkan (22.39 kg/tree and K-2 (21.55 kg/tree) for Pusa Arunima, on K-3 and Kurakkan in Pusa Surya and on Olour in Amrapali. The heaviest fruits in Pusa Arunima (269.558 g), Pusa Surya (243.47 g) and Amrapali (128.19 g) were recorded on Olour rootstock.

INM and Drip irrigation studies on mango. Maximum shoot length (133.64 cm) was recorded in treatment NPK 100% + AMF (250 g)+ *Azotobacter* (250 g) followed by 131.08 cm in the treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g), while minimum (116.90 cm) in treatment NPK 50% + AMF (250 g). Among cultivars, maximum shoot length (144.31 cm) was found in Pusa Arunima and minimum (97.54 cm) in Pusa Pratibha. Maximum plant height (3.16 m) was recorded in treatment NPK 100 % + AMF (250 g)+ *Azotobacter* (250 g) followed by 2.94 m in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g), while minimum (2.27 m) in treatment NPK 100%. Among the cultivars, maximum plant height (2.79 m) was found in Pusa Arunima and minimum (2.41 m) in Pusa Pratibha.

Rootstock Research and canopy management in guava. After pruning treatment, maximum plant height and canopy volume were recorded in Hisar Safeda followed by Punjab Pink, while minimum was in Thai Guava. Flowering was earliest in Shweta followed

by Lalit and Allahabad Safeda. Maximum number of flowers/ branch was recorded in Punjab Pink followed by Shweta and Sardar. Highest of photosynthetic rate (7.82 μmol/m^2/s) was recorded in Punjab Pink followed by Hisar Safeda (7.38 μmol/m^2/s) and Sardar (7.00 μmol/m^2/s).

Fruit quality improvement in grape. Two bioregulators, viz., Methyl jasmonate (MeJ) and benzothiadiazole (BTH) that were applied at verasion stage at different concentrations, methyl jasmonate (15 mM) significantly affected the accumulation of total monomeric anthocyanins (1012.5 mg/ kg). However, spray of benzothiadiazole (0.3 mM) elicited the accumulation of total monomeric anthocyanins (855.4 mg/ kg).

Quality improvement in Kinnow. Prohexadione calcium (ProCa) at 100, 200, 400 ppm when applied pre-harvest to 'Kinnow' mandarin during colour break stage. Most beneficial effect was noted with 300 ppm ProCa in terms of fruit quality, *i.e.* TSS (10.10 ^{0}B), titratable acidity (0.74%) and ascorbic acid content (19.22 mg/100 g), total carotenoids content in juice (305 μg/100 ml) and peel (685 μg/100 ml) compared to untreated plants.

Temperate fruits. Eight walnut genotypes were selected from different parts of Himachal Pradesh and evaluated to determine phenotypic diversity. High variability was noted for the phenological and pomological traits. Dry nut weight ranged from 10.1-12.2 g, 33.2-40.1 mm nut size index and 41.2-51.1% for kernel. The promising accessions were the Chamba Collection, Kinnaur Collection, Lahaul & Spiti Collection and Soghi Collection, which had thin shell, heavier kernel, light kernel, more fruitfulness and late flowering.

2.3 ORNAMENTAL CROPS

Varieties released. Six flower crop varieties were identified by the Institute Variety Identification Committee and were further released by the State Seed Sub-Committee for Agriculture & Horticultural Crops, Govt. of NCT Delhi.

Rose:Pusa Mahak: It is a Hybrid Tea rose. The plants are tall and vigorous with a height of 100 - 120 cm. The flowers are dark pink in colour and have outstanding fragrance. The flowering starts in 40-45 days after pruning. Flowers are large and semi-double having 22-23 petals. The variety is ideal for garden display and for fragrant flower production.

Pusa Mahak

Marigold: Pusa Bahar: It belongs to African marigold group. Plants are vigorous having height of 75-85 cm. Flowers are compact, flattened, attractive and large in size (8-9 cm) of yellow colour (RHS Yellow Group: 9A). The variety is very floriferous producing on average 50-60 flowers per plant. In northern plains, it blooms

Walnut germplasm showing precocity in pot as well as in field conditions

from mid-January to March. It is suitable for bedding as well as for floral decorations

Marigold:Pusa Deep: It is an early flowering variety of French marigold which flowers in 85-95 days after sowing. It produces compact and medium sized flowers of dark red colour (red group 46 A-RHS colour chart). The variety is very floriferous and produces on an average 80-90 flowers per plant resulting in high flower yield (18-20 t/ ha). In Northern plains, it flowers during October-November. It is suitable for loose flower production.

Chrysanthemum: Pusa Guldasta: It 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. It does not require pinching and staking. This variety is suitable for spray and pot culture purposes.

Pusa Guldasta

Chrysanthemum:Pusa Shwet: It is an open-pollinated seedling of cv. Lalpari. Plant attains a height of 41 cm with a good spread of 48 cm. The plant is of semi-spreading growth habit. It bears semi- double medium sized flowers (6.0 cm) with white ray florets and yellow disc. The flowers stay for longer duration (40 days) under field conditions. This variety is suitable for pot culture and garden display purposes.

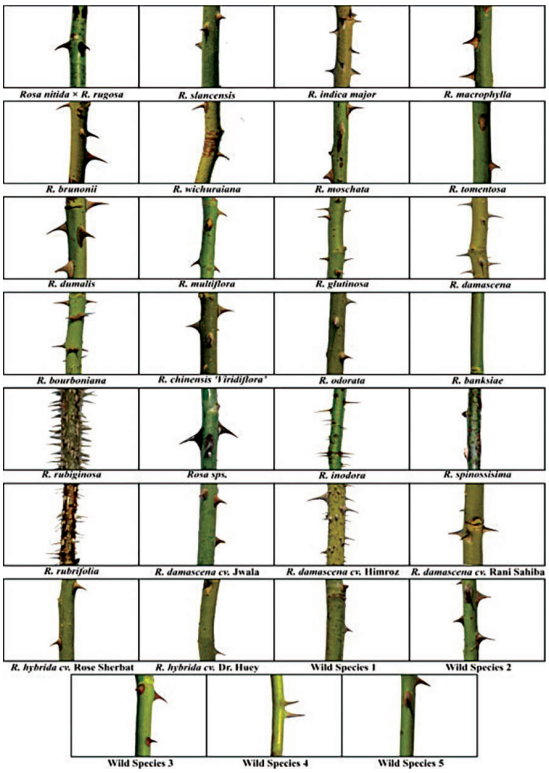
Gladiolus:Pusa Sinduri: It is a mid season variety and flowers in 105.22 days after planting with robust and compact spikes. The florets base colour is bright red (44C as per R.H.S colour chart). Two yellowish spots on base of inner tepals with red coloured rainbow type stripe on throat. The variety produces long spike (>98.77 cm), having more number of florets per spike (>18.66). The variety is very much suitable for cut flower, bouquet preparation, etc. It produces 1.00-1.20 lakh spikes and corms per acre.

Pusa Sinduri

2.3.1 Rose

Phylogenetic relationships in the Rosa species. A wide range of diversity with respect to various important 18 vegetative traits was observed in 31 *Rosa* species. Few species such as *R. brunonii*, *R. moschata*, *R. dumalis*, and *R. glutinosa*, wild species 3 and wild species 5 had strong anthocyanin colouration in young shoots and could be an effective source of resistance against abiotic stress. Dr. Huey and *R. banksiae* were found to be the only completely thorn-less species. High prickle density was noticed in *R. rubiginosa*, *R. rubrifolia*, and *R. dmascena* cv. Himroz. Clasped and winged types of stipules were common among species. Only *R. banksiae* and wild species 4 had scaly or rudimentary stipule type of.

Two pairs of roses, namely, *R. banksiae* - *R. chinensis*'Viridiflora' and *R. banksiae* - *R. rubiginosa* showed the highest diversity with dissimilarity correlation coefficient of 0.60. Based on dissimilarity correlation coefficient matrix, cluster analysis and



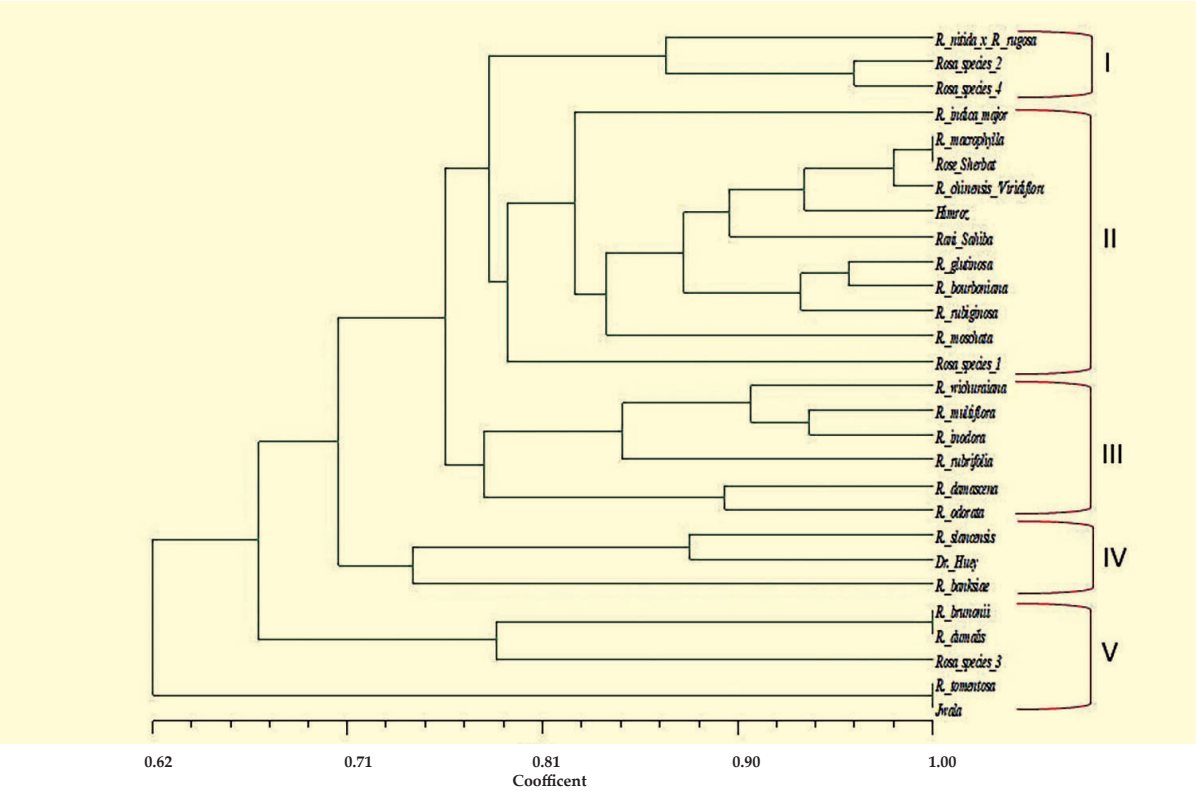
Stem characteristics of 31 Rosa species

Principal component analysis, *R. banksiae* was found to be unique and diverse species. Among all 31 species, maximum similarity was observed between *R. brunonii* and *R. dumalis* with a coefficient value of 0.05, and grouped into the same sub-cluster.

Hierarchical cluster analysis of species was done by "Ward D clustering" method and a dendrogram (tree) was constructed, where 31 species were grouped into five major clusters. Clustering of *R. chinensis* 'Viridiflora' and *R. odorata* into the same cluster was in accordance with Rehder's classification in section Indicae, they are reported to be diploid in nature. There was significant diversity in the species *R. damascena*. Its cultivar Jwala fell into a cluster 3, whereas the *R. damascena,* cultivars Himroz and Rani Sahiba grouped into the same clusters. Both the Indian originating species *R. brunonii* and *R. moschata* fell into the same cluster. Two other species, *R. wichuraiana* and *R. multiflora* fell into another cluster showing great diversity in *Synstylae* section.

Genetic Diversity analysis using SSR markers. Out of 56 SSR markers tested, 33 markers gave good amplification. Out of these, 10 markers were found to be monomorphic, while 23 showed polymorphism. Diversity analysis detected a total of 47 alleles ranging from 1 to 3 alleles with an average of 1.42 per locus. Highest MI was observed for primer Rw29B1 (5.2), closely followed by Rw52D4 (4.88) and H20D08 (4.72), while lowest MI was reported for primer H5F12 (0.654). The Rp of five main SSR markers are: Rw60A16 (1.60), RA027a (1.55), C187 (1.26), Rw34L6 (1.22) and C139(1.18). Markers such as Rw60A16, RA027a, H4F06, C187 and Rw34L6 exhibited maximum discriminatory power. The similarity coefficient ranged from 0.33 to 1.00. The maximum similarity was observed between *R. brunonii* and *R. dumalis*; *R. macrophylla* and *R. hubrida* cv. Rose Sherbat; and *R. tomentosa* and *R. damascena* cv. Jwala with a similarity coefficient of 1.00. Maximum diversity was observed between *R. tomentosa* and *R. slancesis* with a similarity coefficient of 0.33.

UPGMA method grouped 28 species into five major clusters. Four rose species, viz. *Rosa* sp. 1, *Rosa* sp. 2, *Rosa* sp. 3, and *Rosa* sp. 4 could not be assigned to any species. *Rosa* sp. 2 and *Rosa* sp. were grouped with *R. nitida* × *R. rugosa* supporting the hybrid origin of these accessions. *Rosa* sp. 1 also did not align with a particular species and falls separately. Although *Rosa* sp. 3 does cluster with *R. brunonii* and *R dumalis* at a similarity level of 0.75, which suggest they might be in its parentage. Section *Synstylae* shows a great variation and appears as apolyphyletic group as two other species *R. multiflora*and *R. wichuraiana wasd* placed into the same cluster and two other species, *viz. R. brunonii* and *R. moschata* groupped into different clusters. *R. brunonii* showed high similarity with *R. dumalis*of section *Caninae*, while *R. inodora* of section *Caninae* fell into the same cluster as of *R. multiflora,* suggesting easy out-crossing among both sections.



Dendrogram based on the similarity index values of 28 *Rosa* species using SSR markers

Evaluation of promising OP seedlings. Two promising seedlings were identified, namely, R-SD-6-201 – a selection from the open-pollinated population of cv. Rose Sherbet. It produces pink (RHS-65-A) coloured large sized blooms. It has 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, while R-SD-7-2015 -a selection a cv. Pusa Virangana. It produces red coloured large sized blooms. The plants are short and narrow bushy. It is a hybrid Tea type, floriferous and suitable for cut flower purpose.

Promising inter-varietal hybrids. Three promising hybrids were identified, namely, RH-1-2017-a hybrid between cv. Taj Mahal × Midas Touch. It produces red coloured large sized blooms. The plants are short and narrow bushy. It is a hybrid Tea type. The variety is suitable for cut flower purpose in northern plains, RH-2-2017- a hybrid between cv. Enna Harkness × Midas Touch. It produces pink coloured large sized blooms. The plants are short and narrow bushy. It has fragrant flowers, less petal shedding, compact and more flower anchorage. It is a Floribunda type and floriferous. The variety is suitable for loose flower purpose and making garlands, while *RH-3-2017* is a hybrid between cv. Dr. Bharat Ram × Delhi Princess, producing pink coloured large sized blooms. It is a Floribunda type, floriferous and suitable for garden display.

Hybridization to develop powdery mildew resistance lines. The tolerant species (pollen parents) and susceptible varieties (Female parents) were utilized in crossing programme for development of pre- breeding lines resistant to powdery mildew. Crosses were made among species and varieties, *viz., R. multiflora, R. brunonii, R. wichuriana, R. macrophylla,* Pink Knockout, Hot Cocoa, Dr. Bharat Ram, Pusa Virangana, Mridula, Golden Shower, Jadis, Happiness, Konrad Henkel, A. Royal Rose, Oklahoma, Dr. S.S. Bhatnagar, *etc*.

2.3.2 Gladiolus

Screening in gladiolus for salt tolerance. Twenty two chrysanthemum (*Chrysanthemum morifolium* Ramat.) varieties of were screened for salt tolerance under hydroponic system at five different salinity levels (0, 50, 100, 150, 200 mmol/l). On the basis of modified standard evaluation score (SES) of visual salt injury, varieties such as Little Pink, Lalit, Haldighati and Pusa Aditya were grouped under the tolerant category, while, Himanshu and Pusa Sona were grouped under susceptible and highly susceptible categories, respectively.

New gladiolus genotypes. Four OP seedling selections were found promising in gladiolus, Pink Parassol Open Seedling, Melody Open Seedling, Suchitra × Melody, Vidushi (mutant) and Green Pasture × Regency, *etc.*

2.3.3 Marigold

Development of in-vitro protocol for direct shoot organogenesis in marigold.Among the various explants, namely, hypocotyl, cotyledon, leaf, ray florets and thalamus used for direct shoot organogenesis/ direct regeneration, the cotyledon explant was found best in case of African marigold var. Pusa Narangi Gainda (PNG) and leaf explant was found best in case of French marigold var. Pusa Deep. Accordingly, protocol for mass multiplication was standardized using the cotyledon and leaf as explant of PNG and Pusa Deep, respectively.

Suchitra × Melody

Salmon Queen Open Seedling

Green Pasture × Regency

Pink Parassol Open Seedling

T_0 (Control- MS medium devoid of hormones)

T_5 (MS +BAP 3.0 mg/l + IAA 3.0 mg/l

Direct shoot organogenesis from cotyledon explant of African marigold var. Pusa Narangi Gainda

Standardization of dehydration techniques in marigold. The experiment was conducted on standardization of dehydration techniques for higher retention of total carotenoids. The variety chosen for study was Pusa Narangi Gainda (*Tagetes erecta* L.) and Pusa Arpita (*Tagetes patula* L.). The drying was carried out using different methods like sun drying, vacuum, hot air oven, and microwave. The highest carotenoids were retained at vacuum drying method followed by microwave and hot-air oven drying methods. In vacuum drying, Pusa Narangi Gainda recorded the maximum carotenoids as 2710.03 mg/100 g on dry weight basis, whereas in Pusa Arpita maximum carotenoids were recorded as 1427.77 mg/100 g on dry weight basis.

2.3.4 Bougainvillea

Standardization of drying techniques in bougainvillea. The variety Spring Festival, which is having high content of betalains (Betacyanin and betaxanthin) and antioxidant activities, was subjected to different drying techniques such as sun drying, shade drying, hot air oven drying, microwave drying and vacuum drying techniques. The vacuum drying was observed to be better over other drying techniques for high retention of betalains and their antioxidant activities in bracts.

2.3.5 Eustoma

Evaluation of hybrids. Fifty new cross combinations among twelve genotypes of were evaluated for various vegetative and flowral traits. The earliest flowering was recorded (73.3 days) in hybrid T11 × T6. The maximum stem length (60.7 cm) and flower size (7.1 cm) was recorded in the cross T12 × T11. The maximum number of flower buds per plant (21.7 buds/ plant) was recorded in cross T11 × T7. Five cross combinations, namely, T11 × T3, T11 × T7, T12 × T11, T7 × T6 and T12 × T6 were found to be very promising for cut flower production under Kullu valley conditions.

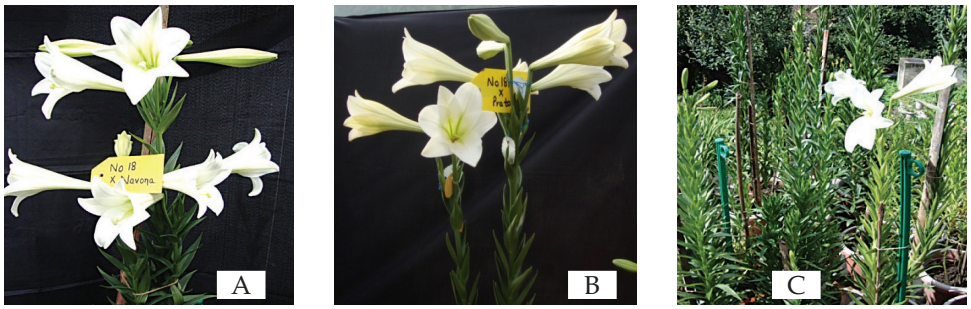
In vitro multiplication. Protocol was standardized for *in-vitro* mass multiplication of Eustoma. The maximum proliferation of *in vitro* shoots was obtained on MS medium supplemented with 2.0 mgl^{-1} BAP, 0.1 mgl^{-1} NAA and 0.1 mgl^{-1} GA_3. Among the three genotypes tested, the maximum *in-vitro* proliferation was recorded in Violet Vixen. The *in vitro* raised shoots were successfully rooted on half-strength MS medium supplemented with IBA 1.5 mgl^{-1} and 45 gl^{-1} sucrose.

Flowers of promising Eustoma cross combinations: a) T11 × T3; b) T1 × T3; c) T1 ×T9; d) T12 × T6, e) T12 × T11 and f) T3 × T5

Standardization of post-harvest technique. The post-harvest studies were conducted in Echo Double Blue and Soirees Pink. Among the fourteen bud opening solutions tested, the maximum display life (21 days) was recorded in the solution containing 3% sucrose + ascorbic acid (100 ppm). Among the different pulsing treatments, the maximum vase-life was recorded with 16 h pulsing of stems with 3% sucrose + Al_2SO_4 (200 ppm).

2.3.6 Lilium

Evaluation of interspecific hybrids. Crosses between KILH 13 with Prato, Brunello and Navona were earliest to flower (176.1 days) as compared to the parents, i.e. KILH 13 (185.3 days), Brunello (239.0 days), Navona (244.0 days) and Prato (238.0 days), respectively. Plant height was observed maximum in KILH 13 × Prato (106.04 cm) followed by KILH 13 × Navona (105.6 cm). Maximum plant height (155.0 cm) and flower size (11.8 cm) were recorded in Cl-10 of a cross between KILH 13 × Prato. Cl 40 and 1 of the same cross produced more number of flowers (7.0) per plant and Cl 13 shows the multi-sprouting trait. Cross



Inter-specific lilium hybrids: a) KILH 16-3, b) KILH 16-1, c) Multiple sprouting in KILH 16-1

between KILH 13 × Navona produced more number of bulbs (6.0) with an average size of 13.66 cm.

Similarly, BC_1 progenies of a cross KILH 13 x *L. formosanum* took average 298.73 days to flowering from seed sowing. Multiple sprouting was observed in Cl 4, 9, 13 and 15 and flowered in 325.75 days. Average plant height varied from 22.0 to 63.0 cm, respectively. However, a cross between *Lilium formosanum* × *Lilium longiflorum* took 329.13 days to flowering. Average plant height varied from 38.0 to 85 cm.

Germplasm evaluation. Four pot and six OT cultivars of lilium were collected and evaluated for flowering traits. Among pot cultivars, cultivar Curitiba took minimum number of days (42.0 days) to flowering. Plant height was recorded minimum (28.5 cm) in cultivar Sunset Matrix. Among OT cultivars, Montego Bay was earliest to flower (189.3 days), while plant height was maximum (90.8 cm) in Zambasi.

Bulblet multiplication in LA lilium. An experiment was conducted with consisting of different storage durations (0, 3, 6, 9 and 12 weeks), scale position (outer and inner) and temperature regime (4^0 and 2^0) on three lilium cultivars, namely; Brindisi, Ercolana and Pavia. The results showed that bulblet production decreased from outer to inner scales and showed a positive correlation with the scale width with storage duration of 9 weeks, which resulted in early sprouting and root initiation due to breaking of dormancy. Maximum number of bulblets (3.28) per scale was produced in the cultivar Pavia followed by Ercolana (3.10) and Brindisi (2.18).

2.3.7 Alstroemeria

Effect of growing media and feeder roots on growth and flowering. Alstroemeria cultivars 'Amor' and 'Rosita' were found suitable for pot culture since both cultivars had greater number of cymes per inflorescence. Growing medium consisting of soil + sand + cocopeat + vermicompost, in equal proportions by volume was the best substrate for vegetative parameters like plant height, spread, number of leaves and stem thickness.

2.3.8 Licoris

Standardization of nutritional requirement. The experiment was conducted with a view to standardize the nutrient requirement for flower production. Uniform sizes (2 cm) of bulbs were planted in 1 m^2 plot. It was recorded higher bulb diameter (2.5 cm), plant height (30.5 cm), width (2.15 cm) and biomass (9.5 g $plant^{-1}$ DW) in NPK (300:300:300) kg/ha.

Pot cultivars of Lilium, a) cv. Curitiba, b) cv. Sunset Matrix

2.4 SEED PRODUCTION OF HORTICULTURAL CROPS

The Division of Fruits & horticultural Technology, Seed Production Unit, IARI, New Delhi, IARI Regional stations at Karnal, Katrain, and Pusa (Bihar) produced nucleus, breeder, and IARI-TFL seeds of different horticultural crops during the period under report. In addition to seed production, 20882 saplings of fruits trees were also produced at Division of Fruits & Horticultural Technology, 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 Fruits & Horticultural Technology				
Papaya			0.00114	**0.00114**
Seed Production Unit, New Delhi				
Vegetable crops	-	1.165	8.385	**9.550**
Flower Crop (Marigold)		0.009	0.066	**0.075**
Regional Station, Karnal				
Vegetable crops	0.20	7.80	3.40	**11.40**
Regional Station, Katarin				
Vegetable crops	0.090	0.007	2.134	**2.231**
Regional Station, Pusa				
Papaya			0.01437	**0.01437**
Total	**0.29**	**8.981**	**14.00051**	**23.27151**

Propagation of Horticultural crops

Division/Unit/Stations	Number of saplings
Regional Station, Karnal	7895 (Mango, Guava, Papaya & Lemon)
Regional Station, Pusa	7557 (Mango, Litchi, & Papaya)
Division of Fruits & Horticultural Technology	5430 (Mango, Grape, Guava, Papaya, Lemon, Mandarin, Acid Lime & Sweet Orange)
Total	**20882**

3. GENETIC RESOURCES AND BIOSYSTEMATICS

The Institute has an active programme on collection, maintenance and 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. About 624 interspecific derivatives from wild species like *Triticum militinae, T. timopheevi, T. turgidum, T. monococcum, T. spelta, Aegilops variabilis, Ae. umbellulata, Ae. speltoides, Ae. markgrafii, Ae. geniculata* and *Secale cereale* were maintained and evaluated for rust resistance .One of the *Ae. markgrafii* introgression line ER9-3-700 having broad spectrum resistance against 16 diverse races of *Puccinia triticina* showed resistant reaction of '0;" to ';". Besides, resistance to stem rust and leaf rust in six B genome species of wheat viz., *Triticum dicoccoides., T. turgidum, T. carthlicum, T. polonicum, T. palaeocolchicum, T. turanicum* and seven S genome species of wheat viz., *Aegilops speltoides, Ae. kotschyi, Ae. longissima, Ae. peregrina, Ae. searsii*, 88 of *Ae. sharonensis* and *Ae. bicornis* were evaluated at adult plant stage. These species have considerable potential as a source of rust resistance and may enhance the existing gene pool of resistance to stem and leaf rusts.

Promising wheat genetic resources for disease resistance. *Durum* wheat production is affected by several biotic factors like rusts, leaf blight, Karnal bunt, flag smut, loose smut, etc., and it is often difficult to get multiple disease resistant high yielding genetic stocks. Genetics stocks HI 8751 (IC0623451; INGR 17032) and HI 8765 (IC0624495; INGR17038) were registered as *durum* wheat germplasm with multiple disease resistance. These genetic stocks were identified to be resistant to stem, leaf and stripe rusts, Karnal bunt and flag smut in multi-location testing. They showed high levels of adult-plant resistance to most prevalent and virulent pathotypes like 77-5 and 104-2 of leaf rust, 40A and 117-6 of stem rust; and 46S119 and 78S84 of stripe rust in isolated nurseries. They also showed resistance to other diseases like flag smut and Karnal bunt. Hence, they can be utilized in *durum* wheat improvement as potential resistance donors to breed new varieties.

A set of 56 genotypes including 50 advance lines and 6 released wheat varieties were evaluated for Karnal bunt resistance. Plants were inoculated at boot stage. Based on less than 5% infected grain, 38 genotypes showed resistant reaction. Based on superior yield and Karnal bunt resistance, two wheat entries viz., CL 3872 and CL 3881 among advance lines and HD 3059 among released varieties were identified as promising.

HS 628, evolved from a cross (HS240*2/FLW20 (*Lr19*)//HS240*2/ FLW13 (*Yr15*) using Bulk-Pedigree Method of breeding was found to possess resistance to all the pathotypes of black rust including newly evolved pathotype 40-3. HS 628 was screened for presence of *Sr25/Lr19* using STS markers *PSY1-E1* and *Gb* and tested positive for these molecular markers. HS 628 also carry resistance to newly evolved pathotypes of stripe rust. The rust resistance gene pool present in HS 628 against black, brown and yellow

rusts of wheat would serve as potent donor for creating new usable variability against rust diseases in wheat.

Pre-breeding and handling of segregating materials of wheat. Among 589 advanced wheat breeding lines evaluated under PDSN at rust hot spot, Dhaulakuan, 353 showed resistance to stripe rust under natural condition, whereas, the incidence of stripe rust was 5S in 110 lines, >5S to 10S (81), >10S to 20S (24) and 14 lines have shown high incidence of stripe rust at adult plant stage. Among 160 CVT entries of wheat, 17 were found to possess seedling resistance to most virulent pathotypes viz., 78S84, 110S84 and 110S119 of wheat. A total of 3427 early and advanced segregating lines were evaluated for rust resistance and agronomic features at adult plant stage of which 1261 were selected as a process of developing superior breeding lines. Besides, 905 segregates representing to 92 diverse crosses of wheat were selected for advancing to next generations. Among 101 advanced bulks ($F_{8:9}$) of wheat evaluated for seedling resistance to most virulent pathotype 77-5 (121R63-1), 18 were recorded as resistant.

3.1.2 Barley

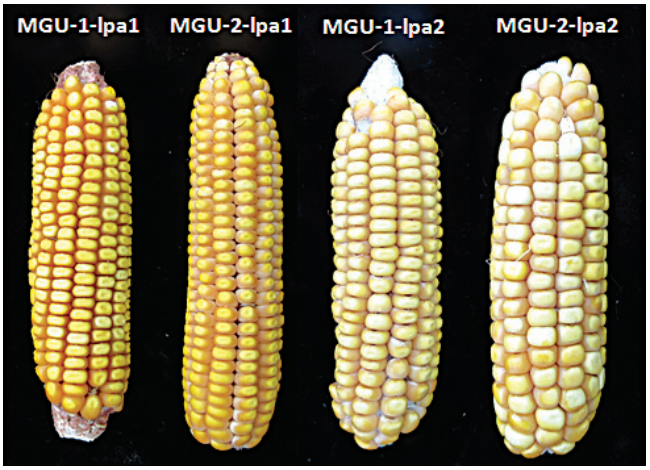
Evaluation of barley germplasm for stripe rust resistance. Thirty seven out of 116 barley germplasm lines evaluated for seedling rust resistance were found to be resistant against M race of stripe rust under green house conditions.

3.1.3 Rice

Pre-breeding - development and evaluation of introgression lines. A set of 100 different accessions of wild rice collections of *O. rufipogon, O. nivara, O. longistaminata* were evaluated and data were recorded for different traits. These lines were also utilized in wide crossing for introgression of useful traits.

3.1.4 Maize

Low phytic acid germplasm. Low phytic acid mutants viz., *lpa1* and *lpa2* procured from exotic source were crossed with seven elite inbreds viz., HKI 323, HKI 1105, HKI 1128, HKI 161, HKI 163, HKI 193-1 and HKI 193-2. F_2 segregants homozygous for *lpa1* and *lpa2* were selected based on foreground selection. Twenty progenies across populations bearing healthy plant growth and desirable ear and grain characteristics were selected. The germplasm developed here possess significance in enhancing the bioavailability of kernel iron and zinc in maize.



Ear and grain characteristics of *lpa1* and *lpa2* based progenies

Maize × teosinte derivatives. Teosinte accession was used as male and crossed with 17 elite maize inbreds. The F_1 plants possessed tillering and intermediate characteristics of tassels, ears and plant morphology. The number of kernel rows per ear were paired and possessed only 2-4 rows/ear. The grains were naked and ears were covered with husks. The F_2 seeds were grown and selfed to generate F_3 progenies. A selected set of 53 progenies was prepared for their utilization in the breeding programme.

Ear and grain characteristics of *maize x teosinte* cross

Maize × Sikkim primitive derivatives. Sikkim primitive accession possesses 6-8 ears per plant. Normal maize bears 1-2 ears per plant due to over expression of *teosinte branched-1* (*tb1*) gene. Sikkim Primitive was used as male and crossed with 35 elite maize inbreds. The F_1s showed uniform three ears per plant across crosses. The F_2 progenies showed 2-5 ears/plant, and progenies with 4-5 ears per plant were selfed. Number of silk bags (white bag) represents number of emerging ears per plant. The segregants with high prolificacy would serve as valuable genetic resource for improvement of baby corn.

Multiple ears per plant in maize x Sikkim Primitive cross

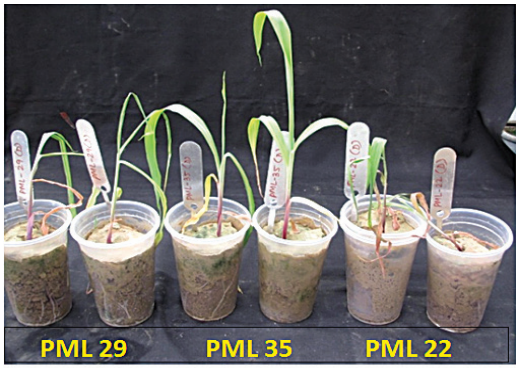
Identification of high yielding lines coupled with resistance to foliar diseases. The inbreds, PDM 96, DIM 303, CDM 318, CDM 350 and CDM 304 were promising with a grain yield of more than 3 t/ha and TLB and MLB score of less than 2.5 under natural epiphytotics.

Inbreds with high kernel row number (KRN). A set of 80 maize germplasm was screened and categorized into low (up to 12 KRN), medium (14-18 KRN) and high (20 and above) KRN lines. Among these, 16 low, 42 medium and 22 were high KRN type. These germplasm will be utilized in systematic way in future maize breeding programme.

Identification of inbreds and hybrids with genetic tolerance to abiotic stresses. Twenty five potential maize inbred lines with high yield *per se* performance as well as four experimental hybrids were subjected

Inbreds with high KRN

to drought and water logging stresses under artificially managed conditions of green house. PML 35 and PML 54-1 were tolerant to drought stress. Similarly genotypes, PML 46 and PML 54-1 were tolerant to water-logging stress. Among the experimental hybrids, AH 4158 was found to be less sensitive to water-logging.



Performance of PML 35 under drought stress conditions

Characterization of maize inbred lines. A set of 40 white and 50 yellow inbred lines were categorized as per 31 DUS characteristics. BM 1415 (medium flint with sparse and narrow tassel and high test weight of 36g), BM 1492 (high test weight of 40g, medium with wide tassel branches) and BM 1441 (late in maturity with high test weight of 38 g, dense and wide tassel) were identified. PML 35, PML 46, PML 50, PML 76 and PML 93 were identified with unique combination of traits viz., maturity, responsiveness to high planting density and kernel characteristics.

3.1.5 Pearl Millet

Maintenance of germplasm. A total of 958 germplasm lines of pearl millet including cytoplasmic male sterile lines, maintainers and restorers were

maintained. The traits in these lines include early flowering, high tillering, thick spike, bristled spike, long spike, variations in compactness of the spike and grain colour.

Heat stress tolerant lines. Four entries viz., 411B, PPMI 1053, 1087 and PPMI 1213 were nominated in PMPHY-7 (identification of heat stress tolerance in pearl millet genotype at seedling stage). The genotype, PPMI 1213 performed better having high shoot length, seedling dry weight, SVI, high root shoot ratio, RWC, MSI, cholorophyll, SOD, CAT and MDA content under heat stress.

3.1.6 Chickpea

Identification of early maturing chickpea line with pea shaped seed. An early maturing chickpea line, BGD 232 (KAK2 x JG 11) was identified with maturity duration of 85 days. It has pea shaped seed with 100-seed weight of 33g.

3.1.7 Lentil

Multi-flowering genotype identified. From the ICARDA germplasm, a unique lentil genotype (LIEN33127-E) having up to 6 flowers per peduncle (range: 4-6 flowers per peduncle) was identified. Crosses have been attempted with a two flower per peduncle genotype (ILL 7663) to understand the genetics of this trait.

3.1.8 Mustard

Maintenance of germplasm. Total 847 germplasm lines including *B. juncea* (562), *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) were maintained by selfing and utilized in breeding programme. Exotic genotypes viz., EC 27, EC 28, EC 30, EC 60, EC 61 and EC 62 were purified and maintained by raising 110 progenies & 40 single plants were selected. Sterility inducing cytoplasm viz., *mori, eru, ber* and *ogu* are being maintained through crossing respective A and B lines.

3.1.9 Soybean

Evaluation of soybean germplasm for agro-morphological traits and terminal drought tolerance. Three hundred and twenty eight germplasm lines were screened for terminal drought tolerance by spraying 0.2% of KI at R_5 stage and the tolerant lines were again re-tested under similar conditions in subsequent year. The lines were classified as tolerant, moderately tolerant and susceptible based on the relative reduction in seed yield and 100-seed weight of treated over control conditions. The Shannon diversity index (SDI) has indicated that germplasm lines are highly diverse for seed colour (H'= 1.20) and hilum colour (H'= 0.93). Four germplasm lines (TGX1835-3E, SL 69, EC 105780 and PK 1243) were identified as relatively drought tolerant lines as they showed less reduction for seed yield and 100-seed weight under KI induced drought conditions.

3.1.10 Fruit crops

Mango. Scion sticks of genotypes, namely, Gadamar, Ajwain, Lalji, Karela, *Mangifera odorata*, Jamadar, Ananas, Shorab, Indian Spring, Jalal, Angurdana, Kohinoor, Ceylon, Neem, *Mangifera zeylanica* were collected from HETC, Saharanpur, and Lat Sundari, Subhash, Meneka, Jawahar, Aliflaila, Prabha Sankar, Mahmood Bahar, Zafaran, Ahra Baramasi, Gaurjit, Police, Karpoory, Zardalu, Gilas, Baramasi Ranchi and Sabri were collected from BAU, Sabour. During August 2017, survey was undertaken in Middle Andaman and Port Blair regions. Twenty-five mango genotypes with fruit traits like red peel and less fibre, including three species, namely, *M. andamanica, M. griffithii, M. camptosperma* and one Burmese type were collected. Paiyur area of Dharmapuri districts of Tamil Nadu was surveyed and 42 genotypes/varieties, including variants of Neelum and Bangalora were also collected.

Grape. Germplasm were collected from, PAU RRS, Bhatinda (Sonakka, Gold, Clone 2A, Muscat of Alexandria), ICAR-IIHR, Bengaluru (ArkaSweta), College of Horticulture, Mandsaur(Manjari Naveen, Ruby Seedless, Flame Seedless, Christmas Rose, Kishmish Maldywisky, Maroo Seedless,

Rizamat Kishmish, Rizawat Red, Bangalore Blue, KR White, Italia, Convent Large Black, Crimson Seedless, Fantasy Seedless, Sharad Seedless, Krishna Seedless, Khatta Khurgan, Merbein Seedless, Jumbo, Bangalore Blue, Muscat of Hamburg, Kishmish Chorney, Medika) and ICAR-NRC on Grapes, Pune (Crimson Seedless, Nath Jumbo, Sarita Seedless, 1613, 3303 P).

Guava. Surveys were conducted in guava growing areas of Raipur (Chhattishgarh), Datia (M.P.) Kosambhi regions of Allahabad (U.P.), and Andaman and Ayakudi (Tamil Nadu). Guava genotypes collected from different regions were evaluated for fruit quality traits. Eight guava genotypes, namely, Pant Prabhat, Shweta, Lalit, Allahabad Safeda, Hisar Surkha, Hisar Safeda, Thai Guava and Allahabad Surkha were evaluated for morphological, yield and physico-chemical attributes. Plant height was maximum in Hisar Surkha (348.27 cm) followed by Lalit (329.26 cm.). No. of fruits and yield in both rainy and winter seasons were higher in Lalit (156.34 and 35.8 kg/tree) with highest TSS (11.22°Brix) followed by Hisar Safeda (11.00°Brix). The highest ascorbic acid (143.28 mg/100 g) and fruit acidity (0.38%) were recorded in Pant Prabhat. Maximum fruit core diameter was observed in Thai guava (4.22 cm) followed by Pant Prabhat (3.12 cm). Maximum free amino acids (0.029 mg/g fr. wt.) and SOD activity (11.32 mg^{-1} protein min^{-1}) were recorded in black guava.

Temperate fruit crops. Seedling peach selection from Saharanpur, Uttar Pradesh was collected for evaluation. Seedling selections of walnut and apricot were established for evaluation. New varieties of apple, viz., Jeromine, Red Velox, Scarlet Supr-II and Super Chief-II were introduced and planted for further evaluation.Twenty five Russian /temperate type pomegranate accessions were collected from ICAR-NRC on Pomegranate, Solapur for evaluation under Shimla conditions.

3.1.11 Vegetable Crops

Cauliflower. Fertile inbred lines were evaluated in three different maturity groups,viz., early (46), mid-early (40) and mid-late (16) for horticultural traits and field reaction to diseases; and maintained by selection of desirable plant types. Besides, 20 CMS lines (13 in early, 5 in each mid-early and 3 in mid late) and 12 self-incompatible lines (8 early, 4 mid group) were also maintained. Conversion of 30 elite inbreds using *Ogura*, (*E. canariense*) *B.napus* (source: NRCPB) and *Trachy* CMS systems was advanced to BC_5 to BC_6 generations. Field reaction of CMS and SI lines for downy mildew, black rot and *Alternaria* blight was recorded. Further, 140 RILs (from PHJ/PS x BR-2/161/207) for black rot resistance were evaluated for horticultural traits and advanced to F_8 generation. Eight *Ogura* CMS lines in early group, four in mid-group and two in mid-late group were used in the hybrid development.

Cabbage. At Regional Station, Katrain, 80 genotypes including 10 self-incompatible lines and 30 CMS lines along with their respective maintainers were purified and maintained. Seeds of 77 EC accessions were multiplied and submitted to the ICAR-NBPGR along with their characterization data.

Other Brassica vegetables. In cabbage, two inbred lines and two CMS lines of 'no-chill' cabbage were maintained. In broccoli, 14 lines were advanced to next generations (F_3 or F_6) by bud-pollination and two CMS lines to BC_3. One CMS line maintained and attempted F_1 crosses using three promising inbred lines. In radish, one CMS line and 12 inbred lines/varieties were maintained through bud pollination.

Cucumber. Forty indigenous/exotic germplasm including two accessions of *Cucumishytivus*, seven accessions of *C. sativus* var. *hardwickii*, *C. javanicas*, *C. prophetorum*, *C. trigonos*, *C. melo* var. *metuliferus*, three accessions of *C. melo* var. *agrestis*, *C. melo* var. *leosperma*, six accessions of carotene rich cucumber, white cucumber, red skinned cucumber, ornamental cucumber, lemon cuke cucumber, round cucumber with yellow, green and golden colour, red hmong cucumber, beit alpha cucumber, seven accessions of Chinese cucumber and other promising indigenous and exotic material were maintained under protected structure. Crosses were attempted with selected carotene rich genotypes to introgress the desirable

traits. Apart from IC 420422 and LOM 402 new carotene rich line AZMC 1, KP 1291 collected from Mizoram through ICAR-NBPGR were found to be very promising with dark orange flesh colour on ripening.

Luffa. Fifty-five germplasm/advance breeding and virus resistant sponge gourd lines were maintained. In ridge gourd, 30 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-day interval.

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

Muskmelon and watermelon. Ninety four germplasm of muskmelon comprising of horticultural goups (*cantalupensis, inodorous, momordica* and *conomon*) were evaluated for horticultural traits and resistance against *Fusarium* wilt and powdery mildew, and maintained. Thirty six muskmelon genotypes from four horticultural groups were screened in polyhouse for resistance against powdery mildew, of which genotype EC 751844-3 and oriental melon was identified as resistant. Sixty four watermelon genotypes from *Citrullus lanatus* var. *lanatus* var. *citroid* and *Citrullus colocynthis* were evaluated and maintained.

Bottle gourd. A total of 100 accessions of bottle gourd (*Lagenaria siceraria* Standl.) including two registered genetic stocks (INGR 10064 and INGR 99009) and nine exotic collections were augmented from the ICAR-NBPGR, New Delhi. Besides, six accessions (BD-1, BD-2, BD-3, BD-4, BD-5 and BD-6) were collected from Tripura.

Longmelon and round melon. Twelve 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 maintained.

Tomato and brinjal. A total of 302 accessions including wild species were multiplied and maintained. Fifteen tomatoes and 8 cherry tomato lines for polyhouse cultivation were also maintained. In brinjal, 80 working germplasm were purified, evaluated and maintained. However, 20 new germplasm lines were grown for seed regeneration and characterization.

Carrot. Forty inbred lines were maintained, seed multiplied and use in hybrid breeding. Two CMS lines were found to be uniform and are being maintained. Six CMS lines which are heterozygous are being purified. Selected roots of 61 accessions from the ICAR-NBPGR were planted, seeds multiplied and submitted for conservation in the National Gene Bank, ICAR-NBPGR, New Delhi.

Onion and garlic. Seventy two onion genotypes originating from Japan and other countries were maintained at IARI Regional Station, Katrain. In garlic, six exotic genotypes were multiplied. Under DUS programme, 49 onion and 12 garlic varieties were maintained. Nineteen new onion germplasm were collected and evaluated.

Garden pea. One hundred germplasm lines were rejuvenated and five new lines were collected and maintained. Total 26 accessions of [*Pisum sativum*(15), *Pisum elatius*(01),*Pisum sativum* var. *elatius*(10)] and 7 garden pea varieties (Kashi Nandini, Kashi Uday, MA 7, Pusa Pragati, Arkel, Pusa Shree and PB 89) were grown for evaluation.

Lettuce. Thirty eight lettuce genotypes were evaluated and maintained. One hundred and sixty five advanced breeding lines were phenotyped based on the leaf colour and other traits and maintained.

Leafy vegetables. Six *palak*, 3 spinach and 5 *Chenopodium* advance breeding lines were maintained.

Broccoli. Fifteen genotypes and five CMS lines along with their maintainer lines were purified and maintained. Multiplied seeds of 12 EC lines were submitted to ICAR-NBPGR after their characterization.

Wild Brassica. Thirteen different *Brassica* accessions collected from Mizoram and nine wild Brassicaceae species, viz., *Alliariapetiolata, Brassica tournefortii, Cardamine hirsute, Capsella bursa-pastoris, Nasturtium officinale, Rorippaislandica, Sisymbrium officinale, S. irio*

and *S. orientale* collected from Kullu Valley are being maintained at IARI regional station, Katrain.

3.1.12 Flower Crops

Rose. Twenty seven *rose* varieties, namely, Abra Ka Dabra, Aristocrat, Beautiful Bhopal, Birendra Nath, Black Delight, Blue for You, Cauvery, Com. Sukumarda, Coffee Country, Delhi White Pearl, Double Hele, Double Delight, Dr NoshirWadia, Hemangini, Hueng Fun, Khudi Ram, Maharani, Orange Flesh, Peter Frankfield, Piroja, Radha Nath, Ranjana, Sentimental, Soma Sila, Supriya, Swaraj, Uzma Alamand Zina were procured from secondary sources to enrich the germplasm.

Gladiolus. Thirty seven Gladiolus varieties including Yellow Star (Yellow), Punjab Morning, Nauvalux (Yellow), Fire Flam, Lady John, ArkaTilak, Arka Ayush (orange), Arka Sapna (white), Arka Nazrana (Red), Kalima (Red), Roshni (Pink striped), Amathyst (Blue), Neelima (Purple), Pink Lady, GS 2 (Yellow), Limon Cello (Red), Ocilla (Yellow), Malviya Kiran (White), and Algarve (Light red), were procured from secondary sources to enrich the germplasm.

Marigold. Two varieties, namely, Bidhan Marigold 1 and Bidhan Marigold 2were procured from secondary sources.

Temperate flowers. Fifty five cultivars of *Lilium*, 5 species of *Lilium*, 22 species/ varieties of iris, 20 varieties of dahlia, 9 varieties of *Alstroemeria*, 100 breeding lines of gladiolus, 25 germplasm of Eustoma, 25 varieties of tulip, 22 varieties of *Narcissus* and other bulbous crops like, torch lily, wattsonia, canna, *Amaryllis*, crinum, *Freesi*a, wild tulip, tithonia, tuberous begonia, cyclamen, zinger lily, *Lycoris*, primula, primrose, temperate orchids and some wild ornamentals are being maintained and used in crop improvement programmes.

Indigenous bulbous flowering plants. At Regional Station, Kalimpong indigenous bulbous flowering plants i.e., Agapanthus-2; Arisaema-8; Crinum-3; Curcuma-3; Costus-1; Eucharis-1; Gloriosa-2; Hedichium-5:Hymenocallis-1; Haemanthus-1; Iris-2 and Kaempferia-1 genotypes have been collected.

3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Diversity, Conservation, Taxonomy and Phylogeny of Fungi and Bacteria

Maintenance and Preservation. About 50,280 fungal specimens at HCIO; 4022 fungal cultures at ITCC were maintained under different preservative methods. Eighty two fungal diseased specimens at HCIO and 40 different fungal cultures at ITCC were added.

Culture Supply. In all 448 authentic fungal cultures were supplied on payment to various scientific and industrial institutions on request.

Identification Services. A total of 225 cultures/ specimens were identified up to species level. Most these request were for plant pathogens, post harvest pathogens, bio-control agents and industrial use fungi belong to Hyphomycetes followed by Coelomycetes and Zygomycetes.

Funds Generated. A total of ₹ 7,79,100/- was generated during the period on account of supply and identification and accession of the fungal and bacterial cultures.

Documentation. Fifteen *Aspergillus* spp., viz., *A. aculeatus*, *A. amstelodami*, *A. clavatus*, *A. fischeri*, *A. flavus*, *A. fumigates*, *A. funiculosus*, *A. japonicas*, *A. neveus*, *A. nidulans*, *A. niger*, *A. ochraceus*, *A. parasiticus*, *A. puniceus*and *A. quadrilineatus* have been digitized.

3.2.2 Insects

Around 2021 insect specimens were examined under identification service sent from different Institutions/Organizations across the Country. Fifty one barcodes of Indian fig wasps were submitted to NCBI database.

Diptera. Faunistic studies on Syrphids of Delhi was undertaken in Delhi northern Ridge area. First record of *Microdon* sp. was made. Besides, survey for *Eumerus* sp. was made in Sunder Nursery, New Delhi.

Revisionary work of the Genus *Eristalinus* (Diptera-Syrphidae) of India

i) Molecular Phylogeny of Indian *Eristalinus*

ii) First record of *Eristalinus tristriatus* from India

iii) Redescription and molecular characterization of *Eristalinus tristriatus*

Hemiptera. A new leafhopper genus *Chandra* and species *Chandra dehradunensis* gen. nov., sp. nov. Meshram was described with molecular phylogeny of related genera and placed in the subtribe Paraboloponina (Cidadellidae: Deltocephalinae: Drabescini). This genus is closely associated with the genus *Parabolopona* Webb but differs in shape of the head, placement of antennae, male genitalia and molecular analysis using Histone H3 and COI genes confirmed the difference. The combined morphological and molecular analysis clearly indicated and confirmed that *Chandra dehradunensis* Meshram gen. nov., sp. nov., is near the distinct genus *Parabolopona.* The synonymic revision of the *Prunus*-Infesting Aphid Genus *Hyalopterus* (Hemiptera: Aphididae). It was determined that *H. mimulus* and *H. persikonus* were junior synonyms of *H. arundiniformis*, syn. nov., and that *Brachysiphum kobachidzei* Rusanova is not a synonym of *H. amygdali* but a valid species of *Aphis*, stat. nov., comb. nov. *Aphis amygdalipersicae* Mosley is likely a senior synonym of *Brachycaudus helichrysi* (Kaltenbach), syn. nov.; to maintain current usage, we establish the former as a *nomenoblitum* with respect to the latter. We conclude that there are three species of *Hyalopterus*, each causing varying degrees of economic damage to stone fruit trees of the genus *Prunus*. These are (i) the mealy plum aphid itself, *H. pruni*, primarily colonizing plum trees; (ii) *H. amygdali*, primarily colonizing almond and apricot trees; (iii) *H. arundiniformis*, primarily colonizing apricot and peach trees.

Lepidoptera. Revision of three genus, viz., *Thysanoplusia, Ctenoplusia,* and *Chrysodeixis* comprising 15 species of subfamily Plusiinae according to morphological and genitalial characters was done. Checklist of Genus *Athetis* from India was prepared, which includes 3 subgenera and 32 species. Four species of *Athetis* spp. were redescribed.

A new species, *Conogethes sahyadriensis* sp. nov. (Lepidoptera: Crambidae), feeding on cardamom, is described from India. The species status is supported by diagnostic morphology as well as by genetic data. A phylogenetic analysis based on the publicly available *Conogethes* COI barcode sequences finds *C. sahyadriensis* as sister to *C. pluto*. The new species is delineated from closely related and superficially similar species of *Conogethes*.

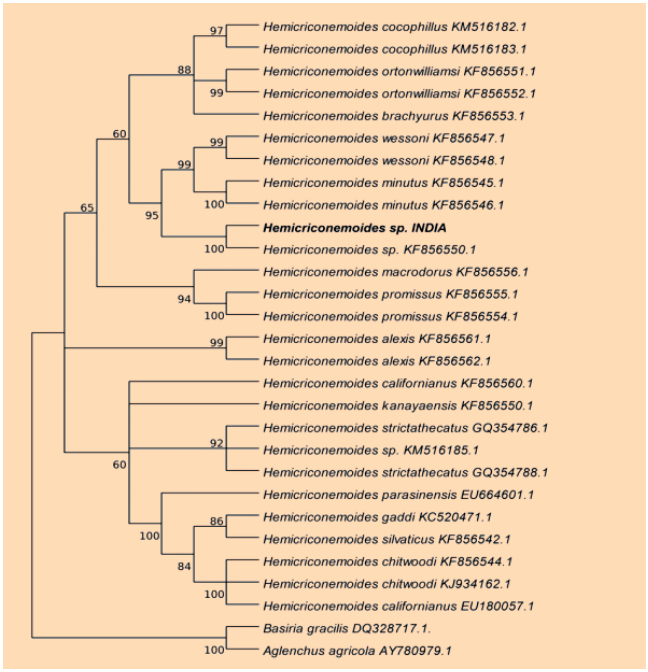
The invasive pest *Tuta absoluta* was monitored in two localities in north India viz., Pusa campus: Delhi and Nuh: Haryana and one in south India Shivamogga: Karnataka. In north India only *Rabi* tomato was monitored using pheromone trap and the average trap catch was negligible. At Shivamogga, Karnataka, infestation level of *T. absoluta* both in *Kharif* and *Rabi* was low during first crop phenologic cycle. Then *T. absoluta* density increased with age of crop under both polyhouse and field conditions. In both *Kharif* and *Rabi* seasons, the incidence of *T. absoluta* showed the positive correlation with the maximum temperature.

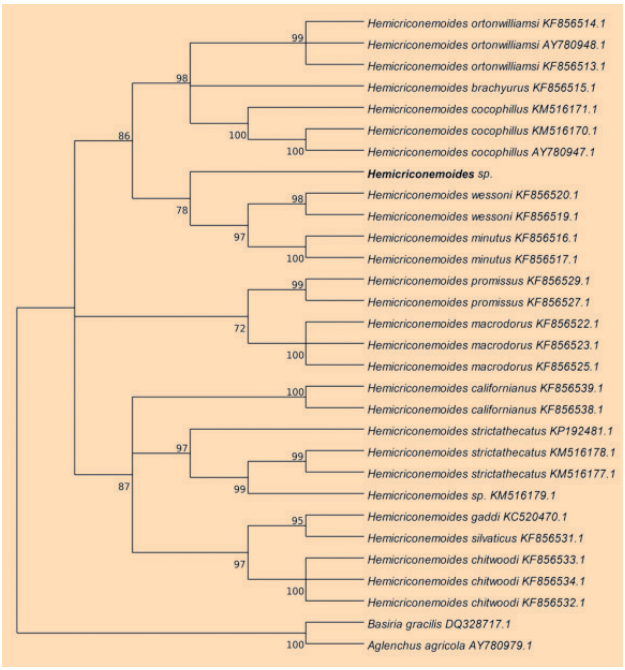
Identification of efficient pollinators for temperate vegetable seed production. Pollination efficiency of two syrphid pollinators,viz. *Eristalis tenax* and *Episyrphus balteatus* was compared with Indian honey bee *Apis cerena indica* for seed production in cauliflower variety PSBK 25. Plots with each syrphid pollinators produced significantly longer pods, which contained significantly higher number of seeds than the plots without any pollinators. Highest pod length as well as seed number per pod were recorded in open-pollinated plots followed by those receiving honey bee pollination. Although the large syrphid pollinator, *Eristalis tenax* was noted to be efficient as honey bee at higher population density (6 flies/m^2), pollination service rendered by the smaller syrphid *Episyrphus balteatus* was found to be insignificant as compared to *Apis cerena indica*. It was established that *Eristalis tenax* could be used successfully as an alternate pollinator in place of *Apis cerena indica* for cauliflower/cabbage seed production under cage conditions.

3.2.3 Nematodes

Molecular identification of 27 specimens was carried out. Some novel isolates were 2 *Xiphinema* spp. isolates, 4 *Heterorhabditoides* spp.(an EPN) and 1 *Rhabditis* spp. (all at various stages of description). Nematodes identified in samples from IARI Regional Station, Wellington (Hort.. Res. Station., Wheat and Potato). Samples (of *Archontophoenix* spp.) from Regional Plant Protections and Quarantine, Chennai analysed for plant nematodes. Identification of root knot nematode species in guava (from Kalyani), garlic, potato and guava (from Gujarat) and *Hemicriconemoides roseae* in sugarcane from Meerut, UP. A *Hemicriconemoides* specimen was identified as a new species on the basis of ITS and D2D3 markers.

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 0.5µm depths and at 40x for large nematodes.





The molecular phylogenetic analysis of genus *Hemicriconemoides* using ITS marker (left panel) and D2-D3 expansion region of the LSU rDNA gene (right panel)

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

Current and upcoming challenges in natural resource management have been addressed by various disciplines with the ultimate aim of enhancing the productivity and quality of crop produce. Crop establishment techniques, irrigation and fertilizer management for various cropping systems were evaluated and improved. In depth research was carried out on various facets of conservation agriculture and integrated farming system for improving soil health and environmental quality as well as profitability of farmers. Enrichment, mineralization, stabilization and saturation of carbon in important soil orders and cropping systems were studied. Feasibility of using waste mica as a source of potassium as well as modified clay, egg shell and green plants for remediation of metal and metalloid polluted soils was assessed. The research has been focused on the development of drip fertigation technology and sensor based irrigation scheduling for maximizing water productivity in both open and protected cultivation. Urea ammonium nitrate applicator, three wheel mini tractor type multipurpose equipment, tractor operated raised bed pulse planter and paddy straw collector cum chopper were designed for rapid and precise farm operations. Innovative technologies/processes were developed to enhance the shelf life and nutritional quality of various agri-horticulture based products. Blue Green Algae based composite liquid inoculants was prepared for sustaining crop productivity and soil health. Biological techniques were designed and developed for biomass degradation in in-situ condition. Carbon, nitrogen and water footprints of rice crop production under different water management practices were estimated.

4.1 AGRONOMY

4.1.1 Crop Establishment Techniques, Irrigation and Fertilizer Management in Soybean-Wheat Cropping System and Potato Crop

In soybean-wheat cropping system, there was 8-12% improvement in seed yield of soybean in conventional-tilled furrow irrigated raised beds (CT- FIRBs) and conventional tilled-flat beds (CT) as compared to zero-tilled flat beds (ZT). Among the irrigation regimes, 25% soil moisture depletion (SMD) plots registered higher seed (6-12%) and biological yield (2-17%) over 50 and 75% SMD. With respect to the performance of genotypes, Pusa 9712 and PS 1347 registered higher seed and biological yields under CT-FIRBs and CT as compared to ZT. While DS 2614, registered higher seed and biological yields under ZT than other crop establishment techniques. All genotypes produced higher seed and biological yields under 25 and 50% SMD and 100% recommended dose of fertilizer (RDF). After harvest of soybean, six wheat genotypes viz., HD 3059, CSW 16, HD 3086, CSH 18, HD 2967 and HD 2687 were evaluated in the same plots. The results revealed that planting of wheat on beds resulted in significantly higher grain yield (4.03 t ha^{-1}) and biological yield (9.4 t ha^{-1}) over CT-flat beds and ZT-flat beds. Among the irrigation schedules, irrigation applied at 25% SMD resulted in the highest grain (4.02 t ha^{-1}) and biological yield (9.97 t ha^{-1}) of wheat over other irrigation regimes. Irrespective of varieties, grain and biological yields were higher with 100% RDF compared to 50% RDF. Among genotypes, HD 2687 recorded the highest grain and biological yields under bed planting, irrigated at 25% SMD and fertilized with 100% RDF followed CSW 18 and CSW 16 over HD-2967, HD 3086 and HD 3059.

In another study, potato yield was significantly higher (38.2 t ha^{-1}) with 50% RDF + 50% N by FYM. Consumptive use of water (45.2 cm), water use efficiency (847 kg ha^{-1} cm), net return (₹ 2,88,060) and B:C ratio (3.50) were also higher under this treatment. Planting on raised bed and irrigation in furrow recorded significantly higher tuber yield (38.4 t ha^{-1}). Consumptive use of water was less in this treatment (39.7 cm) and water use efficiency was higher (967 kg ha^{-1} cm) thereby consuming 16.4% less water. Net

return (₹ 2,86,420) and B:C (3.50) ratio were also higher under the same treatment. Irrigation at 50 mm CPE recorded significantly the highest tuber yield (38.2 t ha^{-1}). Consumptive use of water (45 cm) was least in the treatment where irrigation was applied at 70 mm and water use efficiency (848 kg ha^{-1} cm), net return (₹2,36,440) and B:C ratio (3.4) were higher under the treatment, where irrigation was applied at 50 mm CPE.

4.1.2 Crop Diversification for Higher Productivity, Input Use Efficiency and Livelihood Security

Maximum system productivity was recorded from fodder maize–mustard (PM 26)–onion and fodder maize–mustard (PM 28)–onion cropping systems. Similarly, maximum maize equivalent yield, net returns, B:C ratio and production efficiency were also recorded from these cropping systems. Inclusion of early mustard varieties (PM 26 and PM 28) showed greater promise in terms of the seed productivity at higher levels of Zn. The economics of inclusion of early mustard PM 26 and PM 28 revealed that maximum profitability could be achieved with PM 28.

Four cropping sequences (rice-wheat; rice-vegetable peas-wheat–mungbean; maize-potato-onion and maize-wheat-mungbean), were compared for their productivity and sustainability. The highest system productivity was obtained from maize-potato-onion cropping system fallowed by rice-veg. pea-okra and maize-wheat–mungbean, recording 34.7 and 38.3% higher system productivity, respectively, over traditional rice-wheat cropping system. However, both rice-veg. pea-okra and maize-wheat–mungbean gave at par rice equivalent yields. The highest net returns were obtained from maize-potato-onion cropping system. The highest value (1.94) of B:C ratio was recorded with maize-wheat-mungbean, followed by rice-veg. pea-okra, (1.68), rice-wheat (1.57) and maize-potato-onion (1.36). Global warming potential (GWP) was observed highest in maize-potato-onion system due to higher nitrous oxide emission.

Under limited irrigation, diversified cropping system babycorn-mustard recorded highest pearlmillet equivalent yield (13.6 t ha^{-1}), which was 29.1, 58.6 and 138% higher over cowpea-barley, greengram-chickpea and pearlmillet-lentil, respectively. Further babycorn-mustard cropping system resulted in highest net returns (₹ 106142 ha^{-1}), B:C ratio (2.2), income (₹ 463 ha^{-1} day^{-1}) and water productivity (₹ 149 ha^{-1} mm^{-1}). Cowpea-barley cropping systems was the second best cropping system in respect of enhancing net returns, income and water productivity.

Under peri-urban areas with drip irrigation, babycorn-*palak*, bottlegourd-green onion and bottlegourd-*sarsonsaag* gave significantly higher okra equivalent yield over okra-garden pea cropping system. Among all the cropping systems, babycorn-*palak* recorded highest okra equivalent yield (12.6 t ha^{-1}) followed by bottlegourd-green onion (8.6 t ha^{-1}). The okra equivalent yield from babycorn-*palak* cropping system was 298% higher over okra-garden pea cropping system. Babycorn-*palak* used only 774 mm water, as a result provided highest water productivity (₹ 324 ha^{-1} mm^{-1}). Highest net returns (₹ 251000 ha^{-1}), B:C ratio (3.1) and income (₹ 984 ha^{-1} day^{-1}) were fetched by babycorn-*palak* cropping systems. Bottlegourd-green onion also proved to be better cropping systems by fetching countable net returns (₹ 1,71,500 ha^{-1}), B:C ratio (2.1) and income (₹ 692 ha^{-1} day^{-1}), while okra-garden pea cropping system gave lowest net returns, B:C ratio, income and water productivity.

4.1.3 Influence of Promising Rice Varieties and Nutrient Management Practices on Crop Productivity, Nutrient Acquisition and Resource-Use Efficiency in Eastern Himalayas

Among different nutrient management practices, rice grain (4.18 t ha^{-1}) and straw yield (6.36 t ha^{-1}) were significantly higher in integrated nutrient management practices (INM) followed by inorganic and organic practice and least in control treatment, respectively. The order of grain yield for different nutrient management practices was INM>inorganic>organic>control, respectively. Among rice varieties, Shahsarang 1 had the highest grain (3.86 t ha^{-1}) and straw yield (5.73 t ha^{-1}) followed by Lumpnah and Megha SA-2, respectively.

The INM practice also had the highest production-efficiency (27.6 kg ha^{-1} day^{-1}) followed by inorganic practice, organic practice and control, respectively. However, the inorganic practice exhibited highest monetary-efficiency (₹ 338 ha^{-1} day^{-1}) followed by INM, organic practice and control, respectively. Among rice varieties, production-(25.2 kg ha^{-1} day^{-1}) and monetary–efficiency (₹ 285 ha^{-1} day^{-1}) were highest in Shahsarang 1, followed by Lumpnah and Megha SA-2, respectively.

4.1.4 Foliar Nutrition Improved Soybean Productivity

A field trial conducted at IARI, New Delhi during 2015-2017 revealed that application of 100% RDF along with chelated Zn (0.5% foliar spray at pod initiation (PI) stage) resulted in the highest average number of pods $plant^{-1}$ (45), seed index (11.3) and seed yield of soybean (2.05 t ha^{-1}). On an average, chelated Zn (0.5%), boron (0.5%), 19:19:19 NPK (2%) and urea (2%) sprayed over and above RDF, recorded 29, 19.6, 16.6 and 17.2%, higher seed yield, respectively over RDF. Net returns from the crop sprayed with Zn chelated (0.5%), 19:19:19 NPK (2%), urea (2%) and DAP (2%) in addition to RDF, were significantly greater than the crop receiving only RDF. Highest B:C ratio (1.2) was recorded with the use of chelated Zn (0.5%) and urea (2%) spray.

4.1.5 Effect of Variable N Rates on Bt-Cotton Productivity and Profitability

The highest seed cotton yield (2.65 t ha^{-1}) was recorded with 175 kg N ha^{-1}, which was 25.6, 14.7 and 3.5% higher than that of the yields obtained with 100, 125 and 150 kg N ha^{-1}, with the cropping increase in lint yield as 30.9, 17.7 and 4.4 %. An increase of 5.1% in seed cotton yield was observed in the treatment, where 30 kg N ha^{-1} was applied as basal dose over the treatment where basal amount of nitrogen was not applied. Net returns and B:C ratio were highest with application of 175 kg N ha^{-1}.

4.1.6 Screening of Rice Genotypes for Higher Nitrogen-Use Efficiency

Rice genotypes under low and recommended N supply were screened for higher nitrogen-use efficiency under field conditions. Results indicated that the highest grain yield was recorded at 100% N rate, which was significantly higher than 50% N rate and control. Among varieties, Nidhi produced significantly the highest grain yield of rice. The next best varieties, w.r.t. grain yield, were CR Dhan 310 and Nagina 22, both producing significantly higher grain yields over BPT 5204, MTU 1010, Rasi, Pusa 44, Panvel, CR Dhan 311 and Taipe 309. The computation of nitrogen-use efficiency indices, viz., agronomic efficiency (AE), recovery efficiency (RE) and partial factor productivity (PFP) shows that Nidhi had the highest values of AE, RE and PF. The higher values of grain yield efficiency index suggested that Nidhi, CR Dhan 310 and Nagina 22 are N-efficient varieties.

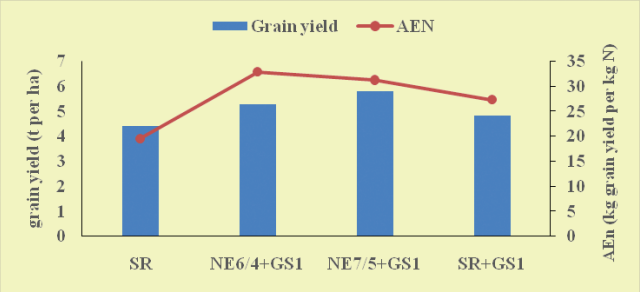
4.1.7 Silicon and Phosphorus Application Reduced Lodging and Improved Productivity of Wheat Grown After Aerobic Rice

A field experiment was conducted to evaluate the efficacy of silicon (Si) and phosphorus (P) in enhancing productivity and controlling lodging in wheat under aerobic rice-wheat cropping system. Significantly higher grain yield (6.15 t ha^{-1}) and straw yield (7.82 t ha^{-1}) were obtained with application of 80 kg Si ha^{-1}. Similarly, application of P at 60 kg ha^{-1} resulted in the higher yield attributes and grain yield. No lodging was observed when Si and P were applied at 80 and 60 kg ha^{-1}, respectively. Highest lodging score (9.8) was recorded with no application of Si and P. Application of 80 kg Si and 60 kg P_2O_5 ha^{-1} was found to be the best combination for reducing lodging in wheat crop and enhancing its productivity.

4.1.8 Precision Nitrogen Management Strategies in Wheat under Maize-Wheat System

Effect of integrated use of decision support tool (Nutrient Expert®, NE) and GreenSeeker (GS) was studied on nitrogen use efficiency (NUE) in wheat. Nitrogen application using GS along with NE based basal and first top dressing for 4 t ha^{-1} targeted wheat yield had maximum grain yield and NUE (32.9 kg grain kg^{-1} N), which was distinctly higher over existing state

recommendation (SR) i.e. 120 kg N application in three equal split (19.6 kg grain kg^{-1} N). Green Seeker based N application at 42 DAS along with SR also had higher yield and NUE (27.4 kg grain kg^{-1} N) compared with SR. The higher NUE was accrued due to smaller N use under GS as well as with NE based recommendation. Overall maximum system productivity (12.7 t ha^{-1}) and additional economic gain (₹ 33,585 ha^{-1}) under maize-wheat system was accrued under 7 and 5 t ha^{-1} targeted maize and wheat yield, respectively, coupled with NE and GS based fertilizer application.



Effect of nutrient management options on grain yield of wheat and agronomic efficiency

4.1.9 Effect of Nutrient Omission, Planting Techniques and Weed Management Practices on Performance of Maize (*Zea mays* L.)-Wheat (*Triticum aestivum* L.) Cropping System in North Eastern Plains Zone

Field experiment was conducted at Pusa, Samastipur, Bihar for three consecutive years on nutrient omissions studies in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system in North Eastern Plains Zone (NEPZ). Treatments comprised omission of N, P, K, Zn, B and omission of 50% NPKZnB. Results of three year experiment showed that the entire yield attributes and yield were significantly lower in control and N omission plots. It was observed that N is the most limiting nutrient. The reduction in grain yields due to K omission was higher than P omission plots. Continuous omission of P and K to both the crops might be resulted in decline in P and K status in soil, which resulted in reduced nutrient uptake, yield attributes and yield. The reduction in yields due to B and Zn omission was marginal and statistically non-significant with optimum nutrition treatments. Planting techniques and weed management practices were also evaluated. Raised bed planting and ridge planting were equally effective in respect to weed density. The application of tank mix (atrazine @ 0.5 kg/ha + pendimethalin 0.5 kg/ha) as pre-emergence followed by one hand weeding proved to be effective for weed control irrespective of planting methods.

4.1.10 Effect of Zn and S Application on the Productivity of Wheat

In a field experiment, eighteen treatment combinations comprised with two wheat varieties (HI 1544 and HI 8737), three levels of zinc (0, 5 and 10 kg ha^{-1}) and three levels of sulphur (0, 7.5 and 15 kg ha^{-1}) were evaluated. Results revealed that durum wheat variety HI 8737 gave significantly higher grain and biological yields (5.91 and 14.5 t ha^{-1}) than HI 1544 (5.50 and 14.2 t ha^{-1}). Whereas, highest dose of applied Zn at 10 kg ha^{-1} recorded maximum grain and biological yields (5.33 and 14.8 t ha^{-1}), which being at par with 5 kg Zn ha^{-1}. In case of S application, the application of S @ 15 kg ha^{-1}) recorded maximum grain and biological yields (5.83 and 14.8 t ha^{-1}) of wheat, which was at par with 7.5 kg S ha^{-1} (5.81 and 14.6 t ha^{-1}). Based on response equations, application of Zn @ 6.0 to 8.36 kg ha^{-1} and S @ 11.3 to 13.5 kg ha^{-1} was recommended for maximizing the yield of wheat in Central India.

4.1.11 Effect of Urea Coating with Zinc and Sulphur on Seed Yield in *Basmati* Cultivars

Field experiment was conducted at Regional Station, Karnal to study the effect of coated urea with zinc and sulphur as compared to prilled urea in *basmati* cultivars. Significant differences in the yield attributes, viz., number of panicles $plant^{-1}$, panicle length and 1000- seed weight were recorded in *basmati* cultivars. Pusa Basmati 1 recorded significantly higher yield than PB 1121 and remained at par with PB 6. Number of panicles/m^2, panicle length were significantly higher in 100 kg N through prilled urea, 100 and 75 kg N through zinc coated urea and 75 kg N through prilled urea + 5 kg zinc compared to absolute control and zinc 5 kg ha^{-1}. Seed yield in zinc coated urea 75 kg N ha^{-1} (5.58 t ha^{-1}) remained at par with 100 kg N through prilled urea

(5.47 t ha^{-1}) and 100 kg N zinc coated urea (5.64 t ha^{-1}) and registered an increase of 20.5 and 10.4% increase over absolute control (4.63 t ha^{-1}) and zinc 5 kg ha^{-1} (5.05 t ha^{-1}), respectively.

4.1.12 Nutrient Management in Pigeon Pea –Wheat Cropping System under CA

For management of nutrient and moisture in pigeon pea–wheat cropping system, four moisture management protocols, viz., control, wheat residue in pigeon pea @ 4 t ha^{-1} + Hydrogel @ 2.5 kg ha^{-1}, pigeon pea residue in wheat @ 4 t ha^{-1} + Hydrogel @ 2.5 kg ha^{-1} and pigeon pea and wheat residue in succeeding crop + Pusa hydrogel @ 2.5 kg ha^{-1} were evaluated with four nutrient management practices in split-plot design. Pigeon pea and wheat residue in succeeding crop + Pusa hydrogel @ 2.5 kg ha^{-1} resulted in the highest system productivity, while pigeon pea residue in wheat @ 4 t ha^{-1} + Hydrogel @ 2.5 kg ha^{-1} was found the second best moisture management protocol in pigeon pea-wheat cropping system. Among the nutrient management practices, 100% RDF + 5 kg Zn+ Zn solubilizer (*Bacillus endophyticus*) resulted in highest pigeon pea yield (3.91 t ha^{-1}), pigeon pea equivalent wheat yield (6.21 t ha^{-1}), consumptive use of water and water use efficiency followed 100% RDF + Zn solubilizer (*Bacillus endophyticus*) under limited irrigation condition.

4.1.13 Sustainable Intensification of Pearlmillet–Mustard Cropping Systems for Improving Productivity and Resource Use Efficiency in Semi-Arid Ecologies under CA

A study was conducted to work out the options for sustainable intensification of pearlmillet–mustard cropping system for limited irrigation conditions under CA. Three tillage practices, viz., conventional tillage, zero tillage and zero tillage with residue retention was compared for three cropping systems, viz., pearlmillet–mustard, pearlmillet–mustard–mungbean, pearlmillet–mustard–clusterbean. Zero tillage with residue retention resulted in a maximum system productivity (9.78 t ha^{-1}) and system net returns (₹ 94,872 ha^{-1}) followed by conventional tillage. The lowest pearlmillet equivalent system yield was recorded under zero till system (7.38 t ha^{-1}). Among different cropping systems, the lowest system productivity was obtained with pearlmillet–mustard, whereas the highest system productivity was recorded with pearlmillet–mustard–clusterbean (9.42 t ha^{-1}). System water productivity (12.9 kg ha^{-1} mm^{-1}), productivity efficiency (32.7 kg ha^{-1} day^{-1}), monetary efficiency (₹ 373 ha^{-1} day^{-1}) was recorded maximum under pearlmillet–mustard–clusterbean cropping system. Zero tillage with residue resulted in higher system water productivity (14.5 kg ha^{-1} mm^{-1}), nutrient use efficiency, productivity efficiency (32.4 kg ha^{-1} day^{-1}) and monetary efficiency (₹ 389 ha^{-1} day^{-1}) as compared to crop establishment practices.

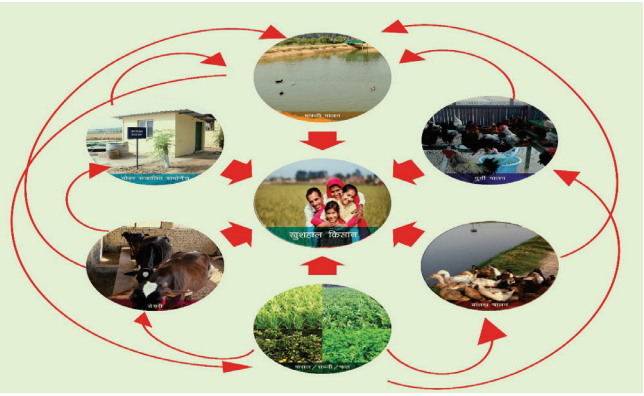
4.1.14 Assessment of Long-Term Impact of Conservation Agriculture on Productivity and Sustainability of Rice-Wheat Cropping System

The long-term effect (1984-2015) of residue retention on crop and water productivity, economic sustainability and carbon footprints was evaluated using APSIM model. The system productivity (SP) was highest under higher residue (HR-9.48 t ha^{-1}), followed by higher-medium residue (HMR-9.07 t ha^{-1}) of conservation agriculture (CA) as compared to conventional tillage (CT-8.96 t ha^{-1}). During experimentation specifically in 1986, 1987, 1989, 2002 and 2009, the productivity under all the CA systems was comparatively higher over CT due to poor monsoon. Coefficient of variation (CV) of wheat and rice yields under CA was recorded as low as 6.3 and 6.4%, respectively, as compared to 14.7% in wheat and 29.2% in rice under CT. Sustainable yield index (SYI) and sustainable value index (SVI) of SP under RWCS were significantly higher under HMR (0.88 and 0.85, respectively) followed by HR scenario. Polynomial optima indicated that retention of residue @ 7.6 t ha^{-1} year^{-1} was optimum in CA. Soil organic carbon (SOC) control was predicted to increase by 27 to 88% in CA-based RWCS with a carbon sequestration rate of 0.1 to 0.37 t ha^{-1} year^{-1}. System water productivity (SWP) was higher under HR (3.65 kg ha^{-1} mm^{-1}), which was ~ 9% higher than CT. Adoption of CA is a novel climate smart agricultural technique that could

reduce greenhouse gas (GHG) emissions and increase C-sequestration, SWP, crop yields and profits under long-term rice-wheat cropping system.

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

Integrated farming system in 1.0 ha area involving crops, dairy, fishery, duckery, biogas plant, fruit trees and agro-forestry resulted in net returns of ₹ 3,78,784 ha^{-1} $year^{-1}$ with an employment generation of 628 man-days round the year. The gross returns, net returns and employment generation of crops (₹ 1,65,354, ₹ 93,198 and 150 man days), dairy (₹ 4,92,120, ₹ 1,61,638 and 365 man days), fishery (₹ 91,080, ₹ 37,288 and 26 man days), duckery (₹ 61,090, ₹ 30,411 and 26 man days), poultry (₹ 53,050, ₹ 24,272 and 26 man days), fruit trees (₹ 19,900, ₹ 11,242 and 15 man days), agro-forestry (₹ 4560, ₹ 3229 and 3 man days) and fence crops (₹ 10,000, ₹ 8,000 and 5 man days), respectively, was recorded. Resource use efficiency was enhanced in these systems through resource recycling and by-product utilization among different enterprises. It reduced the production cost and maximized the system profitability and sustainability.



Components of IFS in north Indian ecologies

4.1.16 Biomass Utilization Unit

Biomass Utilization Unit produced about 6000 tonnes of good quality composts during 2017-18. The Unit has distributed approximately 2000 tonnes of FYM and residue mixed compost, 400 tonnes of leaf compost to the different divisions and units of IARI. About 3500 tonnes of compost is ready for distribution at the end of current year. A net revenue of ₹ 5,15,325/- was generated during the year by selling different types of composts. The value of material prepared in the Unit has been estimated to be of more than ₹ 2.0 crores worth during 2017-18. The Unit has provided training on different aspects of composting to the farmers, students, teachers, small scale entrepreneurs, NGOs and officials from state governments. During the reporting year, about 600 people have been benefitted by the exposure visits, demonstrations, training and lectures conducted by the Biomass Utilization Unit.

4.2 SOIL MANAGEMENT

4.2.1 Stabilization of Soil Organic Carbon in Relation to Pedogenic Processes under Different Cropping Systems in the Brahmaputra Valley of Assam

Soil carbon pools were studied in relation to pedogenic processes under different cropping systems in the Brahmaputra Valley of Assam. Soil with bamboo plantations in the upper Brahmaputra valley had *cambic* horizon and was classified as *coarse loamy, mixed, hyperthermic family of Typic Dystrudepts*. Under sugarcane and tea plantation, *argillic* horizon with low base saturation was observed and the soils were classified as *mixed, hyperthermic family of Typic Hapludults.* In the rice cultivated soil profile, *gleyed* sub-surface horizon was identified and the soil was classified as *loamy, mixed, hyperthermic, Typic Endoaquepts.* In the middle valley of the Brahmaputra plains, three soil profiles with different land uses showed similar morphological characteristics with *gleyed* sub-surface horizon and aquic soil moisture regime and were classified as *fine-loamy, mixed, hyperthermic Humic Endoaquepts*. Higher positive correlation of stabilized and labile C pools with clay, Fe and Al indicated that ferrolysis pedogenic process in the soils of Brahmaputra plains favoured sequestration of organic C. Carbon sequestration is accentuated by specific cropping systems described above involving pedogenic factors. It can be inferred that there is enough scope for carbon sequestration under sugarcane and rice-mustard cropping sequence to the tune of about 123 and 88 Mg ha^{-1}, respectively.

4.2.2 Carbon Utilization Efficiency and Stability of Clay Humus Complexes in Four Major Soil Groups of India

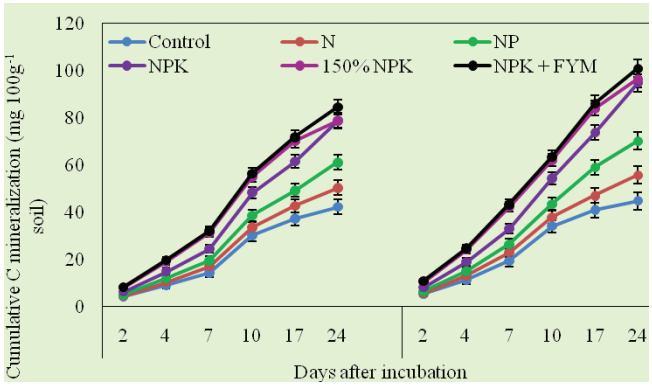
Long-term effect of manuring and fertilization on total soil C (TSC), soil organic C (SOC), soil inorganic C (SIC), various factions of SOC, namely, C mineralization (C_{min}), microbial biomass C (MBC), particulate organic matter C (POM-C), dissolved organic C (DOC), potassium permanganate oxidisable C ($KMnO_4$-C) was studied in four major soil groups of India. Results indicated that carbon utilization efficiency (CUE) was higher in 100%NPK, 50%NPK+50%N-FYM and 50%NPK+50%N-Starw in Inceptisol and Alfisol, while in Mollisol and Vertisol, CUE was the highest in 50%NPK+50%N-FYM. The priming effect (PE) was the lowest in 50%NPK+50%N-FYM in Inceptisol (50%), Mollisol (27%) and Alfisol (41%), while it was the lowest in 50%NPK+50%N-Straw in Vertsol. Among the nutrient management options, 50%NPK+50%N–FYM/50%NPK+50%N–GM emerged as the best management practices for enhancing SOC. Among the soil orders, preservation of SOC (lower priming effect (PE) and higher CUE) was highest in Mollisol followed by Vertisol, Alfisol and Inceptisol and this trend could perfectly be explained by higher CUE and lower PE in these soil orders in the same sequence.

Stability of clay-humus were significantly higher in the soils receiving organic manures [NPK+FYM, NPK+Straw and NPK+ green manure (GM)] than the minerally fertilized (NPK) ones. In rice-wheat cropping system, application of NPK+FYM and NPK+GM showed higher stability than straw. Whereas in maize - wheat system of Ranchi, application of NPK+GM and NPK+straw showed higher stability than NPK+FYM. Among the soil orders, soil of Jabalpur (Vertisol) showed the highest stability followed by Pantnagar (Mollisol), Ranchi (Alfisol) and Ludhiana (Inceptisol).

4.2.3 Assessing Mineralization, Stabilization and Saturation of Soil Organic Carbon under Long-Term Fertilization and Manuring

Maximum C carrying capacity (*Cm*), C saturation deficit (*Sd*), stability of C and microbial C utilization efficiency were studied under long-term fertilizer experiments located at Bhubaneswar (Odisha, since the year 2002), Pattambi (Kerala, since the year 1996), Junagadh (Gujarat since the year 1996) and Parbhani (Maharashtra since the year 1996). Results indicated that *Cm* was higher in Alfisol of Pattambi (78.47 Mg ha^{-1}) than in Alfisol of Bhubaneswar (56.55 Mg ha^{-1}), while among Vertisols, the Vertisol of Parbhani (138.25 Mg ha^{-1}) had higher *Cm* than the Vertisol of Junagadh (97.81 Mg ha^{-1}). The saturation deficit (*Sd*) in Alfisols of Bhubaneswar and Pattambi was observed to be the highest in 50% NPK (0.41 and 0.36, respectively) and the least in 100% NPK + FYM (0.15 and 0.05, respectively), whereas in Vertisols of Junagadh and Parbhani, the *Sd* was observed to be the highest in control (0.43 and 0.86, respectively) and least in 100% NPK + FYM (0.21 and 0.63, respectively) indicating more potential for C sequestration in these soils. The activation energy (Ae) of aggregate associated C was in the order: Alfisol (Pattambi) > Alfisol (Bhubaneswar) and Vertisol (Parbhani)> Vertisol (Junagadh). The activation energy (Ae) of SOC in micro-aggregates was higher compared to that in macro-aggregates, indicating higher thermal stability of the former than the latter. Overall, Vertisol has higher carbon sequestration potential than Alfisol. The balanced fertilization with NPK or NPK with FYM could be recommended for enhanced stabilization of SOC for long-term C sequestration in Alfisols and Vertisols of India.

After 44 years of cropping, effects of continuous application of fertilizers and manures on cumulative

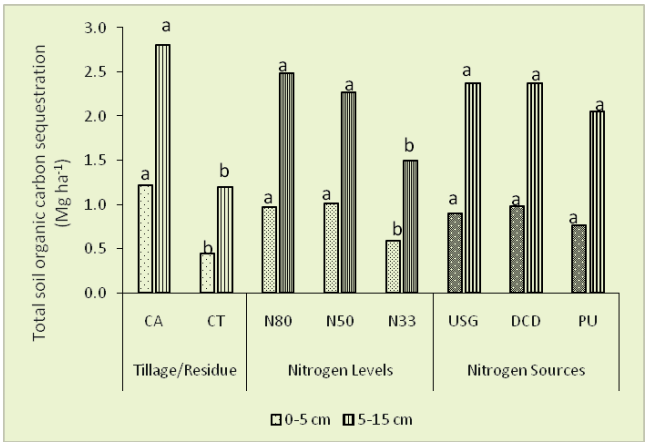


Cumulative C mineralization from bulk soils (0-15 cm) as affected by 44 years of fertilization under a wheat based cropping system in an Inceptisol at two thermal regimes

SOC mineralization (Ct) of bulk soils were studied in an incubation study in surface soil (0-15 cm) at two thermal regimes (25 and 35°C). At 25 °C, Ct values of N, NP and unfertilized control were significantly less than NPK, 150% NPK, NPK + FYM. The maximum values of Ct were registered under NPK + FYM plots across the incubation study periods. At 35°C, more or less similar trend was observed. Increases in C mineralization rates in the plots under NPK, 150% NPK and NPK + FYM were significantly higher at 35°C than those at 25°C.

4.2.4 Soil Aggregation, Organic Carbon Accumulation and Biological Parameters under Conservation Agriculture

Under maize-wheat-mungbean cropping system at Karnal, impact of tillage practices and nutrient management options under CA was assessed on soil aggregates, aggregate associated C and SOC pools in a clay loam soil of north-west Indo-Gangetic plains. The results revealed that the macro-aggregate as well as micro-aggregate associated C was highest (1.10 and 0.58%, respectively) under permanent bed with retention of maize, wheat and mungbean residue (PB+RR+MB) for both 0-5 and 5-15 cm soil depths. The aggregation stability indices i.e. mean weight diameter (MWD) and geometric mean diameter (GMD) were 27.3 and 5.45% higher ,respectively, under PB+RR+MB compared to conventional tillage with residue removal (CT-RR) in surface soil. Overall, the highest aggregate formation and SOC content were recorded in PB+RR+MB compared to other tillage practices. Under maize-wheat cropping system, distribution of soil organic carbon (SOC) was also studied under different levels of N application (80, 50, 33% as basal) through different sources as urea super granules (USG), slow release N fertilizer (IFDC) and prilled urea (UBP) under conservation (CA) *vis-à-vis* conventional (CT) agriculture at Delhi. Total SOC concentration was significantly higher under CA compared to CT. On an average, plots under N80 and N50 as basal registered significantly higher total SOC in both the soil depths as compared to N33.



Total organic carbon sequestered due to different tillage, residue, levels and sources of N fertilizers

Conventional transplanted rice-mustard system was compared with direct seeded rice -mustard from C enrichment point of view involving CA practices for 7 consecutive years. Treatments consisted of zero tillage direct seeded rice (ZTDSR)-zero tillage mustard (ZTM), zero tillage direct seeded rice (ZTDSR) + brown manuring (BM) - zero tillage mustard (ZTM), mustard residues (MR)+ZTDSR – rice residues (RR)+ZTM, MR+ZTDSR+BM+RR-ZTM, mungbean residues (MBR)+ZTDSR-ZTM-zero tillage summer mungbean (ZTSMB),MBR+ZTDSR-RR+ZTM-MR+ZTSMB, transplanted rice (TPR)-ZTM and TPR- conventional tillage mustard (CTM). Results indicated that CA practices had significant impact on soil aggregation as well as on aggregate associated SOC stock. The effect of CA on total SOC stock were more pronounced in macro aggregates than micro aggregate, indicating a greater sensitivity of macro aggregates to CA practices. Zero-till direct seeded rice based system was more effective from soil carbon enrichment point of view as compared to that of conventional transplanted rice. Biological soil quality index was varied from 0.24 to 0.98 with the highest being noted under summer season with MBR+ZTDSR-ZTM+RR-ZTSMB treatment and lowest under winter season with TPR-CTM treatment in rice-mustard cropping system. In another experiment, effect of CA practices on soil microbial diversity and function was also assessed under maize-wheat cropping system. Results revealed that plots with CA based ZT+R, PBB+R and PNB+R had higher dehydrogenase, fluorescein diacetate and β-glucosidase activity in the topsoil (0-5 cm) than conventional tillage (CT).

4.2.5 Management of Aluminium Toxicity in Acidic Soil

Impact of manuring and fertilization on Al dynamics and microbial functions in acidic soil under rice was studied in an on-going long-term integrated nutrient management (INM) experiment at Assam Agricultural University (AAU), Assam. Results indicated that exchangeable Al and strongly organically bound and interlayer Al were significantly lower, while other three fractions i.e., weakly organically bound Al, amorphous Al and free Al were significantly higher under 25% RD of NP + 100% RD of K + enriched compost @ 2 t ha^{-1} treated plot over 50% RD of NP + 100% RD of K + biofertilizers, 100% RD of NPK and control. Grain yield of rice was enhanced due to use of enriched compost probably through reduction in aluminium content in rice straw. It can be concluded that integrated use of enriched compost and biofertilizer with reduced doses of inorganic fertilizers could be followed to improve the yield of rice and reduce the toxicity of aluminium in acidic soil.

Effect of manuring and fertilization on grain yield and Al content in rice

Treatments	Grain yield (t ha^{-1})	Straw Al (mg kg^{-1})	Microbial Biomass Carbon (µg C g^{-1} soil)
Control	2.48^{c}	61.9^{a}	380^{c}
100% RDF of NPK	4.43^{a}	52.6^{b}	444^{b}
50% RDF of NP + 100% K + Biofertilizers	4.00^{b}	46.1^{c}	462^{ab}
50% RDF of NP + 100% K + Enriched compost @ 1 t ha^{-1}	4.30^{ab}	41.2^{cd}	485^{ab}
25% RDF of NP + 100% K + Enriched compost @ 2 t ha^{-1}	4.38^{ab}	38.5^{d}	506^{a}
LSD (*p=0.05*)	0.41	5.84	58.8

Values followed by common letters are not significantly different at $P \leq 0.05$

4.2.6 Enhancing Efficacy of Phytoextraction of Zinc, Cadmium and Lead in Contaminated Soil

An attempt has been made to study the effect of selected organic and inorganic amendments on solubility of zinc (Zn), cadmium (Cd) and lead (Pb) in contaminated soil and their subsequent transfer to plants using Indian mustard (*Brassica juncea* cv. Pusa Vijay) as test crop. Results indicated a significant redistribution of metal from non-labile to labile pool in soil as a result of application of different amendments. Substantial increase in free ion activity of Zn, Cd and Pb was recorded in amended soil. Cadmium uptake by shoot of mustard was enhanced to the extent of 125, 62.5, 175, 175 and 212% in green manure, EDTA, S+S oxidizing bacteria, metal solubilizing bacteria and green manure + metal solubilizing bacteria treated soil, respectively, over control. Conjoint application of green manure and metal solubilizing bacteria proved to be the most efficient in enhancing the Zn, Cd and Pb uptake by mustard, which could be an effective option for enhancing solubility of metals in soil *vis-a-vis* their phytoextraction from practical point of view. An effective option of disposal of metal contaminated plant material after phytoextraction is yet to be evolved.

4.2.7 Immobilization of Pollutant Elements in Contaminated Soils Using Modified Clays, Clay Polymer Composites and Egg Shell

Arsenic immobilization potential of modified clays was evaluated. Modified clay products were Fe-exchanged, Ti-pillared smectite, phosphate-bound kaolinite, citric acid activated, surfactant-modified smectite and chitosan grafted clay polymer composites. Results indicated that modification of smectites and kaolinites resulted in changes of interlayer space, incorporation of functional groups led to enhanced arsenic sorption by increasing surface area. Among the modified clays, Fe-exchanged smectite and phosphate-bound kaolinite were found most effective. Modified clays amended soils showed a significant reduction in As uptake by rice and spinach suggesting that As was efficiently immobilized in soils. Hazard quotient

of rice grains and leafy parts of spinach was reduced significantly but was above the significant risk to human health except Fe-exchanged amended soil.

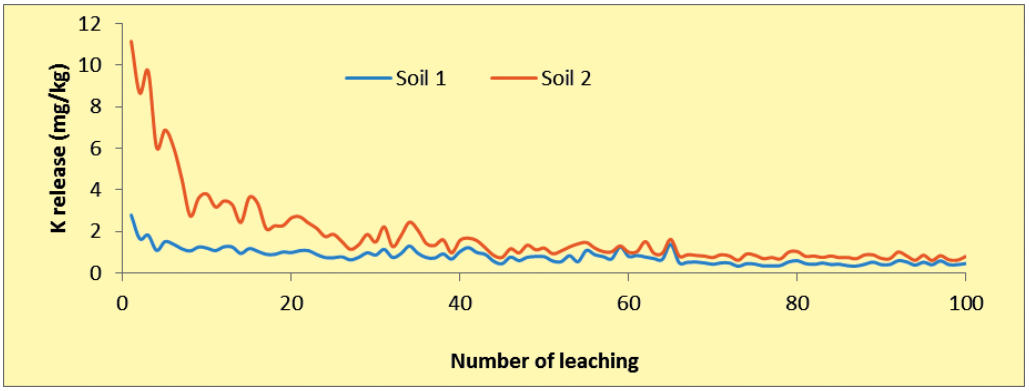
Effect of egg shells and limestone as lime-based waste materials on immobilization of Zn, Cu, Ni, Cd and Pb in contaminated soils was evaluated. For this purpose, soil samples were collected from the agricultural lands receiving industrial effluents and solid wasted and had evaluated levels of trace toxic metals. Egg shells and limestone were applied @ 0.25, 0.5, 1 and 5% w/w and incubated for seven months. The toxicity characteristic leaching procedure (TCLP) test was employed to assess the mobility of Zn, Cu, Ni, Cd and Pb in soils. The results showed that the addition of egg shells and limestone effectively reduced the metal mobility as indicated by the decrease in the concentration of TCLP-extractable Zn, Cu, Ni, Cd and Pb due to significant increase in soil pH in case of both the amendments.

4.2.8 Use of N-Loaded NCPCs and Polymer Coated Area for Enhancing Use Efficiency of Applied N

A field experiments was conducted to evaluate the efficacy of N-loaded NCPCs and polymer coated urea as source of N under maize-wheat cropping system. Treatment combinations consisted of 100, 75 and 75% of recommended N applied through urea, NCPC and coated urea, respectively. Results indicated that application of 75% N through NCPC and coated urea as well as 100% N through urea were equally effective as far as grain yields of maize and wheat. In continuation with the last year report, a greenhouse experiment was repeated to assess the response of rice to N application through NCPCs. Treatment combinations consisted of control, 100% N applied through Urea, 50% N applied through NCPC and 100% N applied through NCPC. Results indicated that application of 50% N through NCPC treatment was statistically at par with 100% N application through urea signifying that half of recommended dose of N applied through NCPC is equally effective in maintaining available N in soil, which was also reflected in yield of rice. Hence, both the studies show that N-loaded NCPC and coated urea have potential of enhancing use efficiency of applied N leading to curtailing the dose of costly nitrogenous fertilizers.

4.2.9 Assessing K Supplying Capacity of Soil

Indian farmers hardly apply adequate amount of K even under intensive cropping and leading to its mining from non-exchangeable pool in soil. Long-term mining of K in soil may cause irreversible changes in K-bearing minerals adversely affecting the K supplying capacity of soil. Hence, a laboratory experiment was conducted to assess the K supplying capacity of alluvial soil. Results indicated that there was differential release of K from soil in accordance with their K-status up to 40th leaching. After that release of K from both the soils were similar and conformed to asymptotic decline pattern, which possibly represents the K supplying behavior in most of the Indian soils under intensive cropping. In these soils, more than 30% of total K released can be attributed to structural K and portion of non-exchangeable K. It can be inferred from such results that substantial amount of structural



Release pattern of K from alluvial soils with contrasting K status

and non exchangeable K might have depleted in most of the Indian soils not receiving adequate K fertilizer particularly under intensive cropping. Study is in progress for assessing distortion in clay minerals in alluvial soil under continued K depletion.

4.2.10 Utilization of Waste Mica as a Source of Potassium

An attempt was made to enhance the solubility of waste mica (K-bearing mineral) using potassium solubilizing microorganisms and organic acids. Results emanated from incubation experiment showed the positive impact of organic acids in solubilization of waste mica, where the effect of oxalic acid was found to be better than citric acid. Between the two bacterial cultures, *Bacillus* sp. showed higher K release than *Pseudomonas* sp. Positive response of mustard in terms of dry matter yield and K uptake to treated mica was recorded in both Alfisol and Inceptisol. Use of waste mica along with organic acid and microbial culture is beneficial in terms of maintaining K supply in soil for crop production. Waste mica may be used as an alternative source of K, though it cannot completely replace K-fertilizer yet it can definitely be used to reduce the use of costly K-fertilizer like MOP.

4.2.11 Soil Test Crop Response Based Integrated Plant Nutrition System for the Targeted Yield of Winter Maize (*Zea mays*)

Soil test crop response correlation studies were carried out following Ramamoorthy's 'indictive-cum-targeted yield' model on an Inceptisol of semi-arid tropics for the development of integrated fertilizer prescription of N, P and K for targeted yield of maize (variety Blund). The basic parameters, viz., nutrient requirement (NR) and contributions of nutrients from soil (C_S), fertilizer (C_F), and farm yard manure (C_{FYM}) were computed using soil test and plant analysis data, maize grain yield, total N, P and K uptake and were used for the formulation of fertilizer prescription equations. The mean nutrient requirement for the production of 100 kg of maize grain was 2.39, 0.53 and 12.23 kg of N, P and K, respectively. The per cent contribution of N, P and K from soil, fertilizer and farm yard manure (FYM) were 36.36, 38.59 and 11.72 for nitrogen 66.58, 30.64 and 7.98 for phosphorus and 32.92, 88.46 and 6.27 for potassium, respectively. These parameters were used to formulate the soil test based fertilizer prescription equations involving IPNS for 5 t/ha targeted yield of maize.

Soil test based fertilizer prescription equations for targeted yield of maize

Fertilization programme	Fertilizer prescription equation
NPS alone	FN = 6.19T – 0.94 SN
	FP = 1.74T – 2.17 SP
	FK = 2.52T – 0.37 SK
NPS + FYM	FN = 6.19T – 0.94 SN - 0.30 FYM
	FP = 1.74T – 2.17 SP - 0.26FYM
	FK = 2.52T – 0.37 SK - 0.07 FYM

Note: FN, FP and FK – fertilizer N, P and K in kg/ha, respectively; T- target yield in q/ha; SN, SP and SK– alkaline $KMnO_4$ – N, Olsen's-P and neutral normal ammonium acetate K in kg/ha, respectively; FYM represents dose of farmyard manure (t ha^{-1})

4.3 WATER MANAGEMENT

4.3.1 Irrigation Water Management Using Fresh Water

4.3.1.1 Development of methodology for site and size of rain water harvesting structures

Analytical hierarchal procedure (AHP) and multi criteria analysis (MA) concepts were used for deciding the size and targeting the location of Rain Water Harvesting Structures (RWHS). The concept was validated in *Pitamberpur* watershed (PW), Jyotiba Phule Nagar, Uttar Pradesh. Watershed morphological parameters, rainfall, estimated runoff and sociological factors were considered to decide accurate locations for construction of different types of RWHS in *Pitamberpur* watershed besides four sub-watersheds (SWS) separately. Different type of the RWHS proposed for installation in the PW comprised 88 rock filled

check dams (RFCD), 39 earthen embankment type percolation ponds (EEPP), 10 small concrete masonry dams (SCMD), 10 medium sized concrete masonry dams (MCMD) and 2 moderate sized concrete masonry dams (MOCMD), respectively. The targeted locations of these structures have been identified on the watershed map.

4.3.1.2 Nitrogen distribution under different surface fertigation strategies in wheat

Field experiments on surface fertigation in wheat showed adequate nitrogen availability in active root zone (15-30 cm) both in conventional as well as raised bed planting methods. Nitrogen uptake by plant was the highest with surface fertigation in second half of irrigation duration (SHID) compared to first half of irrigation duration (FHID), entire irrigation duration (EID) in both planting methods. Nitrogen application through fertigation benefited in terms of yield due to uniform availability of nitrogen in effective root zone. Contents of N were higher in active root zone area (15 to 60 cm) under SHID and EID in both the planting methods. Leaching of N was the minimum in case of SHID and the maximum under broadcasting method.

4.3.1.3 Soil nitrogen distribution as affected by urea ammonium nitrate (UAN) applied through drip fertigation in cabbage

Drip fertigation with liquid fertilizer like urea ammonium nitrate (UAN) could provide advantages over fertigation with urea and traditional method of broadcasting or soil application. Mineral nitrogen availability in UAN applied plots was significantly higher as compared to urea and subsequently decreased with increase in depth near emitter and 22.5 cm away from the emitter. Application of 80 kg N through UAN (47 t ha^{-1}) and 120 kg N through urea resulted in similar cabbage yield, net returns and benefit cost ratio which indicated that the drip fertigation using UAN could reduce application of N up to 30% in cabbage.

Application of urea ammonium nitrate through drip fertigation in cabbage

4.3.1.4 Estimation of water application efficiency and flow rates in maize-wheat cropping system

An attempt was made to estimate the water application efficiency by dividing the farm land to different basin sizes and irrigating with different flow rates. Surface irrigation hydraulic parameters under different basin sizes and inflow rates for wheat cultivar HD 3086 during *rabi* 2016-17 and maize cultivar PEHM 5 during *kharif* 2017 were worked out in field trials. Three basin sizes [viz,. 15 × 3.75m (BS1); 20 × 3.75m (BS2); 25 × 3.75m (BS3)] and with flow rates of 8, 6 and 4 lps were evaluated. Periodic data on soil moisture before and after irrigation, quantity of irrigation water applied in each irrigation, flow rate and advance of water front at 5 m interval in cropped fields were being recorded. It was observed that for maize cultivar PEHM 5, the water application efficiency ranged from 0.64 to 0.75 for the flow rate of 6 lps under BS3 and BS1, respectively. However, the application efficiency was highest ranging from 0.7 to 0.75 for the lowest flow rate of 4 lps for all three basin sizes. Similar trend of application efficiency was also observed for the wheat cultivar HD 3086 under three flow rates and basin sizes. Moreover, the water productivity (WP) was highest for maize (11.3 kg ha^{-1} mm^{-1}) and for wheat (14.9 kg ha^{-1} mm^{-1}) with the basin size BS2 and flow rate of 1.6 lps. Therefore, it may be recommended to irrigate the farm land by dividing to 20m × 3.75m sized basins with 6 lps to enhance application efficiency and water productivity in maize-wheat cropping system under surface irrigation.

4.3.1.5 Performance evaluation of soil moisture sensors for irrigation scheduling in wheat and mustard

Field experiment was conducted at research farm of Water Technology Centre, ICAR-IARI, New Delhi during *rabi* 2015-16 to evaluate different soil moisture sensors based on total water use and yield of wheat and mustard using time domain reflectometry (TDR), frequency domain reflectometry (FDR), tensiometer and gypsum blocks. Performance of these sensors was compared with the control plots, where crop stage based irrigation scheduling (conventional) was followed. In mustard, irrigation water use efficiency (IWUE) was the highest using TDR (13.7 kg ha^{-1} mm^{-1}) compared to tensiometer -30 kPa (10.7 kg ha^{-1} mm^{-1}) and gypsum block -30 kPa (10.5 kg ha^{-1} mm^{-1}). However, there was no significant different in IWUE for wheat. In control plots with crop stage based irrigation scheduling, the IWUE of wheat and mustard were significantly lower with 14.7 and 9.6 kg ha^{-1} mm^{-1}, respectively. Soil moisture sensor based irrigation scheduling enhanced the water productivity of both the crops as compared to the conventional irrigation scheduling.

4.3.1.6 Water budget and productivity of surface irrigation systems in *rabi* crops

Water budget and productivity under different *rabi* crops, viz., wheat, mustard and chickpea were studied in IARI farm (Mid-block, MB).

Results indicated that the deep percolation losses varied from 29.3-31.8 % for sandy loam soil to 40.2-42.2 % for clay loam soil under different crops which implies the need of better water management. The operational guideline for increasing the application efficiency were developed using WinSRFR 4.1 software, which will provide the measure to achieve more efficient irrigation management system in IARI farm.

4.3.2 Water Conservation under Rainfed Conditions

4.3.2.1 Hydrological response and carbon sequestration in different farming systems of Umiam watershed

To solve the multipronged challenges in north-eastern hills (NEH) region, eight farming system models were developed on watershed-basis in the research farm as remedial measures for *jhum* cultivation areas and enhancing productivity during 1984. Out of these, four micro-watersheds viz., livestock, Forestry, Agri-pastoral and Agri-horti-silvi-pastoral (FS-W1, FS-W2, FS-W4 and FS-W5, respectively) based farming systems were selected to study the hydrological behavior and impact of farming systems on productivity and carbon sequestration. All the micro-watersheds are performing better w.r.t water yield and sediment reduction compared to pre-treatment period of 1983.

Water budgeting parameters of different experimental blocks at IARI farm

Field No.	Crop	Grain yield (t ha^{-1})	Irrigation water applied (mm)	Effective rainfall (mm)	Deep percolation (mm)	Water productivity (kg m^{-3})
MB 3A-1	Mustard	1.9	212.0	58.9	97.6	0.70
MB 3A-2	Mustard	2.1	211.1	58.9	87.0	0.78
MB 3A-3	Wheat	5.0	324.6	66.9	140.6	1.27
MB 6A	Wheat	4.9	364.4	58.9	176.1	1.15
MB 9A	Chickpea	1.9	182.9	58.9	80.6	0.79
MB 12A	Wheat	4.6	311.0	66.6	137.9	1.20

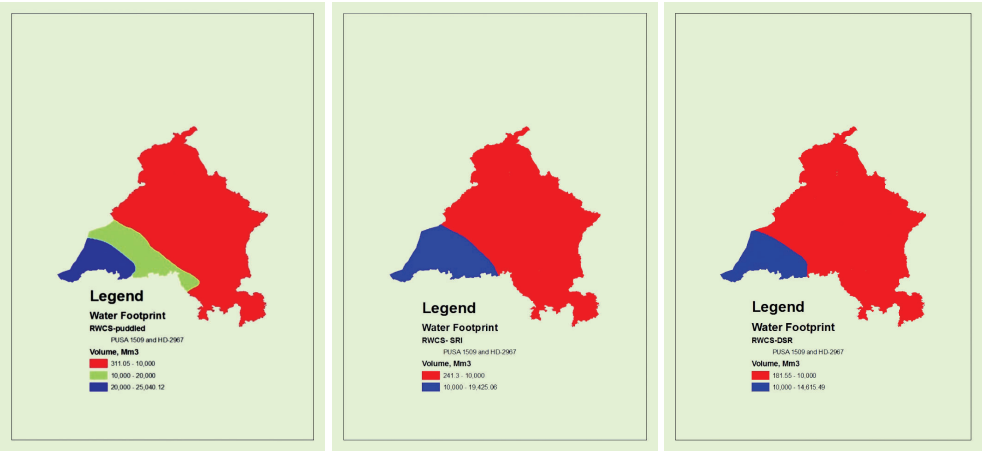
Total carbon stock combining the soil and plant carbon stock was observed to be highest (1138 t ha^{-1}) in micro-watershed FS-W2 with forest landuse followed by agri-horti-silvi-pastoral system (617 t ha^{-1}), live stock based system (546 t ha^{-1}) and agri-pastoral (438 t ha^{-1}). Overall, the agri-horti-silvi-pasture system with soil and water conservation measures was found to be the best model for reducing the runoff, soil loss and enhancing economical conditions, which can be adopted by the people of the NEH region for sustainable livelihood and mitigating the climate change.

4.3.2.2 Water foot print of rice - wheat cropping system in the ACR-VI

Water footprint information for different crops and cropping system are useful for judicious allocation of water to enhance water productivity besides ensuring its environmental sustainability under changing climate and equitable water distribution in the region. India tops the list in terms of use of green and blue water with share of 11.3 and 22.7%, respectively, but the average water footprint for rice, wheat, maize, sugarcane and cotton crops are higher than the global average. Experiment generated data of crop yield, total water use (effective rainfall and Irrigation) for the rice-wheat cropping system (RWCS) pertaining to different soil textures of ACR-VI were used for estimation of water foot print. Further, the geostatistical module of ArcGIS was used to generate the spatial variability map of water footprint for the ACR-VI. It was observed that combinations of rice cultivar Pusa 1509 and wheat cultivar HD 2967 under DSR, SRI and puddled methods of rice cultivation resulted in water productivity of 8.5, 7 and 5.2 kg ha-mm^{-1}, respectively. Similarly, the water footprint for the entire RWCS adopted region of ACR-VI was estimated to be lowest with 182, 241 and 311 Mm^3 for DSR, SRI and puddled method of rice cultivation, respectively. Protocol developed in this study can be replicated for other crops at different regional settings to estimate the crop water footprint.

4.3.2.3 Sensitivity of evapotranspiration and surface runoff to climate change and adoption strategies for Betwa river basin

Simulation of hydrological response of Betwa basin using validated Soil and Water Assessment Tool (SWAT) indicated that CO_2 had significant effect on ET, rainfall and surface runoff. When rainfall was increased by 20%, annual ET increased by 2.9% and when CO_2 concentration was doubled, ET decreased by 6%. Increase in temperature by 2 ^{0}C and in rainfall by 20% would increase ET by 4.2%.The combined effect of increase in temperature by 2 ^{0}C and decrease in rainfall by 20% decreased the ET by 1.8% whereas doubling the CO_2 under same condition further decreased the ET by 3.5%. An increase in rainfall by 10 and 20% coupled with 2 ^{0}C increase in temperature resulted in 30 and 66% increase in annual runoff. Moreover, the increase in temperature by 4 °C with 10 and 20% decrease in rainfall would result in 32.5 and 72% decrease in



Spatial variability of water foot print in puddled, SRI and DSR methods of rice cultivation in the RWCS of ACR-VI

annual runoff. However, runoff would reduce to 61% under doubled CO_2 level. Simulation results using the Representative Concentration Pathways (RCPs) data suggested that by 2020, the rainfall would decrease by 2.94, 0.96 and 3.25% under RCP2.6, RCP6.0 and RCP8.5, respectively. Hence, short term adaptation strategies would be construction of water conservation structures, crop diversification and introduction of drought resistant crops and varieties. Medium term adaptation strategies may include construction of rain water harvesting structures, enhancement of the capacity of the existing storage facilities, adjustment in sowing/planting dates. Rainfall, surface runoff and temperature are projected to increase in 2080 under all RCPs. Thus the long term adaptation strategies should focus on management of flood and water logging condition during wet seasons, enhancement in the storage capacity, adjustment of operating policy of reservoirs and improvement of drainage efficiency in waterlogged areas.

4.3.3 Wastewater Use in Agriculture

4.3.3.1 Heavy metal removal efficiency of vertical subsurface flow constructed wetland

Long term investigations to remediate wastewater using vertical subsurface flow constructed wetland planted revealed that wetland planted with *Typha, Phragmites, Vacha, Arundo, Vetiver*either as mono cropping or co-cropping had significantly higher heavy metal removal efficiency (Cr: 62 to 79%; Ni: 70-87%; Pb: 85-89%) compared to unplanted systems (Cr: 33-48%; Ni: 17 to 23%; Pb: 10-17%). However; metal removal efficacy above macrophytes planted in mono or co-cropping system was similar. In the vegetated wetland system, vegetation contributed towards removal of 33-48% Cr; 21-23% Ni and 10-17% Pb while microbes could remove 6-20% Cr; 7-13% Ni, 8-36% Pb and substrate was responsible for removal of 11-28% Cr, 41-53% Ni, and 43-63% Pb. The non-significant differences between experimental and simulated overall per cent removal values of Cr, Ni and Pb and their partitioning in the wetland - plant and substrate fractions indicated utility of interactive model developing environment of STELLA software in effective wetland designing.

4.3.3.2 Rice husk biochar: A potent adsorbent for nickel removal from wastewater

Rice husk pyrolysed at 400, 500 and 600 °C removed about 47% of Ni from wastewater within 30 minutes but the removal was increased to 65% when the contact period was increased from 30 minutes to 4 hours. Out of 0.2 to 2.0 mg L^{-1} Ni present in wastewater, 54 to 68% of it was adsorbed on rice husk biochar. There was a significant reduction in Ni adsorption with further increase in its concentration in wastewater. It was observed that one kg of biochar was sufficient to remove 58 to 67% of Ni from 22 to 25 litres of Ni polluted wastewater. Nonetheless, biochar pyrolysed at 400 °C was more efficient in removing Ni from wastewater. Different size fractions (viz., >0.5 mm, 0.25-0.50 mm, 0.10-0.25 mm and <0.10 mm) of rice husk biochar pyrolyzed at 400 °C showed no effect of reduced particle size on adsorption of heavy metal from the wastewater. Irrespective of size fraction, rice husk biochar removed about 66% of Ni from wastewater.

4.4 PROTECTED CULTIVATION TECHNOLOGY

4.4.1 Standardization of Low Cost Agro-Techniques for Coloured Capsicum and Tomato Production under Shade Net-House Condition

A study was conducted to standardize the Agro-techniques for coloured capsicum production under shade net-house protected condition using mulch

Capsicum production under shade net house

cover. The maximum fruits yield (9.0 kg), net return (₹ 86.4) and B:C ratio (1:2.78) per m^2 was recorded in commercial hybrid Atlante, followed by KSP 1070 and BSS 518, while in Baby Capsicum maximum fruit yield (8.4 kg) per square meter in variety Solan Bharpoor was recorded in the best combination of 3rd week of August planting with optimum dose of NPK @ 30:15:35 kg per 1000 m^2.

In case of tomato, the maximum fruit yield (28.0 kg), net return (₹ 87.0) and B:C ratio (1:2.84) per m^2 were recorded in commercial hybrid No.74-560, followed by GS 600 and Heem Sohna in the best combination of 2nd week of August planting with optimum dose of NPK @ 35:15:40 kg per 1000 m^2.

Tomato production under insect proof net house

4.4.2 Genetic Improvement of Tomato Suitable for Protected Environment

Total seventy five diverse tomato accessions were evaluated under protected conditions in respect of yield and horticultural traits. The tomato accession number 112, 181, 182, 206 and 304 were found highly suitable for protected cultivation. These accessions had TSS ranging from 4.9 to 6.6^0 Brix, and lycopene from 4.4 to 4.8 mg per 100 g with average fruit weight ranging from 95-130 g. Among Cherry Tomato accession number, 305 and 220 were found promising. Cherry tomato number 305 recorded as TSS 10.2^0 Brix and, lycopene as 4.7 mg per 100 g, while number 220 recorded TSS as 9.5^0 Brix and total carotenoids as 5.21 mg per 100 g.

Large fruited tomato no. 206 and cherry tomato no. 220 under naturally ventilated polyhouse

4.4.3 Development of Long and Round Fruited Indeterminate (Vine) Type Varieties of Summer Squash (Zucchini) Suitable for Protected Structures during Off-Season

The indeterminate *desi* type local germplasm of summer squash crossed with cultivated varieties, namely, *Australian green* (long-fruited) and *Pusa Pasand* (round-fruited) and F_1, F_2, F_3, F_4 and back cross materials were evaluated. It was observed that these lines varied among themselves and had long internodes, medium leaf canopy, thick stem, good fruits characters with indeterminate growth habit. Fruit yield was recorded as 3-5 kg $plant^{-1}$ during off-season (November-March) under polyhouse.

4.4.4 Standardization of Production Techniques for Off-Season Long Melon (*Kakari*) and Musk Melon in Protected Structures

For off-season production of *Kakari*, variety Chandralekha was transplanted at a spacing of 30 × 50 cm with NPK @ 25:17:26 kg per 1000 m^2 in polyhouse conditions. The maximum numbers of fruits per plant were 4, with an average fruit weight of 442 g, length of 83 cm and diameter of 3.40 cm. The total yield was 2.25 kg $plant^{-1}$ and 8.90 kg m^{-2}. The cost of cultivation was ₹ 276 m^{-2}. The net return was calculated as ₹ 316 m^{-2}. The B:C ratio calculated for polyhouse production remained 1:1.95. In another study, musk melon (Pusa Sarda, yellow fruits) was transplanted in 3rd week of September at the spacing of 50 × 50 cm with drip irrigation system. The NPK was added @ 25:17:26 kg/1000 m^2 by fertigation.

Hand pollination was done daily before 8 AM during flowering. The fruit yield, net return and B:C ratio were recorded as 6.30 kg m^{-2}, ₹ 525.5 and 1:3.40 m^{-2}, respectively, under polyhouse condition. The net-house condition produced fruit up to November with 12.7% TSS but polyhouse condition produced fruits up to December-February. Pusa Sarda was found economically suitable and highly profitable in polyhouse condition due to off-season production.

Off-season melon production under protected structure

4.4.5 Off-Season flower induction in chrysanthemum under the influence of artificial long days

Chrysanthemum varieties, namely, Pusa Centenary, White Star, Yellow Star, Zembla and Thai Chen Queen were planted on 20th October, 2017 and long days @ 4 h daily was maintained artificially for 12 days from 5 to 9 PM. Maximun plant height was attained in Pusa Centenary (110.7cm), followed by 96.2 cm (Zembla), 83.9 cm (Yellow Star), 81.4 cm (White Star and 67.5 cm (Thai Chen Queen). It was noted that White Star and Yellow Star did not blossom. Whereas Pusa Centenary, Thai Chen Queen and Zembla produced good quality flowers with 15.3 cm, 12.7 cm and 11.6 cm diameter across, respectively. Under open field conditions, plants were transplanted on 20th January with the objective of extending chrysanthemum flowering. It was observed that a normal flower induction occurred in Pusa Centenary, Thai Chen Queen and Zembla. Whereas no flowering was observed in Haldi Ghati and Golden Ball.

Off-season flower induction in *Chrysanthemum* in open fields

4.4.6 Sensor Controlled Fertigation Scheduling and Water Productivity for Chrysanthemum

Tensiometers, EC, pH, temperature, humidity and solar radiation sensors were used to control fertigation scheduling for chrysanthemum (var. Zembla). Fertigation scheduling corresponding to 80% ETc gave the maximum stem dia (0.44 cm) and flower size (9.7 cm), while 100% Etc gave maximum plant height (53 cm) and number of leaves per plant (22). Crop water productivity was found to be maximum 280 stems m^{-3} and minimum 240 stems m^{-3} for treatment corresponding to 100% Etc and 80% Etc, respectively. The values of the sensors standardized for getting maximum crop water productivity for tensiometer (20-25 centibar), soil EC (0.28 dS m^{-1}), fertigation EC (2.3 dS m^{-1}), fertigation pH (6.5), greenhouse temperature (19-25 ^{0}C), greenhouse humidity (51-62 ^{0}C) and solar radiation (280-340 watt m^{-2}).

Sensor controlled experiment on greenhouse chrysanthemum

4.4.7 Designing Hydroponic System for Vegetable Production under Protected Structure

Hydroponic system was designed and fabricated using PVC pipe network for continuous flowing of nutrients. The spacing between pipe systems was 30 cm and space of 60 cm provided between two blocks

for various operations. Lettuce crop is transplanted in the pot having dimension of different sizes at a spacing of 30 cm. Water solution from tank was pumped by using 1 hp motor for about 10 minutes for circulating water twice in a day. Maximum yield of lettuce (147 g plant^{-1}) was recorded in hydroponic system having pipe diameter of 90 mm and pot diameter of 45 mm).

Sensors for monitoring for EC and pH were installed for making decision about replacement of water and addition of nutrients.

Developed hydroponics system

4.4.8 Designing of Vertical Soilless Structure for Vegetable Crops

An experiment was carried out during November, 2017 to February, 2018 to design a vertical soilless structure for leafy vegetable crops. Four types of vertical stand were made using angle iron viz., structure 1- dimension of structure is 6.10 m × 1.47 m × 1.80 m, structure 2- 6.10 m × 2.18 m × 1.80 m, structure 3- 1.96 m × 0.44 m × 0.89 m and structure 4- 1.96 m × 0.44 m × 0.89 m. Pots having dimensions of 13 cm x 13 cm x 13 cm were arranged in vertical strands. Pots were filled with soilless media containing coco peat, perlite and vermiculite in the ratio of 3:1:1 on volume basis. Eight vegetables, namely, Kale, Knol khol, Cilantro leaves, Green lettuce, Spinach, Beet root, Amaranths and Parsely were grown in these vertical stands. Irrigation and fertigation was scheduled by mixing nutrient in tank of 454 litres of water. Every day 5 minutes, system was operated to meet the crop water requirement of these crops. The yields of crops were obtained as 140, 190, 120, 180, 150 and 200 g per pot for Knol khol, Cilantro leaves, Green lettuce, Spinach, and *Cholai*, respectively. The cost of making structure, growing material and nutrient solution was ₹ 28558 for structure 1, ₹ 55176 for structure 2, ₹ 4746 for structure 3 and ₹ 7957 for structure 4. Vegetable grower can choose these structures according to structure cost and space available.

Designed vertical farming structure

4.5 AGRICULTURAL ENGINEERING

4.5.1 Effect of Depth of Application, Doses and Schedule of Urea Ammonium Nitrate (UAN) Application in Direct Seeded Rice

A field experiment was conducted at the research farm (Mid A-6), ICAR- Indian Agricultural Research

Paddy variety Pusa 1612 @ 21 DAS

Crop response to UAN Application @90DAS

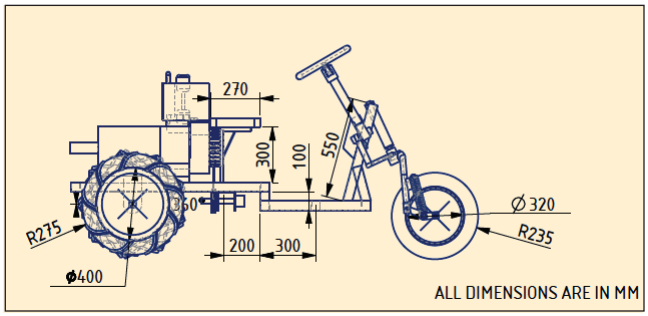
Institute, New Delhi during *kharif* 2017 to evaluate rates and sources of nitrogen using rice crop (cv. Pusa 1612). Urea ammonium nitrate (UAN) applicator was designed to place the fertilizer beside 2.5 cm the seed at a depth of 5cm and 10 cm.

Results indicated that UAN was a better source of nitrogen in comparison to common urea for direct seeded rice. Grain yield obtained with 150 kg N ha^{-1} through common urea were equivalent to that produced by 120 kg N ha^{-1} through UAN. Hence, on an average, 30 kg N ha^{-1} could be saved by applying UAN over common urea. The UAN placement depth of 5 cm was better than 10 cm, with respect to the performance of UAN applicator as well as grain yield of direct seeded rice.

4.5.2 Development of Integral Power Equipment for Small Farm Mechanization

The three wheel mini tractor type multipurpose equipment was designed to overcome the limitations of power tiller (walk behind, difficult to steer, single operation, less traction) as well as tractor (large size and unsuitable for small farms). The prototype was designed to incorporate the advantages of both tractor (riding type, multipurpose and better traction) power tiller (smaller size and less turning radius). The developed prototype integral power equipment is three wheeled riding type with single chassis for better stability and steerability.

The developed integral power equipment can perform 8 different operations (shallow ploughing, inter-culturing, weeding, sowing, roto-tilling, harvesting, spraying, irrigation water pumping) with a single power source and the operations are hydraulically controlled as that in tractors. The developed intervention has great potential to abridge the mechanization gap on small farms.



Three wheel mini tractor

4.5.3 Development of Raised Bed Pulse Planter

A tractor operated raised bed pulse planter was developed for planting of pigeon pea seed. The major components of the planter were main frame, bed former, three point hitching, hopper with metering plates, furrow opener, furrow closure and ground wheel. The developed planter made raised bed of 330 mm top width and 255 mm deep with 380 mm wide furrows. The planter made two beds to plant pigeon pea seeds on raised bed in single pass. Row spacing in the beds were 250 mm. Seeds were placed in twin rows and single row per bed. Field performance evaluation of the planter revealed that the average field capacity of the planter was 0.25 ha h^{-1} for continuous operation at an average speed of 2.2 km h^{-1}. Field efficiency of the planter was observed to be 73%. The average depths of placement of seeds were 50-70 mm. The average plant

Prototype raised bed pulse planter

population was observed to be 18 per meter square. The average multiple index and miss index were 20% and 5%, respectively.

The estimated cost of the prototype planter was ₹ 60 thousand. The cost of operation of the machine per hectare was substantially lower than the manually planting/dibbling of pigeon pea seeds. Thus, the monetary gains can leverage the initial cost of machine and can promote its use.

4.5.4 Development of Multi-Crop Planter for Small Vegetable Seeds

A multi-crop planter was developed for planting of small vegetable seeds. The major components of the planter were main frame, hopper, metering roller, furrow opener, furrow closure and ground wheel. The developed planter plants small and irregular seeds at desired spacing. The manually operated prototype has the provision of soil covering after planting. The planter has less number of parts prone to wearing. The planter can be used for different spacing and different seeds by changing the vertical roller. The seed spacing can also be adjusted by changing the sprockets used in the transmission system. Field performance evaluation of the planter revealed that the average field capacity of the planter was 0.021 ha h^{-1} for continuous operation at an average speed of 1.02 km h^{-1}. Field efficiency of the planter was observed to be 65%. The average depths of placement of seeds were 15-20 mm. The average multiple index and miss index were 0 and 8%, respectively. The estimated cost of the prototype planter was ₹ 8000/- only. The cost of operation of the machine per hectare was substantially lower than the manually planting/ dibbling of seeds.

Multi-crop planter for small vegetable seeds

4.5.5 Development of Paddy Straw Collector Cum Chopper

A paddy straw collector cum chopper was developed and evaluated in the field. The machine cuts the paddy straw stalks in combine harvested field at a height of 2-3 cm from ground level. The chopping action reduces the size of the paddy straw to a pre-selected level of 4-5 cm for rapid *in situ* degradation. The chopped straw then flows through trapezoidal shaped hopper and get collected or can be dropped in the field for *in-situ* degradation. The machine has a field capacity of 0.4 to 0.6 ha h^{-1} and chopping performance of 63.5% of the paddy straw less than 5 cm. Paddy straw collector-cum-chopper was evaluated in IARI field under three straw load conditions i.e., low (< 5 t ha^{-1}), medium (5-10 t ha^{-1}) and high (>10 t ha^{-1}). It was observed that the paddy straw collector cum chopper works effectively and efficiently in low to medium paddy straw load conditions in the field .

4.5.6 Development of Precision Paddy Planter for Direct Seeding

A prototype precision planter with electronic seed metering system was developed for direct paddy seeding. The electronic metering of precision planter was based on speed synchronization with proximity sensor and PWM based microcontroller. The observed values of seed rate, spacing and seed placement index of mechanical method were 22.7 kg ha^{-1}, 14.4 cm and 74.3%, respectively and corresponding values for electronic method were 19.9 kg ha^{-1}, 14.8 cm and 86.4%. A saving of seed rate to the extent of 12% was observed

Precision paddy planter

by sowing with electronic metering method over mechanical. The variation in spacing was less in case of electronic method by 4.0% as compared to mechanical method of sowing. The seed placement index was found to improve by 16.3% with electronic metering. Hence, electronic metering based planter had better precision as compared to mechanical sowing.

4.5.7 Development of Battery Assisted Spinach-Cum-Coriander Seeder for Small Farmers

A two row seeder was developed for line sowing of spinach and coriander at varying row spacing of 21 to 45 cm. The developed seeder was mounted on battery-assisted four-wheel unit. It consists of trapezium shaped hopper, metering unit on drive lugged wheel shaft and boot type furrow opener. Two independent seeders were mounted on left and right sides of main square shaft enabling different row spacing. Row spacing is adjusted by fixing the independent seeder with bolt on main shaft. The weight of battery-assisted two-row seeder is 35 kg. The hopper volume of each seeder is 2.0 L. The seeding depth is 25-35 mm for spinach and coriander with adjustment provision. The area covered was 0.045 ha h^{-1} and 0.065 ha h^{-1} with row spacing of 215 and 300 mm, respectively. Deviation in seed dropping in furrows was negligible due to design of metering system and low-seed drop height. The speed of operation was 2.16 km h^{-1}. The power consumption varied from 100-175W.

Battery assisted spinach-cum-coriander seeder

4.5.8 Development of Eight Row Tractor Drawn Planter for System of Wheat Intensification (SWI)

An eight row tractor drawn planter was designed and developed to plant wheat seeds in the hills for system of intensification. The row-row distance was adjustable from 20 to 25 cm. It opens the furrow, places the seed at 5 cm depth maintains seed to seed distance

8-row tractor drawn planter for SWI

of 20 cm and firmly covers the seed. The tractor drawn system of wheat intensification (SWI) planter was evaluated in the field at two forward speeds (1.5 and 2.0 km h^{-1}). The wheat seeds used for sowing were dry and soaked. Draft requirement was 320 kg. The average number of hill per square meter were 23 to 25 and plants per hill were 2-3.

4.5.9 Development of Harvester for Selected Cereal Crops

A walk behind powered harvester was developed for harvesting cereal crop, which is suitable for small and marginal land holdings. The machine weighs 16 kg and powered with 1.7 HP petrol engine. Field capacity of the machine is 0.25 ha day^{-1} with 0.3 km h^{-1} working speed. Low cost of the machine and higher field capacity compared to manual harvesting are two important features which make it suitable for small and marginal farming community. Moreover, light weight of machine also makes it viable for hilly terrains.

A walk behind powered harvester

4.5.10 Development of Robotic Precision Planter

Robotic Precision Planter was designed and developed for precision planting of seeds. Control, actuation and movement was implemented with the help of ATmega2560 AVR based microcontroller with designed C-language program for the traction, steering and Cartesian co-ordinate movement. To achieve precise actuation, different capacity of stepper motors and drivers were used powered by 48 Volt batteries. The actuation corresponds to the position resolution for the motion with an accuracy of 0.21 mm. It has a power bank unit consisting of four batteries (12V, 70Ah each), attached on both the sides of the robotic vehicle platform. It provided power to all four traction motors, four steering motors, and three motors used for Cartesian Coordinates (X, Y and Z axis). The robotic planter was tested for its action, speed and accuracy of movements and found working as per the assigned crop geometry and depth of seed placement.

Robotic precision planter

4.5.11 Development of Solar Powered Movable Cold Storage Structure for Perishables

A solar powered movable cold storage structure of 1000 kg capacity for perishables was designed and developed for storage of fresh fruits and vegetables to enhance their shelf life. The Solar photovoltaic (SPV) system consisting of 8 solar panels of 210Wp each, one solar inverter (3000VA) and a battery bank of four batteries of 12V/150Ah each was used to power the AC to cool the storage. The average temperature in the cold storage could be reduced up to 26 to 9.7°C from the average ambient temperature of 35°C. Temperature and relative humidity inside the system ranged from 9.5 to 11°C and 73 to 92%, respectively. Lower temperatures and higher relative humidity maintained inside the storage structure increased shelf life of tomato up to 20 days. This cold storage structure is very useful for rural areas where there is shortage of electricity or its supply is erratic for storage of fresh fruits and vegetables.

Solar powered movable cold storage structure with 0.8 ton AC connected and stored tomato

4.5.12 Solar Refrigerated Evaporatively Cooled Structure for Fruits and Vegetables Storage

A stand-alone, battery less, off-grid, solar-refrigerated evaporatively-cooled (SREC) structure for storage of 2000 kg perishables was developed. The SREC structure employs walls composed of inexpensive fabric over iron mesh to make a chamber of size 3 × 3 × 3 m. Refrigeration was provided by a mini split inverter air-conditioning (IAC) unit, available locally and providing a low cost per BTU of cooling and markedly improved mechanical performance (COP of approximately 4.3). A simple cold-water reservoir provides low cost thermal storage obviating the need for batteries for night time cooling. The grid independent inverter with secure power supply is used to operate the refrigeration system from solar panels. The SREC structure can achieve temperature reduction of about 10 to 12 °C in Delhi area at about half the cost of traditional brick structures. There was very little leaf abscission in amaranth leaves stored in solar refrigerated store as compared to those stored in evaporatively-cooled store or uncooled laboratory.

Stand-alone, batteryless, off-grid, solar-refrigerated evaporatively-cooled (SREC) structure

4.5.13 Development of Digital Seed Rate Calibration System

A digital seed rate calibration system was developed, which consists of a micro controller (ATmega 2560), LCD display, Hot pot potentiometer membrane, Load cell (5 kg), HX711 load cell module, LED and a buzzer. The system was attached to the fluted roller metering mechanism (two rows). It had a provision to feed pre-determined seed rate and row spacing. Developed system was evaluated with three

Digital seed rate calibration system

wheat varieties, HD 2967, HD 2643 and Kundan for two seed rates (100 kg ha^{-1} and 120 kg ha^{-1}). The difference in calculated weight and weight of the actual metered seed for 100 kg ha^{-1} and 120 kg ha^{-1} seed rate for all the varieties, respectively, was negligible. Precise seed rate was achieved with the developed digital seed rate calibration system.

4.5.14 Farm, Horticulture and Landscape Operation Services

The farm, horticulture and landscape operation service unit (FHLOSU) has five main components, namely, i) Farm operation management, ii) Irrigation system management, iii) Biomass/Crop residue management, iv) Management of non-cropped area, v) Ornamental horticulture and landscaping unit (OHLU). All field operations starting from land preparations to harvesting and threshing of 750 acres of IARI research farm utilizing conventional and precision farm machineries during all three seasons i.e., *Rabi*, *Kharif* and Spring Summer were managed. In addition to it, transportation of farm produces from different divisional field to PUSA produce Sale Centre was taken up. Scheduled, preventive and breakdown maintenance of farm machinery was done either in-house workshop or specialized workshop. Technical service for operation, repair and maintenance of farm machines owned by different divisions/units were also imparted. FOSU brigade also contributed significantly in fighting with exigencies and restoring normality. A tractor of 45 HP, two disk harrow (10×10) and a track mount power sprayer were procured for completing farm operations well in time.

Inter linking of tube wells installed in block of Genetics and Entomology was done for assured irrigation water. The tube well installed in ATIC was also linked with water reservoir to meet water requirement in pick demand period. Pilot installation of time totalizer at submersible tube well found to be effective aid for precise monitoring and management of operator as well as energy budgeting. FOSU in collaboration with Divisions of Agronomy and Agricultural Engineering, collected and transported the crop residues and other biomass produced at IARI experimental farm for composting to earmarked farm area. Approximately 16500 m^3 per year load of crop residue/biomass were hauled from various corners of IARI farm to composting site. In order to operational ease, cleanliness and aesthetic sense of non-cropped area i.e., farm road sides, bund and channels, *nala* side and security road were maintained weed free with the help of human work force, hand tools, manual and smart machines. The overall management of the DPL's and contractual labours for all divisions and projects of IARI were efficiently undertaken. Overall management of garden/lawns and landscaping work of the institute was undertaken with support of efficient machinery and hand tools. Significant contribution was provided in organizing meeting, seminar, *Kishi Unnati Mela* and other institute functions.

4.6 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.6.1 Influence of Indigenously Developed Particle Films on Kandhari Pomegranates

Three sprays of each developed clay film (PCS-1, PCS-2, PCS-3 and PCS-4) were given at 15 days interval, starting from 15th June, 2017 on Kandhari pomegranate plants at Indo-Italian Project Orchard located at Bajaura (H.P.). The results revealed that PCS-4 clay film developed attractive red colour (hunter colour 'a' = 56.2) with high anthocyanin content, total phenolic content (118.2 mg/100 ml GAE), anti-oxidant activity (16.6 uM Trolox/ml) and TSS (15.5%) than other films and control (untreated) fruits. This film also produced

Particle films on pomegranate

russet-free fruits (92.8%), reduced fruit cracking (1.2%), sunburn (2.3%) and incidence of *Virachola isocrates* (1.1%) significantly over other such films and control.

4.6.2 Influence of Pre-Harvest Fruit Bagging on Kinnow Mandarin

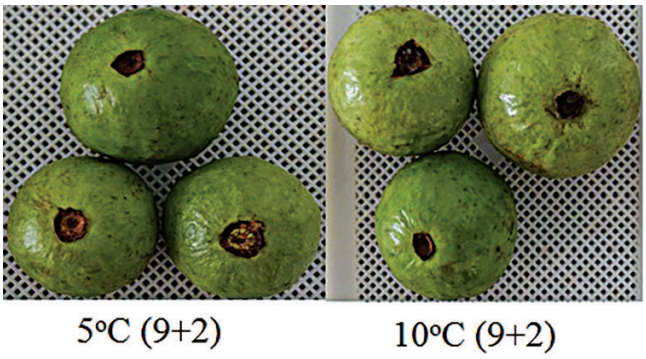
Fruit bagging was done with PP Non-woven bags in September and observations were recorded for colour and other quality attributes. Results revealed that bagging improved the fruit size of Kinnow (220 g) in comparison to non-bagged fruits. Further, bruising of fruits significantly reduced by fruits bagging (11.1%) over non-bagged fruits. Similarly, there was a greater influence on ascorbic acid content and TSS of the fruits. Besides, incidence of granulation (0.8%) was reduced by pre-harvest fruit bagging.

Non-bagged Kinnow

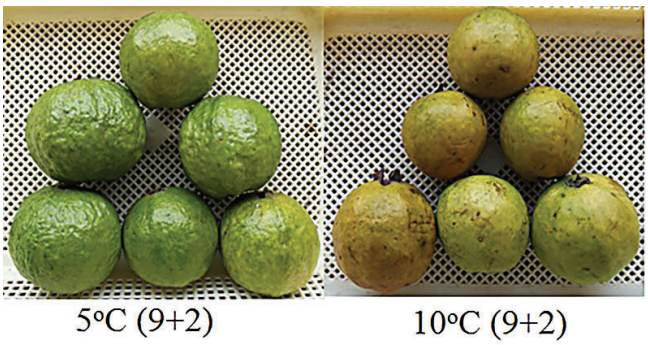
Bagged Kinnow

4.6.3 Enhancement of Postharvest Life of Guava Fruit by Application of Edible Coatings and Salicylic Acid

Guava fruits of white fleshed cv. Allahabad Safeda were treated with salicylic acid (SA) and 5-sulfosalicylic acid (SSA) at 1 mM or 2 mM concentration and stored at 5 or 10 °C for 12 days. At each interval of 3 days, cold storage fruits were transferred to ambient conditions for a 3 day shelf life simulation period. Treatment of fruits with SA or SSA at 2 mM concentration retained better quality as compared to other treatments and also suppressed ripening and delayed the yellow colour development. Experiments conducted revealed that either 2 mM SSA or vegetable wax alone or in combination can be successfully applied to enhance the postharvest life of guava fruits.



Guava fruits (cv. Allahabad safeda) treated with SSA+vegetable wax



Guava fruits (cv. Lalit) treated with SSA+vegetable wax

4.6.4 Preparation and Packaging of Osmo-Vac Dehydrated *Aonla* Segments

An investigation was carried out for the preparation of osmo-vac dehydrated *aonla* segments from firm and matured *aonla* fruits. Result revealed

that good quality of osmo-vac dehydrated *aonla* segments could be prepared after blanching of *aonla* fruits in alkali (2% NaOH) for 8 minutes followed by dehydration of segments in vacuum drier at 40±2 ^{0}C with an atmospheric pressure of 640 mmHg. Further, dehydrated *aonla* segments were packed in 200 g LDPE, 200 g HDPE, 260 g ALPE and 250 g co-extruded pouches with two modes of pack, air pack and nitrogen pack. The samples were stored at RT (15-33.5 °C) for 6 months for storage study. Among the

packaging material 250 g co-extruded pouches or 260 g ALPE were found to be the best followed by nitrogen pack for retention of better quality in respect of acidity, β-carotene, ascorbic acid, rehydration ratio, sugar content and sensory score during storage. However, the values for moisture and NEB were lower compared to 200 g HDPE pouches.

4.6.5 Pre-Treatment Suitability for Dehydration of Onion

Three mm thick onion slices from 2 cultivars of onion, namely, Pusa White Round and Pusa Red were dipped in $CaCl_2$ (1%), $CaCl_2$ (2%), $CaCl_2$ (1%) + KMS (0.2%), NaCl (2%), NaCl (2%) + sulphuring solution for 10 minutes and subsequently dried at 58 ± 2 °C up to 4-5% moisture level. Dehydrated slices prepared from Pusa White Round treated with (1% $CaCl_2$ + 0.2% KMS) was found to be better as compared to other treatments.

4.6.6 Suitability of Packaging Material for Extending Self-Life of Banana

To enhance the self-life of banana fruits, the fruits were packed in different packaging material of CFB boxes, LDPE with or without perforation, PP with or without perforation along with control and stored at 15 ± 2 °C, RH 70-80%. During 12 days of storage, LDPE non perforated film was found to be better in comparison to other packaging material so as to retain high amount of ascorbic acid, antioxidant capacity and total phenol content over the control and other packaging materials.

4.6.7 Nutritional Quality of Dehydrated Spine Gourd Slices

The slices were prepared by cutting of spine gourd fruits into two pieces by manually with stainless steel knife. Slices were allowed for pre-treatments, and blanching carried out in boiling water for 3 minutes. Dehydration of treated spine gourd slices was done by cabinet dryer and vacuum drier. Vacuum drying was found superior and exhibited maximum dehydration

Dehydrated spine gourd slices

ratio, titratable acidity and with minimum moisture as compared to cabinet drying. Cabinet dried slices maintained good nutritional status of dehydrated spine gourd slices after dehydration and during storage period.

4.6.8 Polyphenolics from Citrus Peels

Peels of citrus can be used for extraction of polyphenolics, which can be used as valuable functional ingredient in foods. Under optimal conditions, ultrasound assisted extraction (80% amplitude, 35 min extraction time and 40 mL g^{-1} ethanol to solid ratio)

was found to be the best for the maximum recovery of phenolics and high antioxidant activity. Naringin was the most abundant polyphenolic quantified in citrus peels. However efficacy of non-encapsulated phenolics in controlling oxidative stability in mustard oil met with limited stability, which is being evaluated in encapsulated matrix.

4.6.9 Development of Antioxidant Rich Naturally Coloured Papaya Candy

Infusion of beet extract (betanins) was done in papaya matrix to develop antioxidant enriched naturally coloured papaya candy. The targeted level of betalains in present study was 100 mg kg^{-1} of raw papaya flesh (50% of maximum permissible limits). Papaya candy was prepared after boiling of raw papaya dices in sugar solution followed by shade drying (room temperature) for 2-3 days. Blanching time, length of infusion time and concentration of anthocyanins in infusing medium ($p< 0.05$) was found to be the major factors influencing the infusion process. Prior blanching (85°C at 2 min), significantly reduced the infusion time by 1.5 to 2.5 folds. The findings of present study showed the potential and possibility of infusing betanins into papaya matrix to transform hitherto unsafe image of commercial candies into a low fat functional product by developing an innovative fusion product.

Betanins enriched papaya candy

4.6.10 Dehydration of Kale Leaves

Drying of kale leaves after application of individual or combination pretreatments was carried out at 50 ºC to achieve a final moisture content of 0.05 kg kg^{-1} of dry kale powder. Steam blanching offered better retention of antioxidant components with ASBK (Annealing followed by steam blanching with 0.5 KMS) application showing retention of total antioxidant activity, β-carotene, total phenols, ascorbic acid and anthocyanins to be 93.8, 79.2, 94.9, 86.4 and 54.6%, respectively. ASBK also demonstrated least change in color compared to fresh green kale leaf. Annealing and HMT both significantly improved physic-functional properties of kale powder such a solubility, bulk density, porosity, etc. but no significant difference was identified between annealed and HMT sample.

4.6.11 Formulation of Gluten-Free Amaranth Pasta and Improving Cooking Quality Using Hydrocolloids

An attempt was made to prepare gluten-free (GF) pasta using nutritious base materials like amaranth and barnyard millet flour. For attaining GF pasta quality similar to commercial semolina pasta, high temperature drying and hydrocolloids were employed. The extruded flours for pasta making were selected over their raw form owing to their superior machinability, hydration and pasting properties. The blend containing equal

Cooked gluten free amaranth pasta

proportion of extruded amaranth and barnyard millet yielded better sensory, cooking and textural quality. After optimization, the hydrocolloids supplemented gluten-free pasta recorded textural attributes close to commercial semolina pasta with a variation of 6, 32 and 14.8% in terms of lower firmness, stickiness and cutting force. Optimized pasta was found to have higher rate of protein digestibility over commercial semolina pasta. Powder rheology and dynamic rheology were also performed for optimized composition to quantify the caking properties and cohesion index of flours and determine the effect of hydrocolloids on mechanical spectra of cooked pasta.

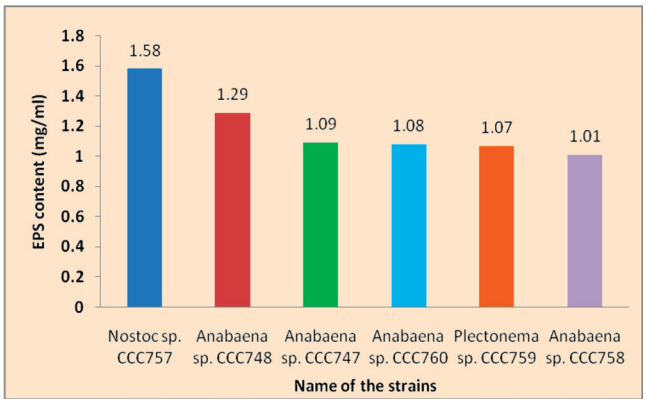
4.7 MICROBIOLOGY

4.7.1 BGA Based Composite Liquid Inoculant for Sustaining Crop Productivity and Soil Health

The BGA based composite liquid formulations was found to maintain a good titre value and is stable up to two years at both 4 and 28 °C. The field experiment was conducted to assess the effect of composite liquid formulation on paddy (var. Pusa 1509). The mean soil available nitrogen (N) and organic carbon (C) in formulation applied treatment were 71.4 kg ha^{-1} and 0.70%, respectively, as compared to that under RDF ($N_{120}K_{60}P_{60}$), which were 62.2 kg ha^{-1} and 0.58, respectively. Similarly, the grain yield recorded was higher in treatments with application of BGA based composite liquid formulation. However, it was observed that the increase was highest (17%) with the application of liquid formulation alone (with no NPK application).

4.7.2 Bioprospecting Rhizospheric and Endophytic Cyanobacterial Diversity Amongst Selected Genotypes of Rice for Nitrogen and Phosphorus Uptake and Crop Yield

Of the 50 cyanobacterial isolates (isolated from *basmati* and non - basmati rice varieties), twenty showed extracellular ammonia release. The highest amount of ammonia, i.e., 1609 µmole ml^{-1} was released from *Microchete* species isolated from stem of PB 1401, whereas *Anabaena* sp. isolated from the roots of variety PS 5 showed the lowest release to the tune of 65.5 µmole ml^{-1}. Only six isolates belonging to *Microchete* sp., *Nostoc* sp. and *Phormidium* sp. were capable of solubilizing phosphorus. Inoculation appeared to exhibit promising effect on growth attributes as well as N and P uptake in comparison to control (un-inoculated) with more pronounced effect in case of non-basmati variety. Besides, six fast growing filamentous cyanobacterial strains representing the genus of *Nostoc*, *Anabaena* and *Plectonema* having EPS production in the range of 1.01-1.58 µg ml^{-1} were identified.



EPS production by the six different strains

4.7.3 Encapsulated Microbial Inoculants for Phosphorus Nutrition and Crop Productivity

A field experiment was conducted with wheat to evaluate the performance of two forms (encapsulated bead and liquid form) of the phosphate dissolving fungus (*Aspergillus niger*). Soil phytase activity was the highest when liquid and bead forms were given @10 g row^{-1} (each row having 5 plants). However, root phytase (0.85 m U g^{-1} root fresh weight) was the most improved with encapsulated form over liquid form and un-inoculated control. There was an increase of 30.6 and 23.8% over un-inoculated control and liquid form @15 g row^{-1}, respectively. Total fungal count and available P did not change significantly among the two forms, but showed significant values over un-inoculated control.

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

Assessing effect of the bacterial inoculants, host genotypes and growth stages of the host on rhizospheric microbial community in terms of soil enzymes and microbial biomass C in soybean and wheat crops indicated that there was no adverse effect of treatments on microbial biomass carbon (MBC), dehydrogenase and alkaline phosphatase activity as compared to un-inoculated control, in case of soybean variety DS 12-13 and DS 12-5. However, FDA activity was impacted by the crop growth stage in case of DS12-13, but no such change was observed in DS 12-5. For wheat, crop growth stage and the variety seemed to have more impact on the soil enzyme activities as compared to inoculants per se in the first sampling at 45 days after sowing. However at 75 days of crop growth, the effects of inoculants were more pronounced for both wheat varieties. MBC and dehydrogenase activities were lower in the 2nd sampling in treatments with *Burkholderia* and *Bacillus* sp. The AMF colonisation and spore counts were better in *Bacillus* sp treatments for soybean as well as wheat.

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

A field experiment was conducted to study the inoculation effect of *Mesorhizobium*, AM fungi and endophyte on symbiotic potential (nodulation and leghemoglobin content), plant growth, nutrient content and yield of chickpea (var. BG 372) after rice cultivation. Inoculation had positive influence on nodulation, plant growth, and nutrition uptake. The available nitrogen content varied from 121 (uninoculated control) to 178 kg ha^{-1} (Triple-inoculation of *Mesorhizobium*+VM+E21). Fresh weight of nodule in uninoculated control recorded 174 mg $plant^{-1}$, whereas triple-inoculation showed 375 mg $plant^{-1}$. The leghemoglobin (lb) content, an indicator of N fixing potential of inoculation also ranged from 263 (T1) to 321 (T9) mM lb g^{-1} fresh weight nodule. Single (T3, T4, T5), dual (T6, T7, T8), and triple (T9) inoculation increased the shoot growth to the tune of 9-10, 14-15 and 23%, respectively. Seed treatment with *Mesorhizobium*+VM+E21 (T9) showed higher N uptake (31.4 mg $plant^{-1}$) in comparison to uninoculated control (T1), which recorded lowest value (25.0 mg $plant^{-1}$).

4.7.6 Microbes Mediated Water Stress Alleviation in Mustard

Effect of seed inoculation of mustard with selected rhizobacteria (NAD 7 and MRD 17) on growth and yield of mustard genotypes (stress tolerant and stress susceptible) was evaluated under water stress condition. Inoculation with these isolates considerably enhanced both root and shoot dry weight under water stress condition. Inoculation had a positive effect on yield under both normal water and water stress conditions, but the effect was more pronounced under water stress conditions. Differential responses were elicited by the two genotypes for antioxidant activities upon inoculation under water stress and normal conditions.

4.7.7 Agri-Residue and Biomass Management

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

Four process variables viz., substrate loading (4.0-7.0% w/v), enzyme loading (10-30 FPU g^{-1} dry rice straw), pH (4.0-6.0) and inoculum rate (7.0-15.0% v/v) were evaluated to develop a simultaneous saccharification and fermentation process for bioethanol production using thermotolerant yeast *Saccharomyces cerevisiae* JRC6 and cold active enzyme cocktail produced by *Aspergillus niger* SH3. These varieties were optimized as the optimum values for substrate loading, enzyme loading, pH and inoculums rate were worked out as 6.71% w/v, 25.7 FPU g^{-1} dry rice straw, 4.15 and 13.2% v/v, respectively. Two putative fusants (1a.23 and 1a.30) developed by protoplast fusions of *S. cerevisiae* LN (hexose fermenter) and *Pichia*

stipitis NCIM 3498 (pentose fermenter) were selected based on their improved xylose consumption (40% on 2% xylose) and propagated on xylose containing medium.

4.7.7.2 Design and development of mechanical and biological techniques for biomass degradation

Two lignocellulolytic fungi ,namely, *Coprinopsis cinerea* LA2 and *Cyathus stercoreus* ITCC 3745 were applied in the field for *in-situ* degradation of rice straw. The degradation of paddy straw was monitored in terms of cumulative carbon dioxide evolution at weekly interval up to 30 days before sowing of wheat. The fungal inoculation increased the degradation resulting in 45.6 mg CO_2 evolved/100 g soil as compared to control (21.5 mg CO_2 evolved/100 g soil). Microbial activity parameters monitored in terms of dehydrogenase and flouresecein di acetate (FDA) hydrolase also registered increase up to 30 days and higher activity was recorded in the soil, where paddy residue was retained along with microbial inoculation,

4.7.8 Bio-resources

Draft Genome sequence of *Pseudomonas stutzeri* strain KMS 55(MTCC 12703), an endophytic diazotroph isolated from rice roots containing 4,637,820 bp and 4,289 protein-coding genes has been published. Analysis of the ~4.64-Mb genome sequence showed 5,006 promoter sequences, 62 tRNAs, a single copy of 5S-16S-23S rRNA, and a genome average GC content of 51.2%. Draft genome sequence of another rice endophytic diazotroph *Bacillus paralicheniformis* strain KMS 80 (MTCC 12704), containing 4,566,040 bp and 4,424 protein-coding genes has been published. This whole-genome project has been deposited at DDBJ/ENA/GenBank under accession no. MUEH 00000000 (BioProject no. PRJNA 360479). Analysis of the genome showed 8,692 promoter sequences, 67 tRNAs, 20 rRNA genes with six copies of 5S rRNAs along with a single copy of 16S-23S rRNA and genome average GC-content of 45.50%. Twenty one genes involved in nitrogen metabolism pathway and two main transcriptional factor genes, *glnR* and *tnrA* responsible for regulation of nitrogen fixation in *Bacillus* spp. were predicated from the whole genome of strain KMS 80. NCBI submissions of 16S rDNA gene, *nifH, nodC* gene has been done.

4.8 ENVIRONMENT SCIENCE AND CLIMATE RESILIENT AGRICULTURE

4.8.1 Seasonal Climate Change Projections for India

The Seasonal climate change projections for India indicated that during *kharif,* minimum temperatures will increase in the range of 0.946 - 4.067 °C (2020 to 2080) in different regional climate projections (RCPs) over baseline temperatures, while the projected increase in *rabi* is in the range of 1.096- 4.652 °C (2020 to 2080). Similarly, maximum temperatures during *kharif* will increase in the range of 0.741 - 3.533 °C (2020 to 2080) in different RCPs while the projected increase in *rabi* is 0.882- 4.01 °C (2020 to 2080). Rise in temperatures are projected to be more in northern parts of India than in southern parts. *Kharif* rainfall is projected to increase in the range of 2.3-3.3 (2020), 4.9-10.1% (2050), while *rabi* rainfall is projected to increase in the range of 12 (2020) to 12-17% (2050). The variability in minimum and maximum temperatures as well as that of rainfall may increase significantly. The CO_2 concentration is projected to increase in the range of 419-432 µmol (2020), 441-572 µmol (2050) and 429 to 799 µmol (2080) in different RCPs.

4.8.2 Estimates of Greenhouse Gas Emission from Indian Agriculture

The updated inventory for the year 2014 showed that the agricultural sector, including crop and animal husbandry, emitted 400 Mt of CO_2 eq. The agricultural soils emitted 20% of the total CO_2 eq. emission from agriculture, whereas rice cultivation contributed 18%. Livestock manure management contributed 7% of the emissions and 2% was attributed to the burning of crop residues in field. The direct and indirect N_2O emissions

Greenhouse gas emissions from Indian agriculture in 2014

Source	Methane (Mt)	Nitrous oxide (Mt)	GWP (Mt CO2 eq)
Livestock	10.05	-	211
Manure management	-	0.09	27
Rice cultivation	3.47	-	72.84
Agricultural soils	-	0.26	80.53
Crop residue burning	0.29	0.01	8.71
Total	**13.82**	**0.28**	**400**

from Indian agricultural soils were 216 Gg and 43 Gg (80.5 Mt CO_2 eq.), respectively, in 2014. Fertilizer was the largest source contributing 77% to the total direct nitrous oxide emissions. The methane emission was highest from the irrigated continuously flooded rice (32%) amongst the different rice ecosystems , followed by rainfed flood prone rice and irrigated single aeration (14% each), rainfed drought-prone, deep water and irrigated multiple aerations rice ecosystems contributed 29%, 8% and 3% of CH_4, respectively.

4.8.3 Impact of Crop Diversification on Greenhouse Gas Emissions

Measurement of methane, nitrous oxide and carbon dioxide emission was carried out in rice-wheat (direct seeded rice), rice-vegetable peas-okra, maize-potato-onion, maize-wheat-mungbean to quantify the impact of crop diversification on greenhouse gas emission. Global warming potential of the different cropping systems was also quantified. Highest GWP were observed in maize-potato-onion system due to higher nitrous oxide emission.

4.8.4 Impact of Conservation Practices on GHG Emission in Rice-Wheat Crop Rotation

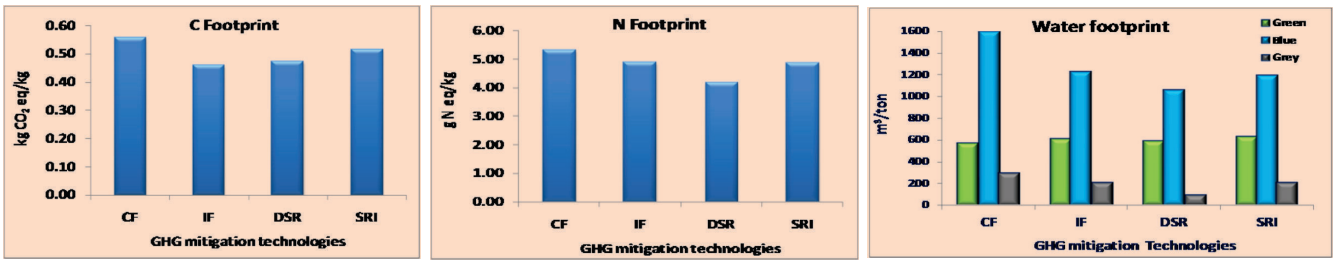
Measurement of methane, nitrous oxide and carbon dioxide was carried out for the second year under resource conserving technologies like, zero tillage, residue retention and different planting methods from soils in rice-wheat with two levels of fertilizer application for quantifying their global warming mitigation potential (GWP). The GWP reduced by 29.7% from the conventional to double zero tilled system. The GWP of double zero till and triple zero till systems were found to be at par. In rice the highest GWP was in MBR (100% N) treatment due to higher carbon dioxide emissions. Incorporation of rice residue in wheat decreased the N_2O emissions but increased the carbon dioxide emissions.

4.8.5 Carbon, Nitrogen and Water Footprint of Different Water Management Practices in Rice Cultivation

Carbon, nitrogen and water footprints of rice crop production under different water management

Greenhouse gas emission from different cropping system

Cropping Systems	Methane (kg ha^{-1})	Nitrous oxide (kg ha^{-1})	GWP (kg CO_2 eq.)
DSR - Wheat	3.45	2.44	829
DSR-Vegetable Pea-Okra	3.96	2.98	1007
Maize– Wheat –Mungbean	-	2.77	859
Maize –Potato- Onion	-	3.78	1172



Carbon, nitrogen and water foot print of different water management practices in rice

practices viz., continuous flooding (CF), intermittent flooding (IF), DSR and SRI were estimated using life cycle of rice up to farm gate. Methane emission was maximum from CF (26.6 kg ha^{-1}) and lowest from DSR (5.46 kg ha^{-1}). The carbon emissions during rice cultivation varied between 2636 and 3421 CO_2 eq ha^{-1} among the treatments. Nitrogen footprint from N input in rice crop ranged from 37.0 to 55.3 kg N ha^{-1}. The total water footprint of crop production was 2538, 2140, 2217 and 2164 m^3/season from CF, IF, DSR and SRI, respectively. The green, blue and grey water footprint varied from 18 to 29, 53 to 63 and 18 to 20%, respectively, in the total water footprint.

4.8.6 Aggregate–Associated N and Global Warming Potential of Conservation Agriculture Based Maize-Wheat Cropping System in North-Western Indo – Gangetic Plains

Effects of a CA (5-years) on total soil N (TSN) changes in bulk soils and aggregates, N_2O emission, GWP and total C fixed in soils under maize-wheat system were assessed. The treatments comprised of conventional tillage (CT) and zero tillage (ZT) with planting on permanent narrow beds (PNB), PNB with residue (PNB+R), ZT with planting on permanent broad beds (PBB) and permanent broad beds with residue (PBB+R). Results revealed that the soils under PBB+R had 37 and 9% more macroaggregate-and microaggregate-associated N concentrations in topsoil (0-5 cm layer) than CT (248 and 299 kg N ha^{-1}). However, topsoil soil aggregation and aggregate-associated N contents of PNB+R and ZT+R were similar to CT plots. The N_2O emission was highest in PNB+R and least in CT treatment. The GWP of ZT+R and PBB+R plots in the maize-wheat system were ~5% higher than CT. Thus, PBB+R practice is a better management alternative for soil N improvement than CT. PBB+R practice also had ~22% greater crop productivity in the maize-wheat cropping system.

4.8.7 Interactive Effect of Elevated Carbon Dioxide and High Temperature on Different Rice Varieties

Four different rice varieties, namely, Pusa Basmati 1509, Pusa 44, Pusa Rice Hybrid 10 (PRH 10) and Nagina 22 were grown inside Open Top Chambers (OTC), at IARI farm, New Delhi to study the impact of elevated carbon dioxide (CO_2) level (500±50 ppm) and temperature (elevated + 2 °C). Maximum grain weight was recorded in Pusa Basmati 1509 variety in elevated CO_2. Grain yield of all rice varieties, except Nagina 22 was reduced due to 2ºC rise in temperature. Negative effect of increased temperature in terms of reduction in grain number was compensated by rise in CO_2 concentration. Biomass and nitrogen (N) accumulation to roots got increased under elevated CO_2 condition, while proportion of N partitioning to grains decreased under elevated CO_2 condition.

4.8.8 Impact of Interaction of Elevated Carbon Dioxide (CO_2) and Ozone (O_3) on Crop Growth and Productivity in Rice

Experiments were conducted with seven rice cultivars grown in free air ozone and carbon dioxide enrichment rings (FAOCE) to study to the impact on productivity and GHG emissions. The experiments were conducted under ambient and elevated CO_2 (550 ppm) and elevated ozone (60 ppb).The decline in yield in different rice varieties varied from 5 to 26% under

elevated ozone. Elevated CO_2 increased yields by 8 to 15%.

4.8.9 Effect of Modified Urea on Nitrogen Use Efficiency and Yield of Wheat

A field experiment was conducted to assess the effect of prilled urea (PU), phosphogypsum coated urea (PGCU), neem oil coated urea (NOCU) and oleo-resin coated urea (ORCU) on yield, nitrogen (N) use efficiency (NUE) of wheat (cv. HD 3086) under irrigated condition. Nitrogen was applied @ 150 kg ha^{-1} in three split doses. The highest grain yield of 6.36 t ha^{-1} was recorded from ORCU and the lowest value of 3.03 t ha^{-1} was obtained from control. The N use efficiency was maximum with resin coated urea (22 kg grain yield increase/ kg of N applied), followed by phosphogypsum coated urea (19.6 kg grain yield increase/ kg of N applied) and neem oil coated urea (18.7 kg grain yield increase/ kg of N applied) treatments.

4.8.10 Emission of Air Pollutants and GHG from Rice Residue Burning in Punjab and Haryana

Based on satellite data, 74.3% of rice area in Punjab and 28.4% in Haryana was subjected to *on farm* burning during the year 2016. In Punjab alone, approximately 14.97 million tons of rice crop residue was burned on farm, whereas in Haryana it was 1.95 million tones. Burning of rice residue resulted in emission of greenhouse gases and particulate matter. The emission of GHG and air pollutants (CH_4, N_2O, CO_2, CO and TPM) was 20.4 Mt in Punjab and 2.66 Mt in Haryana. This may have direct or indirect effect on the radiation balance of this planet affecting its climate and contributing to global climate change.

4.8.11 Effect of Particulate and Gaseous Pollutants on Growth, Yield and Sulfur Nutrition in Crops

A controlled experiment was conducted in enclosed tunnels to assess the effect of different level of particulate and gaseous air pollutants in the air on growth and yield of bread and durum wheat, barley, chickpea, leafy and root crops. Four different environments were created using filters and releasing a known concentration of SOx and NOx into the tunnels. Results indicated that exposure of crops to elevated level of SOx and NOx had maximum detrimental effect on growth and yield of the crops. Amongst the crops, the yield performance of bread wheat was comparatively better than those of durum wheat and barley both under polluted and pollution free ambient environments, while chickpea and spinach were found most sensitive to particulate and gaseous pollution.

4.8.12 Impact of Gaseous and Particulate Pollutants on Crops Near NTPC, Dadri

Level of total suspended particulate matter (TSP), SO_2, NO_2 and O_3 and aerial dust deposition on crop canopy was quantified at the selected experimental sites of Akilpur Jagir, Pyawali Tajpur, Jarcha, Uncha Amirpur, Khangoda, Nagla Kashi, Nidhauli, Ranauli Latifpur, Tatarpur and Salarpur Kalan villages in the vicinity of NTPC, Dadri. Anticipated performance index (API) value showed that *Triticum aestivum* and *Oryza sativa* were best-suited crops in the selected study areas as compared to other crops.

4.8.13 Impact of Air Pollutants on Physical, Chemical and Biological Properties of Soil

The soil samples were collected from the sites in the vicinity of NTPC, Dadri, UP (in 10 km periphery) to assess the effect of particulate matter deposition on the soil surface. The maximum deposition of particulate was observed during winter months of 2017-18 at Piyawali Tajpur (3.35 g m^{-2} $month^{-1}$), followed by Akilpur Jagir and minimum at Nagla Kashi (1.12 g m^{-2} $month^{-1}$) as compared to 2016-17. The particulate sizes from 0.3 to 10 µm were also analyzed at different sites, but there were no significant differences in their concentrations. The maximum concentration of PM10 was observed at Salarpur Kalan (568 µg m^{-3}) and minimum at Nagla Kashi (193 µg m^{-3}). The concentration of heavy metals in soil was found more during 2017-18 as compared to 2016-17 at all selected sites in case of Zn (except Nidhauli), Pb and Cd. This

was probably due to more particulate deposition from the coal-based thermal power plant. The heavy metal concentration in particulate matter is variable during 2016-17 and 2017-18 at all sites, because the composition of particulate matter depends on coal properties and plant efficiency. The pH value of soil ranged from 7.57-8.84 and 7.60-8.90; EC value ranged from 0.242-0.481 mmhos cm^{-1} and 0.250-0.497 mmhos cm^{-1} during 2016-17 and 2017-18, respectively. The bacterial population mostly reduced during 2017-18 as compared to 2016-17 but fungal populations do not show any specific trend during the study.

4.8.14 Air Pollution Tolerance Index (APTI) of *Rabi* Season Crops

Air pollution tolerant index (APTI) is an index denotes capability of a plant to combat against air pollution. APTI values for *rabi* crop species, i.e., wheat (*Triticum aestivum*), *methi* (*Trigonella foenum-graecum*), garlic (*Allium sativum*), chickpea (*Cicer arietinum*), tomato (*Solanum lycopersicum*), broad bean or bakla (*Vicia faba*), pea (*Pisum sativum*) and carrot (*Daucus carota*) grown in surrounding villages of NTPC, Anta are assessed. Analysis of tolerance level of crop plants showed that wheat, tomato, pea, *methi*, and chickpea with APTI values of 12.2, 12.1, 12.0, 10.8 and 10.8, respectively, were identified as intermediate tolerant species to pollution. Whereas, garlic, broad bean, and carrot with APTI values of 9.48, 9.73 and 9.78, respectively, were designated as a sensitive crop species.

4.8.15 Pollution Resistance of Airborne Bacteria

Heavy metal resistance of twenty five airborne bacterial isolates was tested on enriched R2A agar plates with heavy metal salt of cadmium sulphate. As the concentration of heavy metal cadmium sulphate was increased to 100 µg ml^{-1}, an increase in pigmentation of isolate S2UK1 was recorded; thereby, indicating that such kind of bacterial isolates can be used for bio monitoring of pollution. S2UK1 has been identified as *Staphylococcus capitis subsp. Capitis*. The isolate S2UK1 *Staphylococcus capitis subsp. Capitis* and IBM5 identified as *Exiguobacterium profundum* also showed high percentage survival in the presence of xylene.

4.8.16 Assessment of Bioremediation Potential of Heavy Metals Contaminated Waste Water through Microbial and Other Biosorbents

Six nickel resistant bacterial strains were isolated from microcosm systems, artificially spiked with different levels of nickel (Ni), chromium (Cr) and lead (Pb) and planted with different aquatic hyper accumulator plants. All the strains showed a minimum inhibitory concentration (MIC) value of 500 mg L^{-1} of Ni. Nickel removal capacity of these microbes was assessed through using Ca-Alginate based immobilization technique. Out of six resistant microbial isolates, optimum condition for best performance/maximum removal of Ni^{2+} by Isolate-1 was found to be 79% under laboratory conditions with bacterial dose of 0.2 g /100 ml beads, 4% Ca-Alginate at pH 1.0.

4.8.17 Ammonia Volatilization Losses from Soils under Wheat in Conservation and Conventional Tillage

A field experiment was conducted to quantify the volatilization losses from conservation and conventional tillage practices in wheat crop. The treatments involved conservation agriculture (no-tillage+residue retention) and conventional tillage (tillage+no-residue) and different N application methods viz., urea super granules with band placement, slow release N fertilizer (Urea stabilized with DCD and N-(n-butyl) thiophosphoric triamide) with band placement, neem coated urea with band placement, neem coated urea with broadcast before irrigation and neem coated urea with broadcast after irrigation. The cumulative emission of ammonia from wheat field varied from 6.23 to 24.0 kg ha^{-1} in conservation tillage and 7.03 to 26.6 kg ha^{-1} in conventional tillage. Maximum volatilization loss was from placement of urea super granules and minimum was from band placement of urea stabilized with DCD and N-(n-butyl) thiophosphoric triamide.

5. CROP PROTECTION

Pests and pathogens cause quantitative and qualitative losses in field and horticultural crops.Changing climate is affecting pest and pathogen dynamics, hence there is need to plan crop protection strategies that include cultural, biological and chemical methods to provide most effective and sustainable options. The school of crop protection develops and employs innovative control measures to counteract the impact of insects, plant diseases and weeds. 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. Correct diagnosis is prerequisite to sustainable management. Besides biological control measures, novel chemical molecules were identified to form a part of integrated management. Identification of sources of resistance against major pests and pathogens were also undertaken, which shall be used for breeding resistant crop varieties.

5.1 PLANT PATHOLOGY

5.1.1 Genetic Variability, Pathogen Characterization and New Records

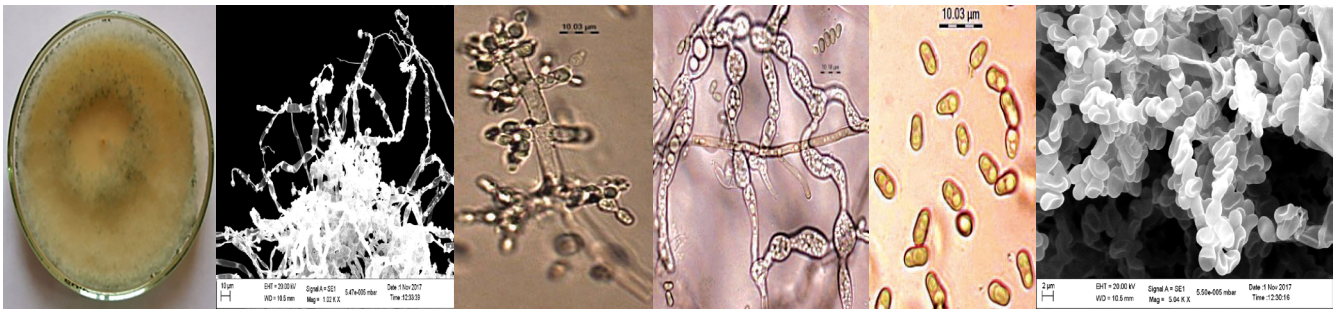
Genetic variability in Tilletia indica. Seven MLST fragments were selected, amplified and sequenced in a panel of 20 *Tilletia indica* isolates. In total, 140 gene sequences viz., Actin related Protein 2 (MG655312-G655331), Tubulin beta chain (MG655332-MG655351), Glyceraldeyde-3-phosphate dehydrogenase (MG386602- MG386621), Eukaryotic translation initiation factor 3 subunit A (MG386622-MG386641), Phospho glycerate kinase (MG701241-MG701260), Serine/Threonine Protein kinase (MG655332- MG655351) were submitted in NCBI database.

Phylogenetic analysis of rice bakanae pathogen, F. fujikuroi. Based on whole genome sequence phylogenetic analysis of the 6 isolates of *Fusarium fujikuroi* from Asia and America revealed Indian isolate "F250" closer to Taiwan isolate "IMI58289".

Characterization of Stemphylium, Alternaria and Ulocladium genera complex. Identification of eleven species of *Stemphylium, Alternaria and Ulocladium was* done using morphology, ITS sequences and chemo-profiling. *A. consortiale* was clustered with *Ulocadium consortiale*, therefore, this species is proposed to be transferred from *Alternaria* to *Ulocladium* .

Characterization of diverse Papaya ringspot virus (PRSV) population. Three vital protein coding regions of PRSV viz., coat protein (CP), helper component proteinase (HC-pro) & nuclear inclusion protein-a (NIa-pro) from 19 PRSV-P & -W isolates when analyzed, showed heterogeneity in CP (846-876 bp), but not in HC-pro (1370 bp) &NIa-pro (723bp). Highest variability in sequence length and identities was noticed among cucurbit-originated Indian PRSV-P isolates, representing warm semi-arid (WSA) climate.

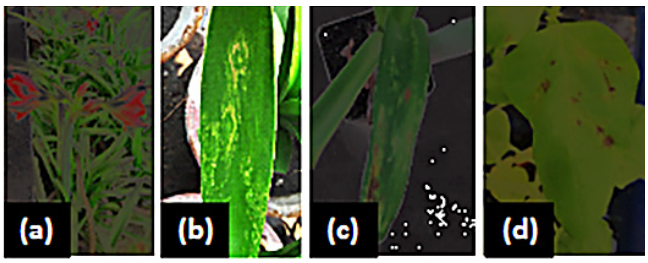
Trichoderma dumbbelliforme* sp. nov., *an undescribed fungus of order hypocreales from India. *Trichoderma dumbbelliforme*, collected from virgin forest soil of Nagaland, was confirmed as a new species of *Trichoderma* based on morphological and phylogenetic analysis. *Trichoderma dumbbelliforme* sp. nov.is distinguished from other species of *Trichoderma* by producing nodules on sterile part of the conidiophores and pyriform to dumbbell shaped conidia with the size of 4.0-6.0 × 2.5-3.0 µm and having two big guttulae at each end. Translation elongation gene (tef-1) sequences did not match with any reported species.



1 2 3 4 5 6

T. dumbbelliforme **sp. nov.: (1) Growth on PDA, (2) nodulation on sterile condiophores under SEM, (3) Phialide disposition, (4) Chlamydospores and hyphal swellings, (5) Conidia, (6) Conidia under SEM**

Red trumpet lily as a new host of Capsicum chlorosis virus (CaCV). The chlorotic and necrotic ring spots were noticed on the leaves of red trumpet lily (*Hymenocallis* sp.) plants reacted with the antibodies raised to *Groundnut bud necrosis orthotospovirus* (GBNV). Further, RT-PCR specific to replication-associated protein (RdRP) of all the orthotospo viruses and the primers specific to N gene of CaCV followed by sequencing confirmed the association of CaCV with the symptomatic plants.



Red trumpet lily plants with natural infection by CaCV (a and b), and with mechanical sap transmission on red trumpet lily (c), and on cowpea plants(d)

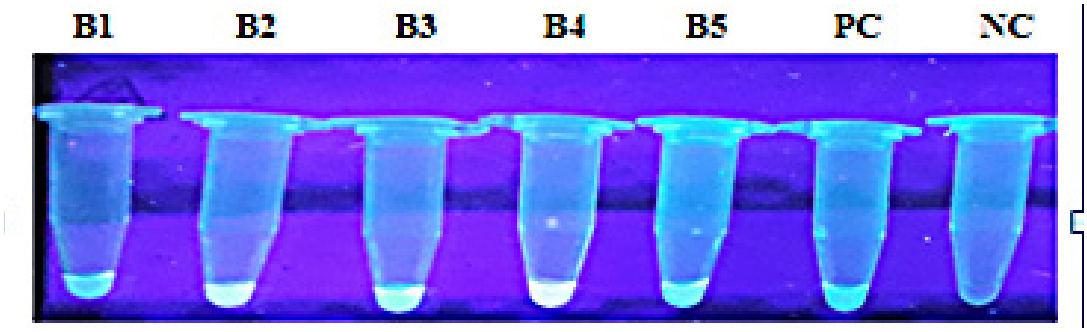
Molecular characterization of phytoplasmas associated with four ornamental plant species in India. Phytoplasma suspected symptoms of phyllody, witches' broom, leaf yellowing, stunting and little leaf were observed in *Chrysanthemum morifolium, Bougainvillea glabra, Jasminum sambac* and *Callistephus chinensis* during survey of flower nurseries and experimental ornamental fields. Pairwise sequence comparison, phylogeny and virtual RFLP analysis of 16S rDNA sequences confirmed the association of two phytoplasma subgroups (16SrI-B and 16SrII-D) in four ornamental plant species. The identification of 16SrII-D subgroup phytoplasma infecting bougainvillea and 16SrI-B subgroup infecting jasmine are the new reports.

Identification and characterization of Candidatus phytoplasma trifolii (16Sr VI-D) infecting potato in India. Sequence comparison for *secA* gene of potato with shoot proliferation symptoms showed 99% sequence identity to *secA* gene sequences of brinjal little leaf phytoplasma strains. Phylogenetic analysis of 16S rRNA and secA gene sequences, and virtual RFLP analysis confirmed their clustering and grouping with strains of clover proliferation subgroup D. Results confirmed potato as a new host of 16SrVI-D subgroup of phytoplasmas.

Chickpea Stunt: A complex disease caused by a mastervirus, cucumovirus and Candidatus phytoplama trifoli in India. The association of phytoplasma was confirmed in symptomatic chickpea plants by direct and nested PCR assays. Analysis of the sequences revealed that 16Sr DNA sequence of chickpea stunt phytoplasma isolate had 99% sequence homology with strains of 16SrVI group phytoplasmas. *Chickpea chlorotic dwarf virus* (CpCDV) (genus Mastrevirus, family Gemini viridae) and *Cucumber mosaic virus* coat-protein-specific primers confirmed the presence of these viruses with the chickpea stunt disease and little lead disease.

5.1.2. Molecular Diagnostics

Development of fluorescence based isothermal reverse transcription-recombinase polymerase amplification assay for on field detection of Cucumber



CMV detection by reverse transcription-recombinase polymerase amplification assay RT-exoRPA using crude leaf sap: (B1 to B5) - CMV infected banana leaf samples, PC-positive control & NC-negative control

***mosaic virus* (*CMV*).** For detection of Cucumber mosaic virus (CMV), primers and probes were designed from the conserved coat protein gene of CMV and fluorescence based isothermal reverse transcription-recombinase polymerase amplification (RT-exoRPA) assay for on field detection of CMV was developed and validated.

Development of immunodiagnostics for GLRaV-4 infecting Indian vineyards. An immune diagnostics (DAS-ELISA) for detection of GLRaV-4 has been developed based on polyclonal antiserum produced to recombinant coat protein of GLRaV-4, which was validated with GLRaV-4 CP (purified) and GLRaV-4 infected grapevine samples from different grape orchards across India.

Development of Recombinase Polymerase Amplification (RPA) assay for simplified detectionof citrus greening (Huanglongbing) bacterium. LAMP based detection assay was developed and validated for Huanglongbing or citrus greening disease using specific primers designed from outer membrane protein (OMP) and 16S rRNA region of CGB.

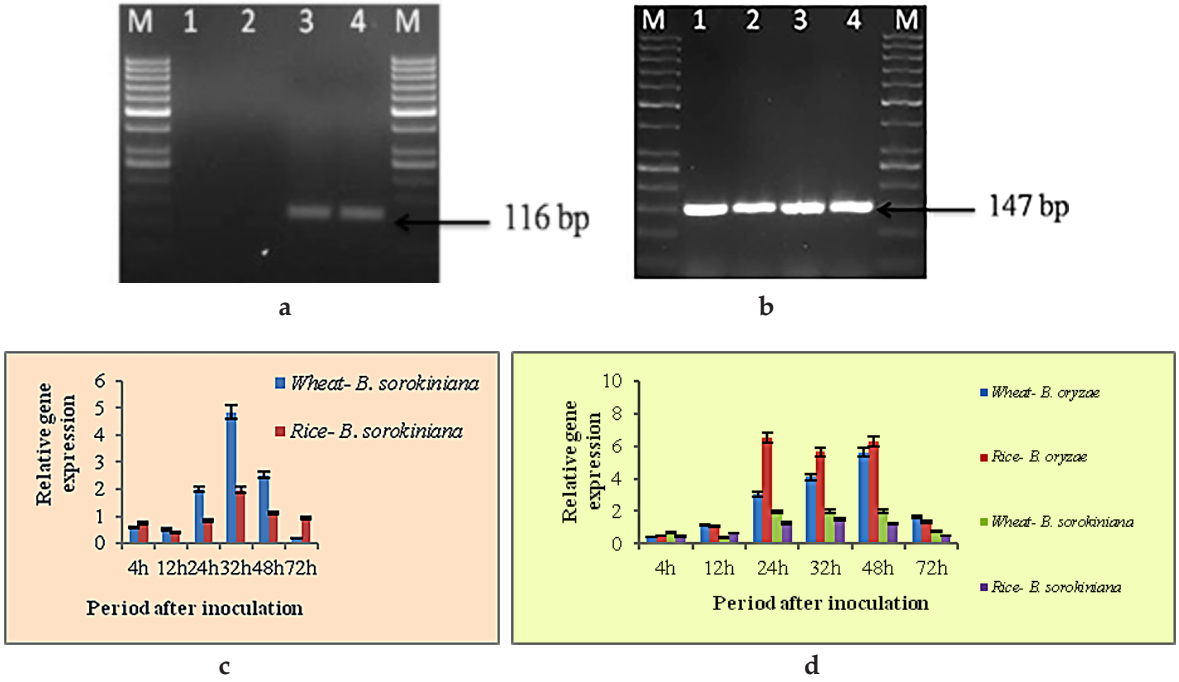
Identification and development of serological and molecular diagnostics of viruses infecting orchids. Out of 37 samples of different orchid species and hybrids collected from Sikkim, 26 samples reacted positive with polyclonal antibodies to either CymMV or CymMV and ORSV together. *Phalaenopsis* plant was found to have mixed infection of *Groundnut bud necrosis orthotospovirus* (GBNV), CymMV and ORSV.

5.1.3. Whole Genome Sequencing and Host-Pathogen Interaction

Whole genome sequencing of Bipolaris sorokiniana (spot blotch of wheat). Genomic DNA of spot blotch pathogen *B. sorokiniana* (Bs112, Gene bank Accession no. KU201275) was subjected to whole genome sequencing on Ion Torrent and Illumina. Joint assembly showed 10566 scaffolds and 22769 contigs. The size of the assembled genome was 34.81 MB. Further sequencing using Oxford Nanopore Technology was also performed and a total of 560150 raw reads were obtained with a N50 value of 75313.

An intergeneric comparative secretomics analysis between Bipolaris sorokiniana and Bipolaris oryzae. Cross infectivity was established i.e., *B. sorokiniana* proved to infect rice and *B. oryzae* infects wheat under *in vitro* as well as under natural conditions which was confirmed by PCR using species specific markers. Comparative secretomics revealed the presence of 262 and 247 small secreted proteins in *B. sorokiniana* and *B. oryzae*, respectively. In expression analysis study, BS_SSP 2 was identified as a potential effector protein for *B. sorokiniana* and another common putative protein (BOBS_SSP2) may act as putative effector for *B. oryzae*, irrespective of the host.

Comparative genome analysis for identification of pathogenicity genes in Tilletia indica. Comparative genome analysis suggested that 3,751 proteins of *T. indica* had orthologs in five fungi whereas 126 proteins were unique. Secretome analysis revealed the presence of 1,014 secretory proteins in the genome. Based on homology of pathogenicity proteins, 97 genes were



PCR amplification of shortlisted SSPs with genomic DNA (a) BS_SSP2 (b) BOBS_SSP2; M- Molecular marker (50bp DNA ladder); Lanes 1: BO-1; 2: BO-2; 3: BS-112; 4: BS-75 Expression pattern of selected SSP in wheat and rice on inoculation with B. *oryzae* and *B. sorokiniana* at 4, 12, 24, 32, 48 and 72 h was observed by q-PCR (c) BS_SSP2; (d) BOBS_SSP2

related to effector (Plant avirulence determinant), 25 genes to increased virulence, 63 genes to loss of pathogenicity and 7 genes resistance to chemicals. Abiotic/biotic stress responsive gene,*TiHOG1* (1104 bp) was identified and functionally characterized in *Tilletia indica*. This gene elicited up to 19.61-fold increase in response to a susceptible host factors may have a role in pathogenesis. Whole transcriptome analysis revealed 503 genes which were upregulated and 387 down regulated (FDR) in resistant genotype.

LAMP based detection of wheat fungal pathogens. The fungi from wheat leaves were identified as *Cladosporium* sp. and *Alternaria* sp. *Fusarium solani* was isolated from wheat seeds. The fungi causing foliar blight in rye was isolated and identified as *Bipolaris sorokiniana*. Rust infected grasses were collected, the rust infecting the grass *Panicum repens* was morphologically identified as Uromyces sp. ITS regions were amplified and sequenced for *Bipolaris sorokiniana* (Rye), *Bipolaris* sp. (Barley) *Fusarium graminearum* (head scab of wheat), *Fusarium* sp.(wheat), *Chaetomium globosum, C. megalocarpum*, *Cladosporium* sp. and *Sphaerellopsis* sp. (mycoparasite on brown rust) by CTAB Method. Four isolates of *Fusarium graminearum* causes head scab of wheat isolated from southern hill zone were used for developing LAMP based detection technique.

Molecular methods to confirm Lr24 gene in P. triticina infected germplasm/genotypes. To confirm variability in infection intensities in target genotypes which may have *Lr*24 gene, SRT analysis was performed repeatedly by using selective isolates of *P. triticina,* which have been originally purified from respective lines/genotypes grown under field conditions. Genomic DNA was isolated and desired amplification types were detected from target gene specific marker. Presence of amplicon of *Lr*24 gene was detected in 10 genotyeps comprising iso-genic lines and varieties of *T. aestivum* (AI0033 Tc*6/Agent-, AI0067 CS 3D/3Ag#3, DL-784-3, 3 Ag# (RNS 130 *Lr* 24), Agent *Lr*24, var. Harshita, Abha, Vadisha, MP 4010 and HW 2021). However, at initial screening using SCAR marker, most of other genotypes which are negative with genetic marker also responded positive with *Lr*24 gene amplicon. To ascertain, two sets of amplicons

from four samples were randomly selected and submitted for specific gene sequencing. This is the first time attempt to sequence *Lr*24 gene for comparison and validation owing to unavailability of specific sequence of *Lr*24 in NCBI data base.

Prediction and validation of bakanae pathogen Fusarium fujikuroi secretome. Of the 13603 proteins predicted in the genome of *F. fujikuroi* isolate F250, a total of 1194 sequences were predicted as secretory proteins, out of which 585 proteins have shown matches with PHI-database.

Whole genome sequence of Ralstonia solanacearum. Genome of *R. solanacearum* Biovar 3, Phylotype I, Race 1 strain UTT-25 was sequenced using Illumina MiSeq. A total of 171 contigs with the longest contig length of 166,162 bp were assembled and 3,679 proteins were predicted.

Characterization of phyllosphere microbiome of rice. The core microbiome analysis showed multi-microbe-core (99 in resistant cultivar and 66 in susceptible cultivar) consisting of *Pantoea, Methylobacterium, Streptophyta, Microbacterium, Sphingomonas, Enterobacter, Pseudomonas, Erwinia, Trabulsiella, Agrobacterium, Hymenobacter, Kineococcus, Klebsiella, Deinococcus,* and *Novosphingobium* species on phyllosphere of susceptible rice genotypes grown in contrasting climatic zones.

Metabolite profiling during Fusarium fujikuroi-rice interactions. A total of 139 volatile compounds were detected in *Fusarium fujikuroi* inoculated rice plants at different hours of treatment through GC-MS analysis, out of which cycloeicosane was present only in inoculated plants which increased with time.

Detection of Apple chlorotic leaf spot virus (ACLSV) in apple and pear plants. A Reverse Transcription Loop-Mediated Isothermal Amplification (RT-LAMP) assay was developed for the detection of *Apple chlorotic leaf spot virus* (ACLSV) in apple and pear plants at IARI, Shimla. The results of RT-LAMP amplified products were also visualized by adding SYBER gold nucleic acid fluorescent dye. The negative samples showed dark orange colour, whereas positive samples showed fluorescent yellowish green colour.

Thrips tospo virus interaction. *Thrips palmi* proteins interacting with the GBNV glycoproteins were identified *in silico*. Cathepsin B, Adaptor protein 2, clathrin were recognized to be associated with GBNV internalization in thrips. Protein-protein docking analysis indicated positive interaction of Gn of GBNV and these thrips protein.

Pathogenic effect of tospoviruses on thrips vector. The effect of *Groundnut bud necrosis virus* (GBNV) and *Watermelon bud necrosis virus* (WBNV) on the life cycle of *T. palmi* showed alteration in the life cycle of the vector. In both the cases, the larval period was shortened and pupal survivability was decreased compared to control.

New phytoplasma disease in bottle gourd from Pune, India. For the first time, a novel phytoplasma subgroup 16SrI-X was found associated with bottle gourd [*Lagenaria siceraria* (Mol) Standl.] virescence and phyllody disease in India. The obtained 16S rRNA gene sequences (LT594117 and LT594118) showed 99.12 % homology with a strain AYWB (*'Ca.* Phytoplasmaasteris', CP000061). The analysis based on RFLP and 16S rRNA gene sequences indicated that this phytoplasma belong to 16SrI-X subgroup.

5.1.4 Biological Control

Characterization of strains of Trichoderma spp. producing higher amount of bioactive compound. Five *Trichoderma* isolates were used to identify higher amount producer of 6-pentyl pyrone (6 pp) under controlled conditions. Results indicated that *T. atroviride* isolate 4 produced higher 6pp while isolate 2 was unable to produce 6 pp under same set of conditions.

Understanding Fusarium wilt resistance of tomato induced by a biocontrol consortium. Biocontrol consortia comprising of varying combinations of *Pseudomonas putida* (TEPF), *Bacillus subtilis* (S2BC-1), *Trichoderma harzianum* (S17TH) and *Chaetomium* spp. (CG-A) were designed earlier based on *in vitro* and pot experiments. In characterization of one defense

gene, *gluB* of tomato induced by a potential biocontrol consortium, the 42-kDa recombinant endo β-1,3-glucanase (*gluB*) displayed enzyme activity over a temperature range of 28-60 °C with a temperature optimum of 60 °C and was active at pH 3-6 with an optimum of pH 4.0. The recombinant protein (20 µg) completely inhibited conidial germination of the pathogen after 3 days of treatment while the control conidia showed germination.

Development of mutant of Bacillus amyloliquefaciensto improve antagonistic ability. Out of mutants of *Bacillus amyloliquefaciens* DSBA-11 developed using UV irradiation and chemical mutagens (N-methyl-N-nitro-N-nitroso guanidine and Nitrous acid), mutant strain MHNO $_2$-20 treated with nitrous acid was found very effective producing 46.0 mm inhibition zone against *R. solanacearum,* which was higher than the parent *B. amyloliquefaciens*DSBA-11 (33.5 mm).

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

Wheat. Among the 576 PDSN wheat entries of IARI breeders evaluated for rusts and leaf blight resistance at different hot spot locations, 45 entries were found to be highly resistant against the rusts and leaf blight at adult plant stage across the test locations. Out of 173 entries evaluated against stripe rust pathotypes, 78S84 and 46S119 for adult plant resistance, 31 entries showed high degree of resistance.

Out of 2160 lines evaluated under field conditions at IARI, Wellington, 94.12% (2033) lines were free from leaf rust infection. Among breeding climate resilient wheat varieties, 82.2% lines out of a total of 669 lines were completely free from leaf rust infection. In off-season summer nursery programme 2017, 3900 wheat breeding lines were screened for adult plant resistance against stem rust. About 3116 lines were found to be immune and 379 expressed susceptible reaction with the field response of 10S whereas 321 lines showed susceptible reaction.

A total of 584 genotypes of preliminary disease screening nursery (PDSN) were evaluated at Indore for resistance to stem and leaf rusts under artificial inoculations using mixtures of important pathotypes during *rabi* 2016-17. Of these, 427 entries (~73 % of the total) showed resistance (coefficient of Infection value up to 10.0) to both stem and leaf rusts. Out of 100 bread wheat entries from Indore, 32 genotypes were found to be resistant to all three rusts. Among 589 advanced wheat breeding lines, evaluated under PDSN at rust hot spot HAREC Dhaulakuan, 353 have shown resistance to stripe rust under natural condition. Among 160 CVT entries of wheat, 17 were found to possess seedling resistance to most virulent pathotypes *viz.*, 78S84, 110S84 and 110S119 of wheat. Out of 143 lines (wheat & triticales) comprising of advance lines (AVT 1st and 2nd year) and popular cultivars evaluated for Karnal bunt (*Tilletia indica*) resistance, 23 lines viz., HPW 251, HS 375, HS 490, HS 507, VL 829, DBW 173, DBW 90, HD 3043, PBW 644, WH 1021, HI 1612, HD 2733, HD 2888, K 1006, DBW 110, UAS 446, DBW 14, KHARCHIA 65, KRL 19, KRL 210, TL 2942, TL 2969, WR 544 showed resistance (<5.0 % Karnal bunt infection). Out of thirty four fixed lines developed by crossing *Triticum militinae* and Chinese Spring, 12 lines were found free from KB. Out of fifty three lines (wheat &triticales) evaluated for head scab (*Tilletia indica*) resistance under controlled conditions, HS 622, PBW 725, PBW 760, TL 3006, TL 3007, VL 3012, WH 1310, WH 1184, MACS 5044, MACS 5046, VL 4001 and VL 3011 showed resistance.

Rice. Out of 571 genotypes evaluated against sheath blight, 4 entries *viz.,* IHRT E 11, RP-Patho-9-12-9, MS,-TH-154-1, 6436 were found moderately resistant. Out of 354 entries evaluated for leaf blast resistance, one entry (3823) showed resistant reaction and 41 entries were moderately resistant. Out of 26 entries evaluated for virulences of *Pyricularia oryzae*, Raminad STR-3, *O. minuta,* Zenith, Tetep and Rasi were found to be resistant.

Maize. Out of 384 maize genotypes evaluated against maydis leaf blight (MLB), *Bipolaris maydis* and banded leaf and sheath blight (BLSB), *Rhizoctonia solani,* 223 entries were found resistant to MLB disease,

32 entries were resistant to BLSB and 20 entries [DKC 9178(IQ8623), CCH 9241, MM 2030, VaMH 13024, VNR 33051, MH 26, SVMH 55, JH 13023, JH 15135, NS 8181, QMH-1435, AH 7005, IMH 1533, GH 150114(CAH 1414), Kranthi, IMHBG 2016-5, GH 150125(CAH 1525), ADV 0990296, Bio 9681 and CP 201] were resistant against both the diseases.

Pearl millet. Out of 126 entries evaluated for blast resistance, only 16 entries (ICMB 07111 (ICRISAT), ICMR 06444 (ICRISAT), IP 11036 (ICRISAT), ICHPR-17-3 (ICRISAT), ICMR 15003 (ICRISAT), ICMR 15009 (ICRISAT), ICMR 100860 (ICRISAT), ICMR 100870 (ICRISAT), MH 2107, MH 2114, MH 2173, MH 2224, MH 2267, MP 574, MPMH 17 and KBH 108 were found resistant under natural as well as artificial phenotyping.

Legumes. Out of 16 lentil accessions screened against 14 isolates of *F. oxysporum* f.sp. *lentis*,JL 3, K 75, DPL 62, L 4147, PL 4, MC 6 and Vidhokar Local Seven accessions showed differential response resulting in identification of five different pathotypes. Out of 500 entries evaluated for resistance against wilt and Ascochyta blight of chickpea, 92 entries showed high resistance against Ascochyta blight. Out of 58 accessions of mung bean and urd bean evaluated against MYMV, 23 entries were found resistant. Of 40 accessions of AVT and IVT entries of urdbean evaluated under artificial inoculated condition against web blight (*Rhizoctonia solani*), 6 entries were found resistant. Out of 81 entries of soybean evaluated against both yellow mosaic and bud necrosis virus, DS 3105, DS 3106, SL 1104, SL 1028, SL 1074, PS 1572, PS 1347, MACS 1460, DS 3105 and DS 3106 were highly resistant.

Optimization of an efficient protocol for transmission of Groundnut bud necrosis virus (GBNV) on tomato to evaluate tomato. An efficient protocol for mechanical sap transmission of groundnut bud necrosis virus (GBNV) on tomato was optimized which showed 100% transmission efficiency, which would be utilized to evaluate tomato genotypes for virus resistance.

5.1.6 Epidemiology and Disease Management

Temperature influence on pathogenicity of leaf blast in rice. Appressoria formation in *M. oryzae*, as a component of pathogenicity, was maximum at 27 °C as compared to sub-optimal temperature (22 °C and 32 °C). Temperature had significant influence on cAMP-dependent phosporylase kinase A (PKA) activity which is responsible for appressoria development. The PKA activity was significantly higher at about 27 °C (optimum temperature) as compared to sub-optimal temperatures. Based on transcription and phosphorylation kinetics, it was observed that at 22 °C expression of R-genes which regulates defence process is effective whereas at 27 °C, severe reductionin phosphorylated protein suggested thatdefence process is interrupted. Pathogen aggressiveness in terms of lesion development rate was faster at 27 °C as compared to 22 °C and 32 °C irrespective of resistance or susceptible genotype.

Natural mixed viral infection on Phalaenopsis species. Three viruses belonging to different plant virus genera were isolated from *Phalaenopsis* plants showing symptoms of mild chlorotic spots, mild mosaic and dark green islands with light green depressions. Electron microscopy revealed the presence of virus particles with enveloped quasi-spherical, flexuous and rod shaped particles measuring 80-110 nm, 480×13 nm and 300×18 nm respectively. In DAC-ELISA, the symptomatic *Phalaenopsis* sample reacted with the antibodies GBNV, CymMV and ORSV. Association of GBNV was confirmed through RT-PCR assay using specific primers. Upon mechanical sap transmission, the *Phalaenopsis* sample with mixed infection could induce the symptoms typical to that of GBNV infection on cowpea, CymMV infection on *C. amaranti color* and the infection by ORSV on *G. globosa* test plants.

Management of stripe rust of wheat using fungicides. Out of 8 fungicides used for the management of stripe rust, minimum mean disease severity of 1.22 per cent was recorded with a strobilurin fungicide, azoxystrobin 25SC (Amistar @ 0.1%).

Potassium Phosphite: New biocidal molecules for blast disease management. Biocidal effect of

potassium phosphite (K_2Po_3) ranging from 25-2000 mM was evaluated *in vitro* in phosphate (Po_4) containing and phosphate free media against rice pathogen *Magnaporthe oryzae.* The fungicidal activity was observed at 400 mM in the presence of phosphate.

Integrated management of viral diseases in vegetable crops. Silverplastic mulch in combination with alternate sprays of insecticide and biopesticides were most effective in reducing the viral disease incidence and aphid, thrips and whitefly population in case of tomato, cucumber, okra, chilli and capsicum.

5.2 ENTOMOLOGY

5.2.1 Integrated Pest Management

5.2.1.1 Rice

Evaluation of rice germplasm against brown plant hopper (BPH). Out of 21rice germplasm lines, evaluated against brown plant hopper (BPH), RP 2068-18-3-5 with Bph33(t) gene and Babawee with bph4 gene were found highly resistant, while Ptb33 with bph2+Bph3+unknown factors and T12 with bph7 gene were rated as moderately resistant.

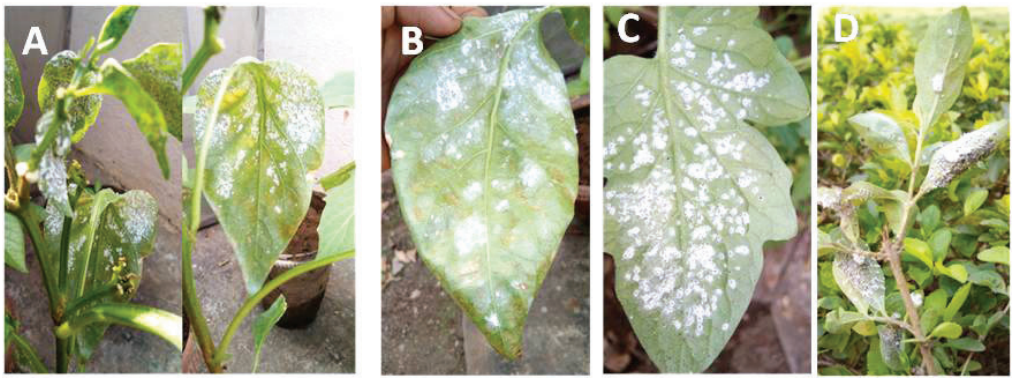
Impact of elevated CO_2 on bioefficacy of buprofezin against rice brown plant hopper. Effect of elevated CO_2 (570 ±25ppm) on bioefficacy of buprofezin 25SC against BPH was studied in open top chambers (OTCs) during *Kharif* 2017. Mortality was highest with spray volumes of 700 l/ha followed by 600 l/ha, 10 days after spraying (DAS) under both the conditions.

Niche partition between BPH and white backed plant hopper (WBPH). Niche partition analysis between brown plant hopper (BPH), *Nilaparavata lugens* and white backed plant hopper (WBPH), *Sogatella furcifera* on Pusa Basmati 1121 revealed that WBPH occupied broader niche with respect to microhabitat temperature, relative humidity and crop phenology in early and late transplanted crop, while BPH occupied broader niche with respect to occupation of stem space and association with predators. Study on functional response of wolf spider, *Pardosa pseudoannulata* in relation to different prey densities of 3rd and 4th instar BPH nymphs revealed higher feeding rate of spider under elevated CO_2 compared (5.7±0.9 to 18.5±3.6 hoppers/ predator) to ambient CO_2 (5.5±0.5 to 16.7±3.1 hoppers/ predator). The predation study revealed functional type II response of wolf spider on BPH nymph. Attack rate, maximum attack rate and efficiency parameters were higher and handling time was lower in under elevated CO_2 compared to ambient CO_2.

Effect of crop phenology on rice insect pests. Effect of three sowing dates viz., 5th July, 18nd July and 5th August was evaluated against BPH on Pusa Basmati 1121. The BPH population at its peak was found to be highest (78.4 hoppers/hill) in III transplanting followed by II transplanting (22.3 hoppers/hill) and I transplanting (9.00 hoppers/hill) and these populations were different significantly among each other. The late transplanted crop thus had higher BPH infestation, which was also observed earlier. Other insect pests such as stem borer and leaf folder were observed to be in very low intensity.

5.2.1.2 Vegetables and fruits

Species diversity of major insect pests and their natural enemies in okra. Insect pests and their natural enemies were observed in 12 treatment combinations under two sets of farm scaping in okra. Set I consisted of without floral plants strip (treated with Azadirachtin 0.03% E.C. and *Beauveria bassiana* 1.15% S.C.) sole okra, okra + baby corn, okra + cowpea and untreated sole okra, okra + baby corn, okra + cowpea. Set II with floral plants strip (treated with Azadirachtin 0.03% E.C. and *Beauveria bassiana* 1.15% S.C) sole okra with flower strip, okra + baby corn with flower strip, okra + cowpea with flower strip and untreated sole okra with flower strip, okra + baby corn with flower strip, okra + cowpea with flower strip. The leafhopper, whitefly and red spider mite population was reduced in okra crop when planted with any of farmscaping treatments with or without foliar spraying of biopesticides as compared to sole crop. Whitefly population was also minimum in FS-7 (7.55) and maximum in FS-2 (19.92) i.e. untreated sole okra without flower plants strip. Population of red



Capsicum (A), chilli (B) tomato (C) and duranta (D) infested by *Aleurothrix ustrachoides* and *Aleurotrachelus sp.*

spider mite was lowest in FS-7 (85.16) and highest in FS-2 (159.50). In brinjal, per cent data on number basis revealed that border cropping with maize/fenugreek/ moong showed significantly less infestation due to brinjal shoot and fruit borer (BSFB) and it ranged from 7.89-9.49% in various treatments as compared to 19.61% in control without border crop.

Evaluation of cabbage breeding lines against DBM under artificial condition. Out of forty cabbage germplasms evaluated against diamondback moth(DBM) under artificial infestation at Katrain, three lines viz., C121, 9A and Primero A3 were found to be moderately resistant.

Evaluation of cabbage breeding lines against cabbage aphid under open field condition. Out of forty cabbage germplasms evaluated for their relative tolerance to cabbage aphid, *Brevicoryne brassicae* under natural field infestation, four germplasms viz., Green Emperor, 9 A, KIRC 8 and KTCBH 81 were found to exhibit moderate level of tolerance.

Evaluation of cauliflower breeding lines against aphid under open field condition. Out of 25 cauliflower germplasms evaluated against cabbage aphid during *Rabi* season of 2016-17 under natural field infestation. Only two line viz., KTK 15 and SupremeX late expressed low level of resistance. All the remaining twenty three cauliflower germplasms were found to be highly susceptible and suffered significant mortality before curd initiation stage.

Emerging threat of new whitefly species Aleurothrix ustrachoides and Aleurotrachelus sp. on solanaceous vegetables in Maharashtra. Invasive species of whiteflies, *A. trachoides* and *Aleurotrachelus* sp., were found heavily infesting brinjal, chilli, tomato and ornamental plant "duranta" in Pune and surrounding areas.

5.2.1.3 Soybean

Seasonal incidence of insect pests. The soybean crop was infested right from its seedling stage by whitefly, *Bemisia tabaci* (Gennadius). The mean numbers of whiteflies per plant were little high compared to last year. 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).

5.2.1.4 Pulses

Development and validation of weather based prediction model for Helicoverpa armigera in chickpea. Weather based prediction model (Y= -10.69 – 0.685 * Tmax + 1.21 * Tmin+ 0.177 * RH_1+ 0.038 * RH_2+ 1.11 * SSH - 0.25 * RF- 0.99 * WS(R^2=0.85)) was developed for *Helicoverpa armigera* in chickpea using pheromone trap catches data. Stepwise regression revealed that Tmin, RH_1 and SSH were the important weather factors that influenced the trap catches of *H. armigera* in New Delhi. The pest-weather model was validated satisfactorily with R^2 = 0.751, RMSE=2.13%, MBE=-1.08% and MAE= 1.51%.

Monitoring of chickpea pod borer, Helicoverpa armigera and Spodoptera exigua moths using

pheromone traps. Studies conducted to monitor the adult population of chickpea pod borer, *Helicoverpa armigera* and *Spodopter aexigua* using pheromone traps in chickpea crop of IARI plots during 2017-18 revealed that the first trap catch of male moth of *H. armigera* and *S.exigua*was recorded during 50th standard week (2017) and adult trap catches increased gradually and reached its peak during 13th standard week (2018) with 23.0 and 27.0 moths/trap/week respectively.

Incidence and seasonal dynamics of pigeon pea insect pests. Studies were undertaken to determine the incidence and seasonal dynamics of pigeon pea insect pests during *Kharif* 2016-17 at ICAR-IARI, New Delhi. Incidence of Spotted pod borer, *Maruca vitrata* and blister beetle were 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 was 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. Population of gram pod borer and pod bug did not reached to the ETL level i.e. 1 larva/plant and 2 bugs/plant, respectively.

5.2.1.5 Maize

Characterization of selected maize genotypes for different biochemical mechanisms of resistance to Chilo partellus. Characterization of six selected maize genotypes was carried out for changes in certain nutritional, biochemical compounds, and activity of various enzymes in response to damage by *Chilo partellus* revealed significant variability in nutritional compounds in healthy and *C. partellus* damaged seedlings of maize, while the total lipids were on par. The amount of anti-nutritional biochemical compounds such as PAL, total carotenoids and total phenols was significantly higher in *C. partellus* damaged as compared to healthy maize seedlings. The activity of enzymes, viz., ascorbic oxidase, catalase, total anti-oxidant, and FRAP was significantly lower, while that of ascorbic peroxidase and DPPH 10, 50 and 100 higher in *C. partellus* damaged as compared to healthy plants.

5.2.2 Storage Entomology

Khapra beetle *Trogoderma granarium* showed ×31.62 fold resistance to phosphine when collected from different 15 localities. To know the trend and magnitude of phosphine resistance selection pressure of LC70 was applied for consecutive ten generations and ×12.74 times resistance was observed. The activity of antioxidant enymes viz., catalase, peroxidase and superoxidase dismutase was determined in different as well as successive generations. Results showed that peroxidase superoxidase was higher in phosphine resistant strain compared to susceptible one. In each generation activity of these enzymes found to be increased with increasing in resistance from parental population to F10.

Effect of temperature and food on the biology of Khapra beetle, Trogoderma granarium. The effect of temperature and type of food on biology of Khapra beetle, *Trogoderma granarium* was studied at temperatures of 30 ˚C, 32 ˚C, 35 ˚C and 40 ˚C with different types of food used were whole grain, crushed grain and flour of wheat in laboratory. The fecundity and fertility were the maximum at 35 ˚C which declined at lower and higher ranges of temperature. The incubation period was the maximum at 30 ˚C which decreased with increasing temperature. The larval life was the shortest at 35 ˚C, of 19.5 days for males on flour and 23 days for female on crushed grain. The pupal period of females was usually longer than the males and duration decreased with an increase in temperature. The total developmental period was the minimum at 35 ˚C while maximum at 30 ˚C on all the tested food types. The survival rate was the maximum at 35 ˚C on flour whereas; it was markedly decreased at 40 ˚C and on whole grain.

5.2.3 Biological Control

Orientation and foraging behavior of Coccinellids. Orientation response of both male and females *Coccinella transversalis* was tested against both hexane and DCM extracts of uninfested leaves (UL), without aphid (WOA), with aphid (WA) and aphid only (AO).

Highest number of beetles moved towards WA extracts followed by WOA and AO, while least response was observed for UL extract for both hexane and DCM solvents. Among the different concentrations, highest number of beetles responded to 10% conc. for both hexane and DCM solvents. It was revealed that synomones (cowpea plant) and kairomones (aphid body) played a vital role in orientation behavior of *C. transversalis* to locate their prey. GCMS analysis of WA extracts in hexane showed the presence of compounds viz., octane, 5-ethyl-2-methyl-Nonane and 5-butyl-tetracosyl acetate, while in DCM, octacosanal, nonadecanol and 2,6,11-trimethyl-dodecane were responsible for eliciting attraction in predator towards WA extracts. Total life span of male and female *C. transversalis* ranged from 47-64 and 60-71 days, respectively under laboratory conditions (27±1°C and RH 65±5%). Both male and female of *C. transversalis* exhibited type-II functional response as maximum prey consumption by females (56.4) and males (53.5) was achieved at maximum prey density of 120 aphids. The prey attack rate or searching efficiency was found to be more in females (0.043) than males (0.041). Females were thus observed to be more efficient predator than males.

Effect of thermal stress on the biological attributes of cotton mealy bug parasitoid, Aenasius arizonensis. Effect of thermal stress on the biological attributes of cotton mealy bug parasitoid, *Aenasius arizonensis* and activity of antioxidant enzymes viz., superoxide dismutase (SOD), catalase and glutathione S-transferase (GST) after one to four hours of exposure was studied. The parasitoid had higher parasitization (%), fecundity, female sex ratio and adult longevity in the temperature range of 27°C to 32°C. These parameters gradually decreased with the increasing temperature, indicating negative relationship with the temperature. Morpho metrics of adult parasitoids revealed that length and breadth of mummies, length and breadth of adults, head width, antennal length and hind tibial length were greater at 27 °C compared to higher temperatures, revealing adverse effect of higher temperature on the parasitoid. The enzymatic activity after 1-h and 2-h exposure to higher temperature did not differ significantly. However, with 3-h of thermal stress, the temperature dependent increase in the superoxide dismutase (SOD) activity was observed and the maximum activity was noticed at 41 °C in both mealy bug and parasitoid compared to that at 27°C. The SOD activity was more with 4-h exposure compared to 3-h exposure at all the temperatures. Catalase activity also increased with the increase in temperature and the effect of thermal stress was found to be significant both in parasitoids and mealybugs. The maximum glutathione S-transferase (GST) activity was observed at 41°C for both mealybug nymphs and parasitoid adults with 3-h exposure.

5.2.4 Insect Physiology

Incidence of Pink bollworm infestation in Gujarat, Andhra Pradesh, Telangana, Maharashtra and Karnataka (2015-2017). Since 2015 PBW has emerged as major pest of Bt cotton in south and central India. In 2015, infestation range was 60-80% which was increased to 82-99% in 2016. Whereas, in 2017 although it is increased to 100% in Kurnool but decreased in Warangal and Junagarh from 98% & 95% (2016) to 74% & 86% (2017), respectively.

Detection of Cry1Ac and Cry2Ab in BG-II cotton hybrids collected from different locations: using ELISA strips. Bt cotton seeds of different hybrids, from which pink bollworm larvae were collected, were tested to validate whether these hybrids expressing Cry1Ac and Cry2Ab toxin. In this study raw Bt cotton seeds from green cotton bolls were separated and kept in 1.5 ml micro centrifuge tube. These seeds were crushed with sterilized pestle and to this 600 µl of extraction buffer added as per manufacturer protocol and ELISA strips were immersed. These Bt express strips shows two bands if it is positive for aforesaid toxins. Upper band is control band and lower band is denoted for cry toxin. The results showed that 16.66 to 30% -ve results in seeds tested from Adilabad, Kurnool and Aurangabad either for Cry1Ac or Cry2Ab toxin or both. Whereas seeds tested from Guntur showed 100% +ve results.

Thus the segregating seeds in bolls of F_1Bollgard-II hybrid plants may be responsible for fast-track resistance development (≤5 year). As F1 bolls carry

seeds that segregate in the ratio of 9:3:3:1 as per the principle of genetics. Thus a spectrum of seeds with in a boll varies from seeds with Cry1Ac+Cry2Ab (9) seeds with Cry1Ac alone (3), seeds with Cry2Ab alone (3) and seeds with no cry toxin seed (1). This condition is most suitable for resistance development, due to selection of resistance to independent toxins as well as in combination.

Efficacy of Cry toxins against neonates of pink bollworm by feeding assays. Pink bollworm larvae were separated from the collected green boll of different locations and transferred on to the semi-synthetic diet. Pupae were separated and adults were maintained in the mating jars where cotton twig is used as substrate for egg laying. Neonate larvae were transferred on to the semi-synthetic diet after hatching from the twigs. Five-day old larvae of seven population (viz., Adilabad, Warangal, Guntur, Kurnool, Parbhani, Anand and Delhi) were screened by subjected to the one ppm concentrations of toxins viz., Cry1Ac, Cry2Ab, BGII (MRC 7031) seed powder under controlled condition of 27 ± 1 °C and 65 ± 70% RH. Observations showed that Guntur and Kurnool populations were least susceptible to BGII (Cry1Abc+Cry2Ab) and rest of the population attained >60% mortality. Adilabad population attained only 40% mortality to Cry2Ab. Anand population was found to be most susceptible to both BGII and Cry1Ac with highest mortality of 83.3% and Guntur population was to most tolerant of the tested populations with 26.67% and 30% mortality with BGII and Cry1Ac, respectively.

Gut bacterial diversity in whitegrub, Anomala sp. About, 23 gut bacterial isolates were identified and characterized from white grub *Anomola dorsalis*. Some of the dominant gut bacterial isolates were *Vibrio rumoiensis, Enterobacter xiangfangensis, Bacillus aerophilus* and *Bacillus subtilis*. Marked differences in distribution of different microbial groups were observed across insect gut segments.

Variant analysis of a conserved phosphine resistance gene in insects. A comparative transcriptomics (RNAseq) and genetic linkage analysis approach identified the *rph1* gene associated with the resistance to the fumigant phosphine (PH3) that is used to control insect pests of stored grain. This gene is reported to have variants in the phosphine resistant strains. Studies documented the missense amino acid substitutions and/or insertion/deletions/frameshift mutations in the gene in different resistant populations of stored grain pests viz., *Tribolium castaneum, Rhizoper thadominica* and *Sitophilus oryzae.*

Sterile insect technique (SIT) for fruit fly management. Radiation doses were optimized for melon fly, *Bactrocera cucurbitae* (Coquillett). Radiation doses up to 30 Gy had no adverse effects on adult emergence, flying ability and deformation, while, exposure of pupae to 40 and 50 Gy decreased adult emergence (58.67 and 41.67%) and adult fliers (54.18 and 37.12%). The sterility increased with increase in radiation dose ranging from 81.47 (30 Gy) to 95.99% (50 Gy).

5.2.5 Insect Toxicology

Semio chemicals. Cis-isomers of maize stem borer, *C. partellus* major pheromone components when analysed individually and in three blends viz., Blend A (100:50), Blend B (50:50) and Blend C (100:10) at 5,10,50 and 100 µg through electro antenna gram (EAG), revealed that cis-11-hexadecenal evoked significant more response than any other treatment at all doses.

Toxicity of essential oils to white fly, Bemicia tabaci. At 0.5 per cent concentration complete mortality was observed for citronella and lemon grass oil after 24 hrs of treatment, whereas, after 48 hrs of treatment citral, cinnamaldehyde and geranium oil gave 100 per cent mortality. A glass device has been fabricated for studying repellency of essential oils formulations (47.6%) to white fly.

5.3 NEMATOLOGY

5.3.1 Management through Transgenic Approach

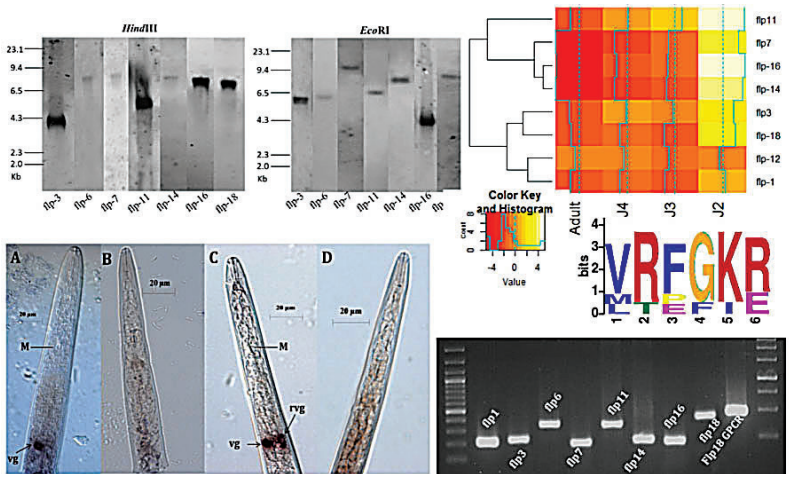
For the first time, interaction among five esophageal gland genes and cell wall degrading enzymes during infection of *Meloidogyne incognita* was

established using RNAi revealing its complex nature of parasitism. In view of this, using *in planta* effector screening approach, possible interaction of pioneer genes (*msp-18* and *msp-20*, putatively involved in late and early stage of *M. incognita* parasitism, respectively) with other unrelated effectors was studied. Host-induced gene silencing (HIGS) strategy was used to generate the transgenic eggplants expressing *msp-18* and *msp-20*, independently. Putative transformants were characterized via qRT-PCR and Southern hybridization assay. SiRNAs specific to *msp-18* and *msp-20* were also detected in the transformants via northern hybridization assay. Transgenic expression of the RNAi construct of *msp-18* and *msp-20* genes resulted in 43.64-69.68% and 41.74-67.30% reduction in *M. incognita* multiplication encompassing 6 and 10 events, respectively. Additionally, transcriptional oscillation of CWMEs documented in the penetrating and developing nematodes suggested the possible interaction among CWMEs and pioneer genes. The rapid assimilation of plant-derived carbon by invading nematodes was also demonstrated using ^{14}C isotope probing approach. This suggests that HIGS of *msp-18* and *msp-20*, improves nematode resistance in eggplant by affecting the steady-state transcription level of CWME genes in invading nematodes, and safeguard the plant against nematode invasion at very early stage because nematodes may become the recipient of bioactive RNA species during their exploratory probing phase on the plant surface.

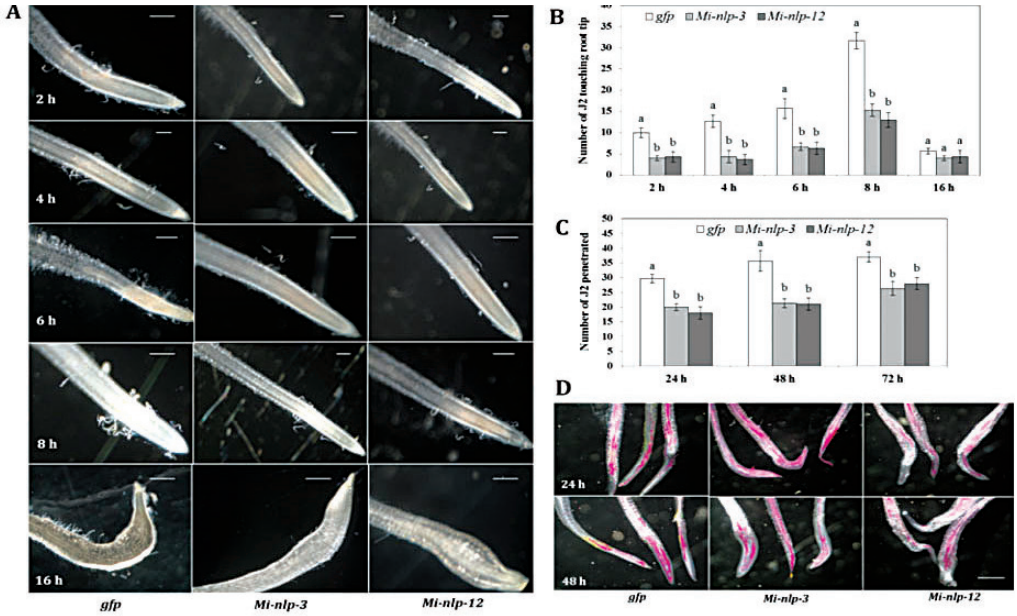
5.3.2 Molecular Characterization and Functional Validation of Neuropeptide Genes in Root-knot Nematodes

The disruption of neuropeptide signalling leading to attenuation in nematode behaviour and thereby perturbed infection, offers an attractive alternative to control nematodes. Putative FMR Famide-like peptides (FLPs) were mined from the transcriptomic dataset of *M. graminicola* followed by characterization of those FLPs via sequencing of PCR products, qRT-PCR and Southern hybridization analysis. Nine *flp* genes (*flp-1*, *flp-3*, *flp-6*, *flp-7*, *flp-11*, *flp-12*, *flp-14*, *flp-16* and *flp-18*) and a partial neuropeptide receptor gene (*flp-18* GPCR) were characterized from *M. graminicola*. In addition, *in situ* localization revealed the expression of *flp-1* and *flp-7* in neurons posterior to the circumpharyngeal nerve ring of *M. graminicola*. *In vitro* silencing of nine *flp* genes and *flp-18* GPCR in *M. graminicola* J2 and their subsequent infection in rice and wheat roots demonstrated the reduced penetration ability of FLP silenced worms which underscore the potential of the FLPergic system as a broad-spectrum target to manage the root-knot nematode problem in rice-wheat cropping system.

Helminth nervous systems are peptide-rich and appear to be putative drug targets that could be exploited by antihelmintic chemotherapy. To characterize the novel peptidergicneuro transmitters, *in silico* mining of *M. incognita* genomic and transciptomic datasets



Characterization of FLP genes in *M. graminicola* using PCR, qRT-PCR, Southern and *In situ* hybridization



Effect of *in vitro* silencing of *nlp* genes on *M. incognita* chemotaxis and infectivity

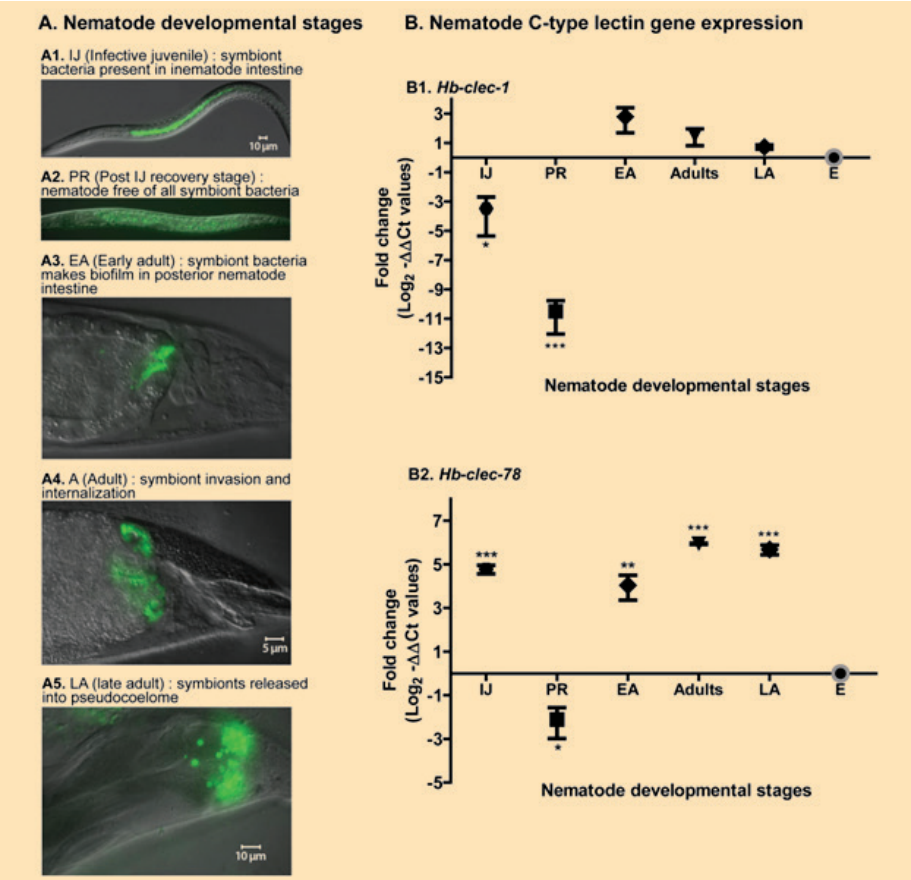
revealed the presence of 16 neuropeptide-like protein (*nlp*) genes with structural hallmarks of neuropeptide preproproteins; among which 13 *nlp*s were PCR-amplified and sequenced. Two key *nlp* genes (*Mi-nlp-3* and *Mi-nlp-12*) were localized to the basal bulb and tail region of nematode body via *in situ* hybridization assay. *Mi-nlp-3* and *Mi-nlp-12* were greatly expressed (in qRT-PCR assay) in the pre-parasitic juveniles and adult females, suggesting the association of these genes in host recognition, development and reproduction of *M. incognita*. *In vitro* knockdown of *Mi-nlp-3* and *Mi-nlp-12* via RNAi demonstrated the significant reduction in attraction and penetration of *M. incognita* in tomato root in Pluronic gel medium. A pronounced perturbation in development and reproduction of NLP-silenced worms was also documented in adzuki beans in CYG growth pouches. The deleterious phenotypes obtained due to NLP knockdown suggests that transgenic plants engineered to express RNA constructs targeting *nlp* genes may emerge as an environmentally viable option to manage nematode problems in crop plants.

5.3.3 Evaluation of Rice Genotypes against *Meloidogyne graminicola* Infection

Evaluation of 430 rice genotypes against *Meloidogyne graminicola* indicated 44 accessions to be highly resistant. Among them, five accessions NKSWR 19, NKSWR 30, NKSWR 259, NKSWR 18 and NKSWR 43 appeared to be immune as there was no infection. Rice cultivars Vandana and Suraksha have been demonstrated to show stable performance against various population densities of *M. graminicola*.

5.3.4 Entomopathogenic Nematodes

The *Galleria* cadaver technology was licensed to several companies for application of entomopathogenic nematodes (EPNs). Investigations on *Heterorhabditis-Photorhabdus* host specificity showed that *Hb-clec-78* gene might be involved in modulation of symbiosis with *Photorhabdus* bacteria. The role of C-type lectins in Heterorhabditid nematodes in nematode-bacteria symbiosis was investigated. The *in silico* analysis of C-type lectin genes *(clec)* genes in *Heterorhabditis* spp. led to identification of 8 C-type lectin genes in *H. bacteriophora* and 4 C-type lectin genes in *H. indica* that had similarity to peptide sequences of *clec* genes of *C. elegans*. Two of the genes, *clec*-1 and *clec-78* were taken for further analysis. The phylogenetic analysis of the *clec-1* and *clec-78* genes revealed the relationship of these genes with *clec* proteins of others free living nematodes, viz., *C. elegans, C. briggsae, C. brenneri, C. remanei, C. japonica, P. pacificus* and animal parasite *Haemonchus*



The symbiosis-relevant developmental stages of *H. bacteriophora* nematodes and the expression of *Hb-clec-1* and *Hb-clec-78*. (A) Nematode developmental stages showing symbiotic association of GFP labeled bacteria, modified from (Waterfield et al. 2009), (B) Fold-change expression of (B1) *Hb-clec-1* and (B2) *Hb-clec-78* at different developmental stages Asterisk (*) shows significant difference as compared to the Egg (E) stage. IJ stage = IJ, post-IJ recovery stage = PR, early adult stage = EA, adult stage = A, late adult stage = LA and egg stage = E

contortus. The copy number analysis by southern hybridization revealed that both these genes are present in a single copy in the *H. bacteriophora* genome. The preliminary developmental expression profile showed that *clec-1* was downregulated at the IJ and pre-adult stage, and is upregulated only after the adult stage. However, *clec-78* was upregulated at all the time-points except at 4 h post IJ (pre-adult) stage when bacteria are regurgitated by the nematodes, and the nematode is free of symbiont bacteria. Subject to genetic validation, our study suggests that *clec-78* might be actively involved in maintenance of symbiosis at all the time points/ developmental stages during the symbiotic transmission process.

A candidate toxin gene, PirB was characterized from entomopathogenic bacterium, *Photorhabdus luminescens* sub sp. *akhurstii*. The recombinant pET 29a contacting PirB expressed a desired protein of 418 aa long (Molecular Wt - 46 kDa). Using BSA as standard, PirB concentration ranged among 1.3-1.5 mg/ml in Bradford assay. The LC50 values ranged between 41.79 to 91.25, 31.62-41.79, 20.18-31.73 and 12.94-24.75 ppm at 12, 24, 48 and 72 h post inoculation, respectively, for PirBH1-H5 proteins.

5.3.5 Biocontrol Agents

An indigenous isolate of *Trichoderma harzianum* ITCC 6888 caused significant mortality in juveniles and egg hatch inhibition in root-knot nematode, *Meloidogyne incognita*. The talc based formulation of the isolate was found to be rhizosphere competent resulting in significant per cent decline in galling, egg mass production, eggs/egg mass and reproduction

factor in tomato cv Pusa Ruby infected with the pest *M. incognita. Pseudomonas fluorescens* (cfu 10^8) @ 80g/sq m was also found effective in controlling *Meloidogyne graminicola* in direct seeded rice, with 55% reduction in the number of galls under field experiment.

5.3.6 Nematode Genomics

The rice-root-knot nematode, *Meloidogyne graminicola* is a serious pest of rice. The genome of rice-root knot nematode (*Meloidogyne graminicola*) was sequenced to create a resource for comparative and functional genomics. *M. graminicola* genome sequence assembly was of 38.18 Mb size, comprising 4304 scaffolds with an average scaffold length of 8.87 Kb. A total of 10,196 protein-coding genes were predicted. 4,359 orthologues were common to all the compared plant-parasites.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Development of Active Molecules for Crop Protection

5.4.1.1 Synthesis, characterization and bio efficacy evaluation of new halogenated 3-substituted-3, 4-dihydro-1, 3-benzoxazines

Twenty new 3-alkyl-3,4-dihydro-4-methyl-2H-1, 3-benzoxazines were prepared by hydroxyl methylation of secondary amines with formaldehyde and were characterized (^{1}HNMR and ^{13}CNMR). Synthesized compounds were screened for their insecticidal activity against *Spodoptera litura* at 5000, 1000, 500 and 100 ppm. Initial screening of ten compounds revealed six compounds which showed 45-70% mortality at 100 ppm.

5.4.1.2 Synthesis, characterization and bio efficacy evaluation of substituted 3-iodochromones

A series of 21 alkoxy/halo substituted 3-iodochromones were synthesized, characterized (^{1}HNMR and ^{13}CNMR) and screened for their fungicidal activity against *Sclerotium rolfsii*. All compounds showed good activity with inhibition percentage of 43-87% at 100 ppm and 6-flouro-3-iodo-chromen-4 one was the best compound (EC_{50} - 24.65ppm).

5.4.1.3 Evaluation of antifungal activity of heterocyclic tetrazole derivatives against *Rhizoctonia solani*

Twenty tetrazole derivatives were screened for their antifungal activity against *Rhizoctonia solani*. These compounds displayed good antifungal activity at 750 and 1000 ppm dose and more that ninety per cent inhibition in growth of *R. solani* was observed at 1000 ppm dose.

5.4.1.4 Preparation of halogen substituted benzylidene aryl amines and their antifungal activity against *Rhizoctonia solani*

A series of forty eight halogen substituted benzylidene aryl amines was prepared by the reaction of halogen substituted aldehydes with substituted anilines. Antifungal activity assay against *Rhizoctonia solani* revealed different substituents attached to the core structure of benzylidene aryl amines affected antifungal activity. Structure activity studies suggested that the halogen substitution in benzene rings resulted in the better antifungal activity.

5.4.1.5 Essential oil based nematicides

Essential oils were isolated from the lemongrass, palmarosa and clove buds. GC-MS analysis of essential oils identified about 59 compounds and citral, geraniol and eugenol were the major constituents of oil. Three essential oil and their major constituents were evaluated for their nematicidal activity against J2s of rice root node nematode, *Meloidogyne graminicola* and theirLC_{50} were: lemongrass oil - 14.99 ppm, palmarosa oil - 7.54 ppm, clove oil - 6.40 ppm, citral - 13.43 ppm, geraniol - 7.23 ppm and eugenol - 5.90 ppm, carbofuran - 3.0 ppm. Results suggested that essential oils have greater potential for use as nematicides.

5.4.1.6 Synthesis, *in silico* docking and *in vitro* evaluation of arylhydrazino amino thiazoles against *Sclerotinia sclerotiorum*

A series of sixteen arylhydrazino amino thiazole derivatives were synthesized, characterized and screened against phyto-pathogenic fungi *S.*

sclerotiorum. Synthesis involved reaction of 2-amino-4-phenyl-1, 3-thiazole with chloro acetyl chloride to get chloroacetyl-amino-4-phenyl-1,3-thiazole, which was further reacted with hydrazine hydrate to prepare 2-(hydrazinoacetyl)-amino-4-phenyl-1,3-thiazole. The reaction mixture was further reacted with various substituted aromatic aldehydes to prepare 2-(arylidene-hydrazino-acetyl)-amino-4-phenyl-1,3 thiazoles. These thiazoles were used for the *in silico* studies to inhibit glutamine synthetase enzyme system. The hydroxy substituted derivative was found as the most active compound with EC_{50} of 18.9 ppm.

5.4.1.7 Chemical profiling of bioactive phytochemicals from *Trachyspermum ammi*

Essential oil from seeds of *T. ammi* was obtained by hydro distillation (3.2% v/w). GC/MS analysis indicated thymol (38.8%), *p*-cymene (31.6%) and γ-terpinene (23.7%) as most abundant constituents of oil. Chemical profiling of methanolic extract of seeds, using high resolution mass spectrometry (HR-MS) analysis, identified 12 phenolic glucosides, 5 phenolic acids and 4 glucuronic acids. Antioxidant assay by CUPRAC, DPPH and ABTS methods indicated maximum activity of essential oil with IC_{50} of 66.4 µg ml^{-1}, 44.0 µg $ml^{-1}$and 130.9 µg ml^{-1}, respectively. Essential oil was highly active against pathogenic isolates of *Candida albicans* ITCC 4719 (EC_{50} 6.9 µg ml^{-1}). *In silico* docking and simulation studies against glutamine-fructose-6-phosphate amido transferase [GlcN-6-P] of *C. albicans* (PDB: 2POC) suggested tetrol, hydroxy thymol and thymol as highly inhibitory.

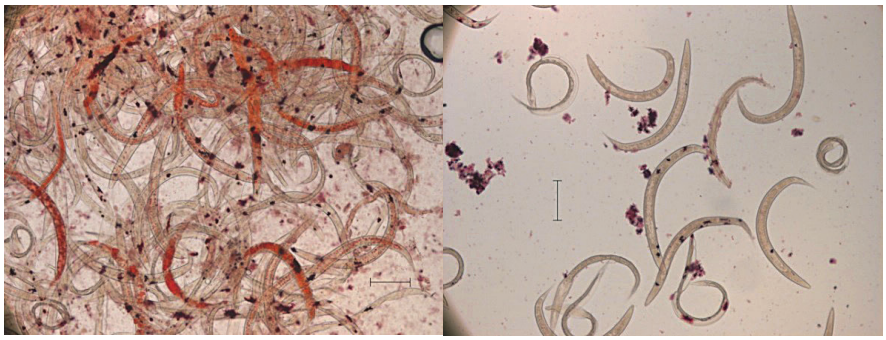
5.4.1.8 Anthocyanin composition of fruits of *Carissa carandas:*

Carissa carandas is a colored fruit and is rich in pigments. Colored pigments from its fruits were extracted with acidified ethanol and purified by adsorbent resins. The total anthocyanin content obtained was 108.6 mg kg^{-1} fruit. The purified anthocyanins were characterized by HRMS and it revealed that cyanidin-3-O-glucoside as major compound and seven minor anthocyanins. Antioxidant activity analysis by DPPH assay suggested EC_{50} (µg ml^{-1})of 83.42 for crude anthocyanins,52.93 for purified anthocyanin and 87.44 for phenolics fraction. Bio-accessibility of crude and purified anthocyanins ranged between 12% and 19%.

5.4.2 Development of Formulations for Smart Delivery of Crop Protection Inputs

5.4.2.1 Biopesticidal biogel formulations

In continuation to previous research on improved EPN based biogel formulation, effect of three lipid metabolism arresting (LMA) compounds (A-1,A-2,A-3) on % survival of *Steinernema thermophillum* IJs was evaluated *in vitro*. The compound A-2 (10 ppm) showed best lipid metabolism arrestant potential and survival of EPNs was 45% as compared to 28% in control (aqueous suspension) at 35 ˚C (3 months old



(A-2 treated) (Control)

Oil Red O stained two months old *Steinernema thermophilum* IJs

sample) and was found to be statistically significant. The qualitative lipid profiling using Oil Red O staining technique showed significant depletion in the stored lipids of control IJs as compared to those in A-2 treated water. The compound A-2 was selected as an adjuvant in biogel formulations.

5.4.2.2 Green gels

A new series of biogels and composites based on a natural gum (BP-1) and carboxy methyl cellulose (BP-2) cross-linked with pre-standardized organic acid (OA-1) were synthesized under open air conditions at temperature range of 50-90 ^{0}C. A total of 30 polymers were synthesized, characterized and evaluated for their water absorption potential and mechanical stability. The XRD spectra showed successful intercalation of polymer chain in the bentonite layers. The synthesized gels showed water absorption in the range of 10-50 g/g. Eight compositions employing synthesized gels and LMA as adjuvant immobilized *Steinernema thermophillum* IJs and evaluated for shelf-life. It showed 100% survival at 25 ^{0}C after 2 months and at 35 ^{0}C after 1 month.

5.4.2.3 Development of nano emulsions of neem and citronella oils

Nano emulsions of crude neem oil and citronella oils with surfactants were developed and characterized by dynamic light scattering (DLS) and transmission electron microscope (TEM). TEM study showed the spherical shape of neem and citronella oil nano emulsions. The average size of droplets of neem nano emulsion (NNE) with different percentage of citronella oil ranged from 11.23±3.86 nm to 17.80±4.52 nm while that of citronella nano emulsion (CNE) with different percentage of neem oil ranged from 8.12±2.80 nm to 12.04±3.74 nm. It was found that increase in surfactant ratio to neem oil or citronella oil decreases the size of droplets in nano emulsions.

5.4.2.4 Synthesis and characterization of new generation hydrogels

New generation hydrogels were synthesized using different clay minerals and monomer (1:0.1 to 1:2) ratio and varying cross linker and initiator content. The synthesized hydrogels were characterized using XRD and FTIR for their structure. The water absorbency of synthesized gel in distilled water varied in the range of 600-1000 g/g dry gel. The synthesized hydrogels showed decreased water absorbency upon increasing the monomer : clay content.

5.4.2.5 Preparation of coacervate hybrid polymer composite for encapsulation of acetamiprid

Earlier developed chitosan-gum Arabic coacervate polymer composite was used to encapsulate acetamiprid. However, method yielded only 14% encapsulation of acetamiprid. Method was modified (without emulsion) to obtain > 90% encapsulation of acetamiprid.

5.4.3 Standardization and Validation of Methods for Detection/Quantification of Contaminants

5.4.3.1 Development of molecularly imprinted polymers for the rapid and selective determination of chlorpyriphos in environmental samples

Selective magnetic molecularly imprinted polymers (MMIPs) were synthesized; MMIPs showed higher adsorption capacity than magnetic non-imprinted polymers (MNIPs). Polymers were highly selective in extracting chlorpyrifos (94.14±1.5%) even in the presence of its structural analogue quinalphos and triazophos. Reusability studies revealed that the polymer can be successfully utilized thrice without any apparent loss in adsorption capacity or selectivity. The prepared polymers were also applied for the extraction of chlorpyrifos from fortified honey and eggplant samples. Results suggested 87.9% and 90.0% recovery of the chlorpyrifos from fortified honey and eggplant with relative standard deviation of 5.35% and 6.0%, respectively.

5.4.3.2 Synthesis of curcumin conjugated zinc oxide nanoparticles for atrazine

Curcumin conjugated zinc oxide nanoparticles were synthesized to develop ano-probes for the detection of pesticides. Curcumin was incorporated

in ZnO [Zn(cur) O] through a wet chemistry method. The materials were characterized by spectroscopic and other techniques. Nanoparticles were effective in detecting atrazine up to 0.1 ppm concentration and showed linearity up to 10 ppm concentration. The nanoparticles which exhibited excellent performance in terms of sensitivity, stability, linearity and quick response time can be used as nano-probe for atrazine detection.

5.4.3.3 Standardization of multi residue method for aflatoxins in cereals

The method for extraction of seven aflatoxins from the black peppers, cumin, fenugreek, onion seed and coriander was optimized using buffered QuChERS method and estimation by LC-MS-MS at 1, 5 , 10, 25, 50 and 100 ng fortification level. Per cent recovery recorded was in the range of 74.4-88.17±1.02 while LOD and LOQ for each aflatoxin was 0.5-1 ng/ml and 1.1-3 ng/ml, respectively.

5.4.3.4 Estimation of dithiocarbamate pesticide formulation by HPLC-PDA

A simple and sensitive high performance liquid chromatographic method was developed for quantification yellow complex obtained from dithiocarbamate fungicides (Mancozeb, Zineb and Propineb) in different formulation as well as food commodities. Method gave acceptable recovery on cauliflower at 0.05, 0.25 and 0.5 mg kg^{-1}fortification levels. The method was used for quantification of different dithiocarbamate formulations and active ingredients in formulation were in the range of 57.0-75.14% (RSD 14.18), 68.8-73.07% (RSD 2.98) and 69.07-78.98% (RSD 7.07), respectively.

5.4.3.5 Method for quantification of 101 pesticides in LC-MS/MS

A method for simultaneous identification and quantification of 101 pesticides using LC-MS/MS was developed after optimization of LC and MS instrumental parameters under electro spray ionization (ESI) mode in positive and negative mode. The various validation parameters viz., linearity, specificity, sensitivity and uncertainty measurement were determined. Seven-point linear calibration curves for each pesticide were obtained in a range of 0.01-2 μgg^{-1} with correlation coefficient (r) of ≥0.98. The method LOD and LOQ for all the pesticides were achieved in the range of 0.01 – 0.05 $\mu gg^{-1}$and 0.03-0.15 μgg^{-1}, respectively.

5.4.4 Management and Assessment of Contaminants in Agricultural Commodities and Environment

5.4.4.1 Environmental fate of sulfa methazole and sulfa chloropyridazine in soils

The dissipation of sulfa methazole and sulfa chloro pyridazine antibiotics in soils at different moisture regimes (dry, field capacity and submerged) and uptake in mustard plants was studied at 10 µg/g fortification level. The half-life for sulfa methazole and sulfachloro pyridazine under varying moisture conditions were 43.0-60.2 and 33.4-50.1 days, respectively. Uptake of both antibiotics in 10 days old mustard seedlings varied between 3.11 and 3.58 µg/g.

5.4.4.2 Degradation of fipronil by microbes sourced from contaminated soil/sediment

Five bacterial strains were isolated from the contaminated soil/sediment collected from effluent treatment site of an industry. The bacterial strains identified, using 16S ribosomal RNA gene, were: *Pseudomonas balearica* (ID: KX495190.2), *Rhodococcus* sp. A27 (ID: KT741026.1), *Brevibacterium* sp. strain Yifu126 (ID: KX900603.1), *Pseudomonas stutzeri* strain CW201 (ID: KY689042.1), *Bacillus* sp. EB354 (ID: FJ785480.1). The half lives of fipronil in broth using individual bacteria ranged from 7.9- 23.1 days while fipronil degradation was 99.4% using consortium and was followed by *Pseudomonas balearica* (85.1%) *Pseudomonas stutzeri* (20%) and *Bacillus* sp. (16.1%).

5.4.4.3 Evaluation of biomixtures for removal and degradation of azoxystrobin and imidacloprid

Four bio mixtures comprising of soil, rice straw (RS)/corn cob (CC) and compost (C)/peat (P) (1:2:2)

were evaluated for adsorption of azoxystrobin and imidacloprid and were named as: RS+C, RS+P, CC+P and CC+C). Adsorption results suggested that imidacloprid adsorption % in biomixtures RS+C, RS+P, CC+P and CC+C varied from 94.4-97%, 66.2-85.4%, 66.2-85% and 40.6-55.2%, respectively. The respective values for azoxystrobin adsorption were: 86.6-93.1%, 91.3-95.4%, 85.7-92.4% and 90.2-91.2%. The K_f values for azoxystrobin in RS+C, RS+P, CC+P and CC+C bio mixtures were 271.95, 392.82, 113.67 and 217.90, respectively. The respective values for imidacloprid were 444.66, 72.40, 102.54 and 15.28. Bio mixtures showed nearly four times variation in K_f values for azoxystrobin sorption while variation in imidacloprid sorption was nearly 30 times.

All the four bio mixtures used for adsorption were evaluated for their ability to degrade azoxystrobin and imidacloprid. Degradation studies of imidacloprid suggested that conditioning of biomixture for 10 days at 60% water holding capacity was required for degradation of imidacloprid as no degradation was observed in the unconditioned biomixtures. Imidacloprid degradation studied in conditions biomixtures at 20 μg g^{-1} levels suggested that rate of imidacloprid degradation varied among the biomixtures and half life values in RS+C, RS+P, CC+P and CC+C biomixtures were: 18.1, 15.6, 11.7 and 8.2 days, respectively. There was not much difference in azoxystrobin (30 μg g^{-1}) degradation in conditioned and unconditioned biomixtures. The half-life in unconditioned RS+C, RS+P, CC+P and CC+C bio mixtures were: 6.4, 7.3, 5.5 and 4.6 days, respectively while respective half-lives in conditioned bio mixtures were 7.0, 3.5, 3.2 and 4.5 days. This study suggested that compost and rice straw based bio mixture can be utilized for decontamination of imidacloprid and azoxystrobin.

5.4.4.4 Synthesis of nano-particles ofmagnetic biochar for pesticide removal from water

Synthesis of magnetic biochars from four agri-waste residues, viz., rice straw, wheat straw, rice husk and corn cob was undertaken. The magnetic biochars were characterized using FT-IR and DLS and were utilized for removal of atrazine from water. The magnetic nanoparticles were able to remove 77-83% of atrazine from solutions at 1-5 ppm concentrations.

5.4.4.5 Microbial degradation of fipronil

Persistence of fipronil, a persistent insecticide, was studies in laboratory incubated sterile and non-sterile soils of sugarcane field. The half life of fipronil dissipation ranged from 100-103 days in non-sterile soil and 300 days in sterile soil. To ascertain the role of microorganisms in fipronil degradation 21 microorganisms were isolated from the soil that was continuously treated with fipronil for two years. Out of these 21 microorganisms 7 microbes (4 actinomycetes and 3 bacteria) were effective in faster degradation (7-10 days) of fipronil in mineral salt medium. These microorganisms will be utilized for their future use in decontamination of fipronil in contaminated soil/water system.

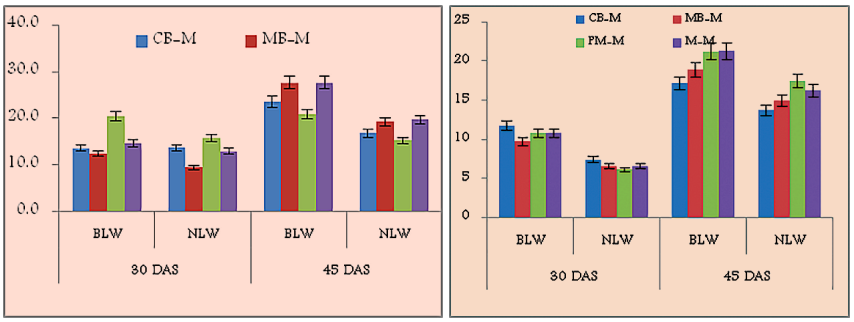
5.4.4.6 Sorption of flucetosulfuron in soils

Sorption behavior of flucetosulfuron were studied in three test soil types (IARI, Arunachal Pradesh (AP) and Karnal) using batch equilibrium method. The partition coefficient (K_d) values of herbicide in Delhi, A.P and Karnal soils were 10.52, 19.35 and 13.73, respectively. The Freundlich adsorption constant (K_f) followed the order: A.P. (27.99) > Karnal (22.18) > Delhi (17.13). Desorption, which was studied at two concentrations (0.4 and 2.0 μg ml^{-1}), suggested higher flucetosulfuron desorption at lower concentration (0.4 μg ml^{-1}) in all the three soils. Further, minimum flucetosulfuron desorption was observed in Karnal soil at 0.4 and 2.0 μg ml^{-1} (12.86% and 1.44%), followed by Delhi (17.45% and 8.17%) and A.P soil (18.38% and 4.4%).

5.5 WEED MANAGEMENT

5.5.1 Evaluation of Herbicides for Control of Broad Leaved Weeds in Wheat

In this field experiment, 11 treatments comprised with Halauxifen-methyl Ester + Florasulam 40.85% WG + Polyglycol 26-2 N, Metsulfuron methyl + surfactant, Carfentrazone, 2,4-D Na (80 WP), 2,4-D E 38 EC, Metsulfuron + Carfentrazone, 2,4-D Na (80



Weed distribution in *kharif* and *rabi* season crops under mustard- based cropping systems(CB-M:cluster bean-mustard, MB-M: mung-bean-mustard; PM-M: pearl millet-mustard and M-M: maize-mustard)

WP) + Carfentrazone, , 2,4-D E 38 EC + Carfentrazone, Halauxifen-methyl + Florasulam + Carfentrazone, weedy check and weed free were evaluated. Wheat cultivar HI 1544 was used in the trial. Results showed that all the herbicides significantly decreased the weed density observed. Maximum wheat grain yield (6.60 t/ha) recorded under weed free treatment was on a par with the application of Halauxifen-methyl Ester + Florasulam 40.85% WG + Polyglycol 26-2 N (6.46 t/ha) and Metsulfuron methyl + surfactant (6.42 t/ha), but significantly higher over the rest of the treatments. Whereas, highest biological yield (15.24 t/ha) obtained under same treatment was at par with Metsulfuron methyl + surfactant (15.13 t/ha), 2,4-D E 38 EC(15.00 t/ha), Halauxifen-methyl Ester + Florasulam 40.85% WG + Polyglycol 26-2 N, Metsulfuron + Carfentrazone (14.93 t/ha), Metsulfuron + Carfentrazone (14.89 t/ha), Halauxifen-methyl + Florasulam + Carfentrazone (14.80 t/ha) and 2,4-D E 38 EC + Carfentrazone (14.65 t/ha), but significantly higher than other treatments. Carfentrazone sprayed alone as well as tank mixed with other herbicides exerted phytotoxic effect on wheat crop.

5.5.2 Weed Dynamics Studies in Mustard-based Cropping System under Conservation Agriculture

The density of broadleaved weeds was higher over narrow leaved weeds, both at 30 and 45 DAS during both during *kharif* and *rabi* seasons. During *kharif* season, highest weed density was recorded in maize–mustard cropping system, followed by clusterbean–mustard system. No significant difference in the weed density was observed due to residue application in either conventional tillage (CT) or zero tillage (ZT) treatments during the first year of the experiment. However, the herbicide application of pendimethalin @1.0 kg/ha *fb*imazethapyr @ 0.75 kg/ha to cluster bean and mungbean; pendimethalin+ atrazine tank mix (0.75 kg/ha+0.75 kg/ha) *fb* to premezon @ 0.025 kg/ha to maize and pendimethalin+ atrazine tank mix (0.75 kg/ha+0.75 kg/ha) *fb*oxyfluorfen @ 0.25 kg/ha to pearl millet resulted in a 54.3% and 53.2% decline in the weed density at 30 DAS and 45 DAS, respectively, across all cropping systems. The herbicide application resulted in an increase of 25.3%, 23.9% and 42.6% in mustard seed yield, system productivity and mustard equivalent yield, respectively. In the succeeding *rabi* season, the weed density reduced by 32.8% and 41.2% at 30 and 45 DAS with herbicide application over weedy check.

5.5.3 Weed Management in Pigeonpea-Wheat Cropping System under Conservation Agriculture

Zero tillage (ZT) alongwith residue application @ 3 t/ha recorded significantly higher system productivity by 5.8% and 7.2 % over ZT and CT, respectively. Weed control efficiency (WCE), water use efficiency (WUE) and net returns were also recorded maximum with ZT + residue @ 3 t/ha. Among weed management practices, two hand weeding resulted in highest system productivity in terms of pigeonpea equivalent grain yield, WCE and WUE. Maximum net return was obtained with integration of pendimethalin @ 1.0 kg (pre-em.) + imazathapyr @ 60 g/ha (post em.) in pigeonpea and pinoxaden @ 50 g/ha + metsulfuron

@ 5 g/ha (Tank-mix) at 30 DAS in wheat. Integrated application of herbicides enhanced net returns of pigeonpea-wheat cropping system by Rs. 6650 and Rs. 37520/ha over two hand weeding and weedy checks, respectively.

5.5.4 Weed Management Influences Nematodes in CA-based Direct-seeded Rice

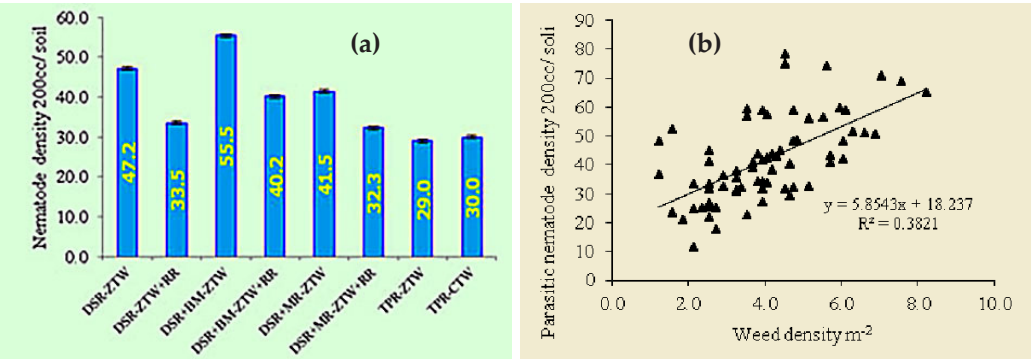
Under long term conservation agriculture (CA)-inclusive direct-seeded rice (DSR) -zero till wheat (ZTW) system, DSR was infested with 82.3% higher weed densities than transplanted rice (TPR) – conventional tilled wheat (CTW). The DSR-ZTW and DSR + brown manuring – ZTW systems encountered significantly higher populations of parasitic nematodes (*Tylenchorhynchus brevilineatus*, *Meloidogyne graminicola*, *Pratylenchus thornei*) than the TPR-CTW, but the retentions of rice residue (RR) and mungbean residue (MR) reduced their populations considerably. The DSR+ mungbean residue - ZTW+rice residue led to greater reductions in parasitic/total nematodes and gave comparable rice yields with TPR- CTW. There was a significant correlation between weed density and nematode density, which indicated that controlling weeds could also suppress nematodes and reduce the cost of nematode control.

5.5.5 Brown Manuring through *Sesbania bispinosa* and *Crotalaria juncea* Mixture for Weed Management in Maize

A field experiment was undertaken to study the effect of brown manuring on weeds and maize revealed that season-long weed infestation (~unweeded control) resulted in highest (~42%) reduction in maize grain yield. A brown manuring treatment, which involved growing of 1:1 mixture of *Sesbania bispinosa* (12.5 kg seed/ha) + *Crotalaria juncea* (12.5 kg seed/ha) supplemented with 2, 4-D 0.5 kg/ha resulted in highest reduction in weed density (~93%) and dry weight (~94%). *Sesbania* + *Crotalaria* (12.5+12.5 kg/ha) mixture applied with 2,4-D 0.5 kg/ha at 25 DAS gave comparable maize grain yield with weed-free control.

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

The dominant weed flora in the experimental area at Karnal were: *Coronopus dydimus*, *Medicago denticulate*, *Spergula arvensis*, *Chenopodium album*, *Chenopodium murale* and *Phalaris minor*. The effect of different chemical weed control treatments on seed yield and quality in onion cv Pusa Red was evaluated. All the weed control treatments registered significantly lower weed dry weight compared to weedy check at 90 DAS. Maximum reduction of weed dry weight (82.2% and 81.4 %) was recorded in Oxyflorofen and Pendimthalinfb hand weeding at 35 DAS, respectively, compared to weedy check. Weed free, Oxyflourofen 150g/ha and Pendimethalin 1.5 l/ha fb hand weeding 35 DAS recorded significantly higher umbels/plant, seed weight/umbel and 1000 seed weight compared to weedy check. Significantly higher seed yield was recorded in weed free, Oxyflourofen 150g/ha and Pendimethalin 1.5lit/ha fb hand weeding compared to weedy check, respectively. There was reduction



(a) Parasitic nematode population (200 CC soil); and (b) correlation between the densities of weeds and parasitic nematodes under CA-based rice

of 58.5% and 56.4 % in weedy check (194.57 kg/ha) compared to Oxyflourofen (469.17 kg/ha) and Pendimethalin (447.17 kg/ha) fb hand weeding. Higher seed quality was registered in Oxyflorofen 150g/ha and Pendimethalin 1.5 lit/ha Fb hand weeding compared to weedy check due to higher 1000 seed weight in these treatments. Seed yield was negatively correlated (-0.93) with weed dry weight and seed yield reduction could be predicted up to 1.69 kg/ha with increase in weed dry weight by one gram per square meter.

6. BASIC AND STRATEGIC RESEARCH

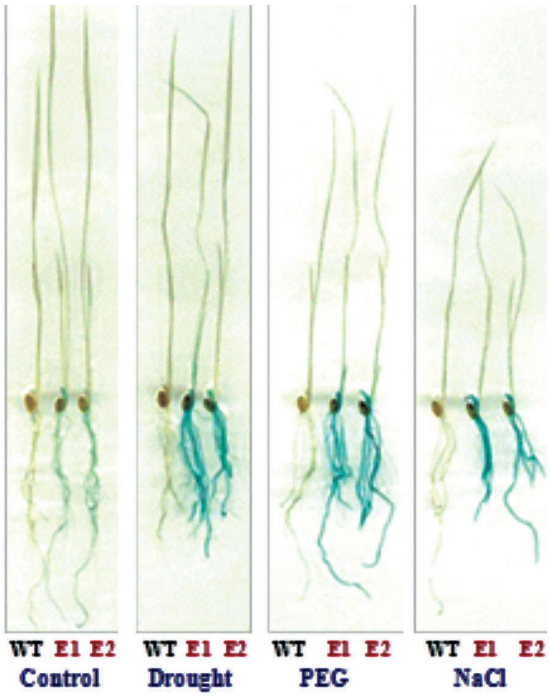
The basic and strategic research at IARI was focused on phenomics and phenotyping, deciphering the molecular basis of stress tolerance, development of molecular markers, mapping of genes for economically important traits, the physiological basis of crop yield, mitigation studies on climate change, development 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 Genomics and Gene Discovery

6.1.1.1 Cloning of drought stress-inducible root specific promoter from rice

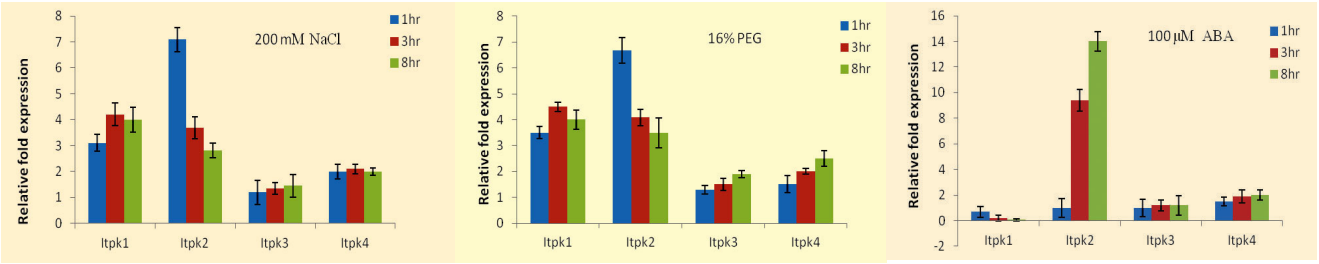
To understand the regulation of root system architecture (RSA), microarray and real-time RT-PCR expression analysis were carried out, and a root tissue-specific and osmotic stress *OsMYB TF* gene was cloned from rice. Rice genotype *Kita-ake* was genetically transformed with the *OsMYB* gene promoter::*GUS* reporter gene construct. The *OsMYB-GUS* transgenics were confirmed and subjected to GUS histochemical analysis to visualize *OsMYB* expression under different stresses. The results showed that *OsMYB* promoter is upregulated specifically in roots under drought, osmotic and salt stresses.



Root specific stress-induced upregulation of OsMYB promoter. Seedlings grown at control conditions and subjected to drought, osmotic (PEG6000 8%, 24h) and salt (100mM NaCl, 24h) were subjected GUS histochemical assay

6.1.1.2 Role of *GmITPK2* isoform in drought and salinity tolerance in soybean

Inositol 1,3,4, tris phosphate 5/6 kinase (ITPK), a polyphosphate kinase that converts Inositol 1,3,4 trisphosphate to Inositol 1,3,4,5/6 tetra phosphate, averting the inositol phosphate pool towards phytate biosynthesis in soybean. Real-time RT-PCR expression analysis of four *ITPK* genes in soybean revealed that *ITPK2* is induced under these stress probably in an ABA-dependent pathway. The osmo-protective role of *GmITPK2* was evaluated by assessing the growth of *E. coli* BL21 (DE3) cells transformed with *GmITPK2* gene. The *GmITPK2* recombinant *E. coli* cells showed tolerance to osmotic and salt stresses suggesting that *GmITPK2* may play a role in drought and salinity tolerance in soybean.



Quantitative RT-PCR analysis of *GmITPKs* genes in soybean. Expression was analyzed in seedlings treated with NaCl, PEG and ABA for different durations. β Tubulin was used as endogenous control

6.1.1.3 Heat tolerance of source-sink metabolism in wheat

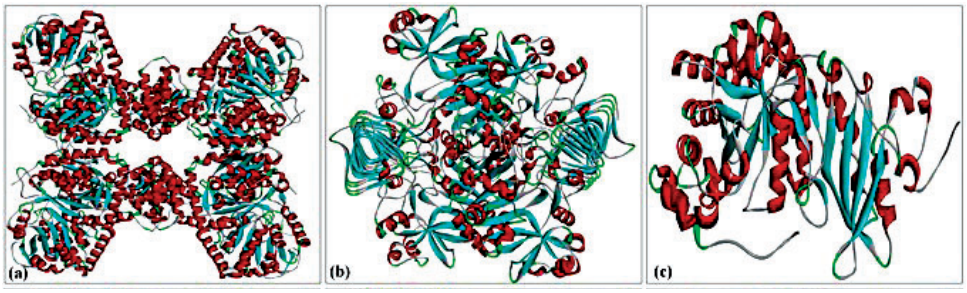
Wheat is highly prone to terminal heat stress (HS) under late-sown conditions. Four popular genotypes of wheat i.e. WR 544, HD 2967, HD 2932 and HD 2285 were evaluated for heat tolerance under field conditions. MALDI-TOF/MS analysis led to the identification of RuBisCO (Rub), RuBisCO activase (Rca), oxygen evolving enhancer protein (OEEP), hypothetical proteins, etcas Differentially Expressed Proteins (DEPs). HD 2967 showed better performance, as compared to other cultivars under terminal HS. SSS activity in HD 2967 was more stable under terminal HS, as compared with other cultivars. The identified DEPs will enrich the proteomic resources of wheat and will provide a potential biochemical marker for screening wheat germplasm for thermotolerance.

6.1.1.4 Characterization of heat stress associated proteins in wheat

TaHSFA6e was cloned from wheat cv. HD 2985 by using RT-PCR and sequenced with Sanger's di-deoxy method (GenBank accession no KU291394). Expression profiling of *TaHSFA6e* TF in contrasting wheat cvs. PBW 343, HD 2985, Halna and HD 2329 under control (C - 22±3ºC) and HS (30°C, 2 h and 38°C, 2 h) at anthesis and grain-filling stages showed that higher abundance of *TaHSFA6e* transcripts in thermotolerant cvs. (HD 2985 and Halna) as compared to thermosusceptible cultivars (HD 2329 and PBW 343). By using iTRAQ tool, sucrose synthase, AGPase and RuBisCo were identified as most abundant proteins in wheat under heat stress. Protein-Protein Interaction (PPIs) study showed a very complex network in case of sucrose synthase and RuBisCo, whereas AGPase showed simpler network structure. Sucrose synthase was observed to interact with some of the important proteins like trehalose phosphate synthase, starch synthase, isoforms of sucrose synthase, probable trehalose-phosphate phosphatase E, hydrolase, etc.

6.1.1.5 Heat tolerance of source and sink metabolism in wheat

Novel and hypothetical stress associated proteins involved in modulating the tolerance of photosynthesis (source) and starch metabolism (sink) under terminal



Three dimensional structure of heat stress associated proteins identified in wheat: (a) Sucrose synthase, (b)ADP-glucophosphorylase and (c) RuBisCO

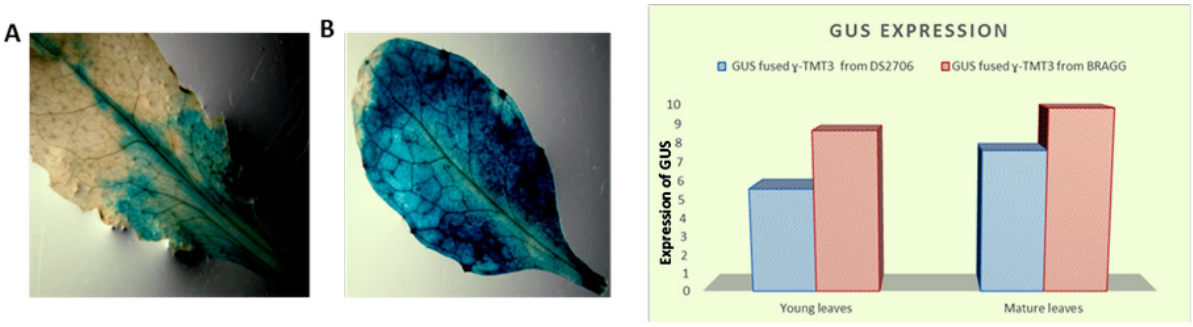
HS using iTRAQ. Under HS, stress associated proteins like CDPK, MAPK, HSPS17 and HSP70 were highly upregulated in both source-sink pathways. Carbon assimilatory pathway showed downregulation of RuBisCo and RCA along with sucrose phosphate synthase under heat stress as compared to control. Most of the signalling molecules and defence/stress associated proteins showed upregulation in leaves of wheat under HS. Because of denaturation of catalytic chaperone like RCA, there is an increase in the abundance of inactive RuBisCo inside the chloroplast causing drastic reduction in the photosynthetic rate. The transportation of sucrose is hampered because of denaturation/aggregation of sucrose phosphorylase and sucrose transporter under HS. Further expression and activities of starch biosynthesis associated AGPase, GBSS, SS-isoforms, SBE and SDE were downregulated under terminal HS. This leads to slowdown of starch synthesis and causes formation of pleated, fragmented, distorted and small starch granules with large empty pockets. The grain becomes shriveled and the quality is compromised under terminal HS.

6.1.1.6 Analysis of γ-TMT3 promoter reveals epigenetic regulation of the gene expression

Studies from gene to metabolite networking data showed 5 key genes in tocopherol (vitamin E) synthesis: 1- deoxy-D-xylulose-5-P-reductoisomerase (DXR), geranyl geranyl reductase (GGDR), arogenate dehydrogenase (TyrA), tyrosine aminotransferase (TAT) and γ-tocopherol methyl transferase 3 (γ-TMT3) from tocopherol-core pathways. Gene clustering analysis and membership values of gene expression showed DXR/DXS genes as the major hub influencing overall tocopherol biosynthesis gene network and the specific role of γ-TMT3 in tocopherol biosynthesis. Functional validation of γ-TMT3 promoter from Bragg and DS 2706 was carried out. Insertion of nucleotide A, C, and T at -787, - 113 and -1149/-1168, respectively, were found in DS 2706 promoter, whereas substitution of A to C at -795, T to A at 804 and C to G at -814 in Bragg promoter. Further γ-TMT3 promoter fused with β- glucuronidase (GUS) gene was stably transformed to *Arabidopsis* plants. Histochemical GUS assay showed significantly higher expression of GUS fused with γ-TMT3 promoter from Bragg. Highest percentage of methylation (88%) in γ-TMT3 promoter from Bragg was observed as compared to γ-TMT3 promoter DS706 (81%).

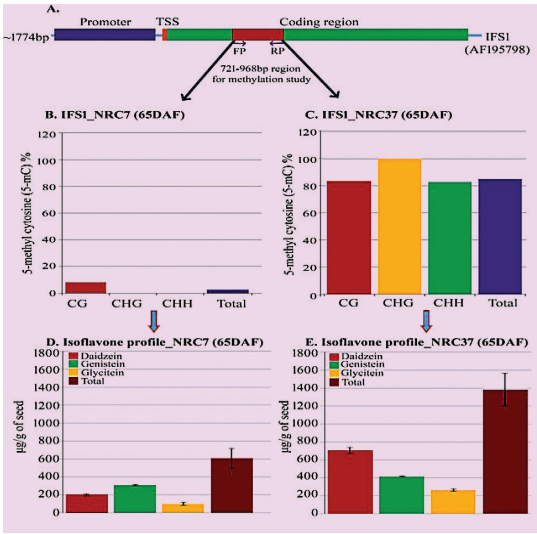
6.1.1.7 Epigenetic regulation of isoflavone synthase gene in soybean

The association between cytosine methylation (5mC) in the coding region of two isoforms of the isoflavone synthase (*IFS1 & IFS2*) genes and their expression levels in two contrasting genotypes of soybean viz., NRC 37 (a high isoflavone accumulating genotype; 1382.5 µg/g) and NRC 7 (a low isoflavone accumulating genotype; 606.4 µg/g) at 65 days after flowering (DAF) stage of seed development was analyzed. In NRC 37, the level of total 5-mC in the coding region of *IFS1* and *IFS2* was found to be 85% and 20.51%, respectively, while it was extremely low in NRC 7 (2.5% and 7.89%). In case of *IFS1*, NRC 37



Glucuronidase (GUS) histochemical assays for functional validation of γ-TMT3 promoter. (A) γ-TMT3 promoter from cv. DS 2706 fused with GUS; (B) γ-TMT3 promoter from cv. Bragg fused with GUS; (C) Expression analysis of *GUS* from stably expressed γ-TMT3 promoter fused *GUS* gene in *Arabidopsis*

showed higher 5-mC in all the three contexts compared to NRC 7; however, for *IFS2* although higher 5-mC level was observed in CG and CHH contexts but no difference was observed in CHG context. In summary, 5mC in coding region elevated the expression of *IFS1* and *IFS2* in NRC 37 as compared to NRC 7 which in turn could be accounting for the isoflavone-rich status of NRC 37.

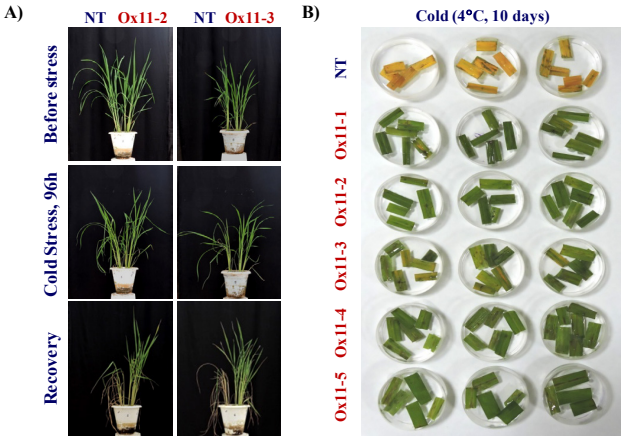


Cytosine methylation, isoflavone synthase 1 (IFS1) expression and isoflavone accumulation in soybean genotypes. Cytosine methylation levels in IFS1 of NRC7 (B) and NRC37; Isoflavone levels in NRC7 (D) and NRC37 (E) at 65 DAF

6.1.2 Genetic Engineering of Crops

6.1.2.1 Overexpression of *Abscisic Acid Receptor 11* (*ABAR11*) gene confers cold and drought tolerance

Towards functional genomics analysis of plant stress hormone ABA receptors (ABARs) in rice, 10 family members of ABARs were cloned from drought tolerant rice cv. Nagina 22 and gene function validation by transgenic overexpression and RNAi/CRISPR-Cas9 knock-out was initiated. Rice cv. MTU 1010 was transformed with *OsABAR11* under *RD29A* promoter. Rice transgenics were confirmed by PCR and qRT-PCR in T1 generation. Five independent transgenic events and non-transformed (NT) rice plants were evaluated for cold tolerance. *OsABAR11* overexpressing transgenic plants showed higher membrane stability, chlophyll stability and cold induced senescence. Upon recovery, *OsABAR11* transgenics showed significantly higher survival and biomass accumulation. *OsABAR11* transgenics lose less water in Excised Leaf Water Loss (ELWL) assay and produced more roots under drought stress as compared with NT plants.



Overexpression of ABAR11 gene confers cold tolerance to rice. A) Cold tolerance of rice plants exposed to 12°C for 3 days, B) Chlorophyll retention assay. NT non-transgenics; Ox11-1 to Ox11-5, different events of ABAR11 transgenics

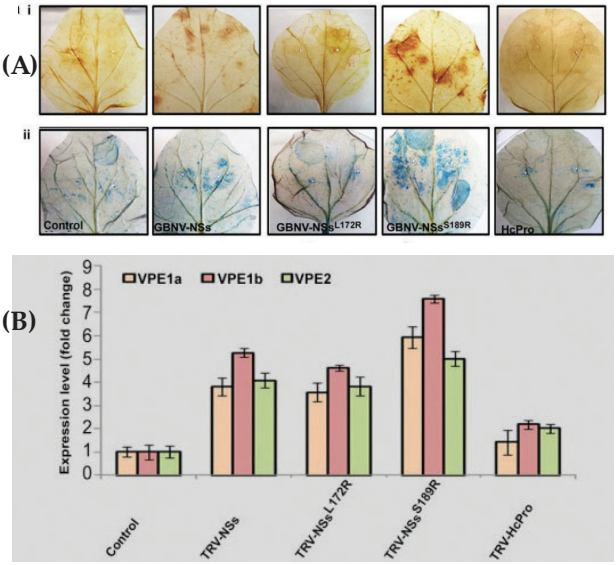
6.1.2.2 Regulation of phytate flux by targeted genome editing (CRISPR/Cas9 technology) in soybean

Low phytate soybean crop is required to enhance the bioavailability of phosphate and micronutrients from soybean. To reduce the phytate content in soybean seeds, Inositol pentakisphosphate -2-kinase (IPK1) was targeted for generating genome editing using CRISPR-Cas9 technology. Binary vector pCas9_IPK1 was constructed with sgRNAs complementary to *GmIPk1*. The construct was validated using a novel transient transformation method – AGRODATE (Agrobacterium mediated Disc Assay for Transient Expression). Transient agro infiltration assay in mature soybean discs combining vacuum, detergent, thiols and reducing agent allowed better delivery, penetration and infection of *Agrobacterium* into interior leaf tissues. Selective PCR amplification of the mutagenized *GmIPK1* gene from transient mutants and their analysis for *InDels* by sequencing revealed 90% deletions and 10% insertion in randomly sequenced clones. Further, we employed HPLC-PDA to measure phytate levels and found significantly reduced gene knock out leaf discs by 6-7 folds.

6.2 BIOCHEMISTRY

6.2.1 Induction of Cell Death by Tospoviral Protein NSs

Groundnut bud necrosis virus induces necrotic symptoms in different hosts. Previous studies showed reactive oxygen species (ROS)-mediated programmed cell death (PCD) results in necrotic symptoms. Transgenic expression of viral protein NSs mimics viral symptoms. Current study showed a role for NSs in influencing oxidative burst in the cell, by analyzing H_2O_2 accumulation, activities of antioxidant enzymes and expression levels of vacuolar processing enzymes, H_2O_2-responsive microRNA 319a.2 ant its target metacaspase-8. The role of NSs in PCD was shown using two mutants NSs: one in the Trp/GH3 motif (a homologue of pro- apototic domain) (NSsS189R) and the other in a non-Trp/GH3 motif (NSsL172R). Tobacco rattle virus (TRV) expressing NSsS189R enhanced the PCD response but not TRV- NSsL172R, while RNA silencing suppression activity was lost in TRV-NSsL172R, but not in TRV-NSsS189R. Therefore dual roles of NSs in RNA silencing suppression and induction of cell death controlled by different motifs was proposed.



Schematic presentation of GBNV-NSs, accumulation of H_2O_2, cell death and VPE transcripts. A) Leaves were stained with DAB (Top panel) for H_2O_2 detection and with trypan blue (bottom panel) for cell death was visualization, and B) qPCR validation of cell death-inducing VPE (VPE1a, VPE1b and VPE 2) transcripts in GBNV-NSs agro-inoculated plants. Data were normalized with actin gene expression levels (Error bars ± SD; n=3)

6.2.2 Inhibitory Effect of Gamma Irradiation on Peroxidation of Proteins & Bioavailability

Gamma-irradiation (1 to 5 kGy) of soybean seeds of two contrasting genotype viz., Pusa 9814 and EC 472143 could lead to improvement of protein quality by inducing certain physiochemical changes at protein and metabolite levels that may ultimately either converge to enhance the antioxidant status of seeds or may do so independently by acting in parallel fashion. The higher antioxidant response was manifested in terms of elevated levels of antioxidant activity, total and free phenolic contents and also by the augmentation of DPPH scavenger ability, while improved quality of proteins is reflected by low turbidity, surface hydrophobicity and high solubility. Based on this, a mechanistic model highlighting the sequence of events leading to the enhanced bioavailability and stability of soybean proteins after gamma irradiation was proposed. The results could prove to be a boon for soybean processing industries to enhance the consumer acceptability of soy products.

6.3 PLANT PHYSIOLOGY

6.3.1 Phenotyping and Identification of Donors for Abiotic Stress Tolerance

6.3.1.1 Inauguration of plant phenomics facility

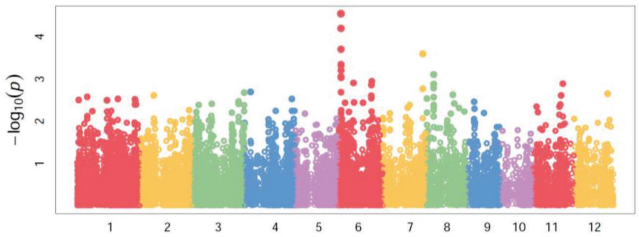
To bridge the phenotype-genotype gap, the Indian Council of Agricultural Research (ICAR) through National Agricultural Science Fund (NASF) established a state-of-the art plant phenomics facility at the Indian Agricultural Research Institute, New Delhi. Phenomics will be useful for dynamic phenotyping of the germplasm in controlled stress conditions to identify superior genes and genotypes. The phenomics centre will enable development globally competent scientific human resources in cutting edge research area of digital phenotyping and big data science for sustaining crop productivity under future climate change scenario. Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated and dedicated the

Hon'ble Prime Minister, Shri Narendra Modi inaugurating the " Nanaji Deshmukh Plant Phenomics Centre" at IARI, New Delhi. Hon'ble Union Minister for Agriculture and Farmers' Welfare, Shri Radha Mohan Singh (left in front row), Hon'ble Minister of State for Agriculture and Farmers' Welfare and Panchayati Raj, Shri Parshottam Rupala (right in front row) also seen in the picture, besides other dignitaries

"Nanaji Deshmukh Plant Phenomics Centre" to the Nation on October11, 2017, on the occasion of the birth centenary celebration of Nanaji Deshmukh at IARI, Pusa, New Delhi.

6.3.1.2 Phenomics of transpiration in rice

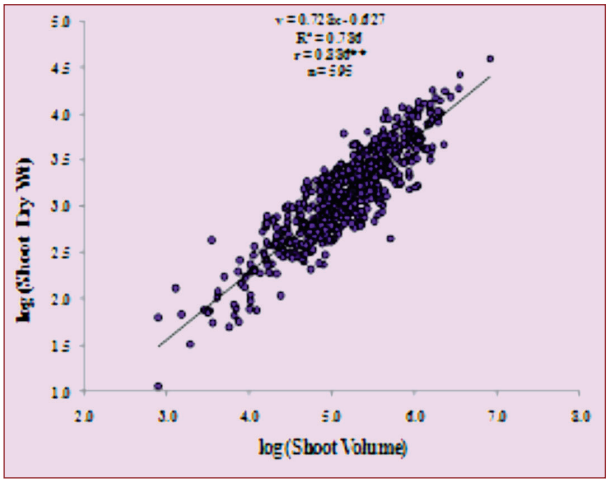
To identify donors and genes for enhancing water use efficiency in rice, phenomics of diurnal and nocturnal transpiration in rice genotypes were studied. An experiment was conducted at phenomics facility during *kharif* 2017 with 150 rice genotypes to study the genotypic variation in diurnal and nocturnal transpiration. Significant genotypic variation was observed in diurnal and nocturnal transpiration. Genotypes with contrasting transpiration rates were identified. GWAS analysis was carried out and QTLs/ Genes for transpiration were mapped in rice. Eighteen QTLs for mean day time transpiration and 12 QTLs for mean night time transpiration per unit leaf area were mapped. A Region on chromosome 6 appears to control whole plant transpiration.



Manhattan plot for mean night time transpiration per day in rice genotypes

6.3.1.3 Rapid and non-destructive field phenotyping of rice crop biomass and growth

Conventional method of estimation of biomass is based on destructive sampling, and time consuming.



Correlation of estimated above ground shoot volume of rice with the shoot dry weight

Hence high throughput non-destructive methods are necessary for phenotyping of large set of genotypes. The plant height and shoot circumference of a rice hill can be used for rapid estimation of rice plant volume based on conical geometry. The estimated volume of rice hill was highly correlated with the actual shoot dry weight from destructive sampling. Thus, measurements of plant height and stem circumference provide simple, rapid, non-destructive and repetitive field phenotyping of biomass production and growth rates in rice crop.

6.3.1.4 Association between ABA- and drought-mediated regulation of root traits in rice

Genetic improvement in root traits is necessary to enhance and stabilize yield of rice crop under rainfed ecosystem. A set of 32 rice genotypes were phenotyped for root traits in 500 nM ABA at seedling stage in hydroponics, and then evaluated under drought stress (soil matric potential -70 kPa) at anthesis stage in field conditions. The stress susceptibility index (SSI) based classification of genotypes under ABA response as well as drought matched with yield for 7 good performing and 7 poor performing genotypes. Rice genotypes, CR 2624, Ching Moiramsbhi, IC 526266, Moroberekan, Nerica-L 26, Nerica-L 42 and Sahbhagi Dhan, which exhibited enhancement or stability in root length in response to ABA, also showed stability in both root length and yield under drought stress in field conditions. Single Nucleotide Polymorphism (SNP) analysis led to the identification of 20 non-synonymous SNPs in 12 genes involved in root traits. This study showed that screening for ABA responsiveness in root traits is a potential surrogate to identify donors for better root traits under drought stress in field conditions.

6.3.1.5 Sink activity and grain quality of rice genotypes under high night temperature

The pattern of starch synthesis and catabolic enzymes in developing rice grain were analysed under high night temperature stress during grain filling. Rice cultivars Vandana (HNT susceptible) and Nagina 22 (HNT tolerant) were exposed to post anthesis 3°C increase in temperature over an average night temperature of 25°C during grain filling. In general, granule bound starch synthase (GBSS) activity was high in Nagina 22 as compared to Vandana and decreased by 5-9% under HNT against 9-26% in the latter cultivar during grain growth. A marked increase in GBSS activity in Vandana at 20 days after anthesis (DAA) suggested the compensation for amylose accumulation in later stages of grain growth. Alpha amylase activity increased by 17% in Nagina 22 at 5 DAA under high night temperature. Grain amylose content decreased by 2% in Vandana but was maintained in Nagina 22. These results suggest that GBSS regulates change in amylose content in rice cultivar under high night temperature.

6.3.1.6 Polyamines improve reproductive stage high temperature and drought stress tolerance in rice

Four rice genotypes, namely, N 22, PRH 10, IR 64 and PB 1121 were grown under normal environment and exposed to high temperature (HT) (38-41°C) and drought stress at anthesis stage. The effect of exogenous application of putrescine (2.5 mM) and spermidine (1.5 mM) at anthesis stage on high temperature (HT) (38-41°C) and drought stress tolerance was analyzed. Spermidine application improved spikelet fertility and panicle grain yield in PRH 10 and Pusa Basmati 1121 particularly under drought stress. Similar trend under drought stress was observed in N 22 but the magnitude of improvement was lower compared to above genotypes. IR 64 showed no significant changes in fertility under drought as well as high temperature stress. This study suggests that polyamines may improve high temperature and drought stress tolerance in selected rice genotypes.

6.3.1.7 Phenomics of water use efficiency in wheat

Enhancing drought tolerance and water use efficiency is important to sustain wheat yield under limited irrigation conditions. A set of 183 wheat genotypes were analysed from sowing to maturity for water use and drought tolerance at Nanaji Deshmukh Plant Phenomics Centre. About nine thousand data points were generated. Variety wise data was analyzed

using two-way ANOVA with time point and treatment as factors with 8 and 2 (drought and control) level, respectively. Digital biomass (in unit voxel) was taken as response variable, which is obtained from images of three side view (0, 120 and 240 degree) and top view. Varieties were grouped mainly into two classes having significant and non- significant differences of digital biomass at 5% level of significance between drought and control plants over eight time points undertaken. Fifty six genotypes showed non-significant differences suggesting the stability of these genotypes under drought stress conditions. WUE in wheat genotypes under non-stress conditions varied from 2.64 to 0.64 g grain kg^{-1} water used, while that under drought stress varied from 2.71 to 0.61 g grain kg^{-1} water used.

6.3.1.8 Ear contribution towards the grain yield in different wheat genotypes

A study was conducted to determine the contribution of the main ear (by ear shading technique) towards its yield in 18 different wheat genotypes grown in field under normal and heat stress (late sown) conditions. Under normal condition, main ear grain yield ranged from 1.72 to 3.53 g. Ear shading caused minimum and maximum reduction in yield for genotypes WR 544 and HD 3086, respectively. Results revealed that contribution of ear to its yield in these genotypes varies from 2.4 to 47.0 % under non-stress conditions. Shading of main ear caused minimum and maximum reduction in yield for genotypes DBW 14 and PBW 343, respectively, under heat stress, and thus contribution of ear to its yield varied from 0.2 to 45.5 % under heat stress conditions. Identification of suitable donors for different ear-related traits will help improve wheat productivity under heat stress.

6.3.1.9 Photo-protective role of photosynthetic pigments for heat tolerance in wheat

A pot experiment was conducted using contrasting six wheat genotypes to analyze the photo-protective role of photosynthetic pigments in heat tolerance of wheat. High temperature was imposed by delaying sowing dates i.e. normal (15thNovember, 2016) and late sowing (15th January, 2017). Among the six wheat genotypes, heat tolerant genotypes under late sown high temperature condition, had higher level of Chl_a, total carotenoids and the ratio of Chl_a/ Chl_b & total carotenoids/ total chlorophyll as compared to relatively sensitive genotypes. Heat tolerant genotypes maintained photosynthetic pigments in general and carotenoids (zeaxanthin & lutein) in particular. Further, heat tolerant genotypes exhibited higher values of non-photochemical quenching (NPQ) under heat stress condition.

6.3.1.10 Physiological analysis of staygreen RILs for drought and heat tolerance

The RILs from DBW 43 x HI 1500 cross were studied under combined stress of heat and drought. For identification of contrasting functional staygreen RILs under heat, drought and combined stress, physiological traits such as chlorophyll content, photosynthesis and related traits, leaf area duration, yield and related parameters and harvest index were studied. Based on these traits, staygreen (P6, P33) and non-staygreen (P23, P30) RILs were identified, which will be useful for improving combined stress tolerance in wheat.

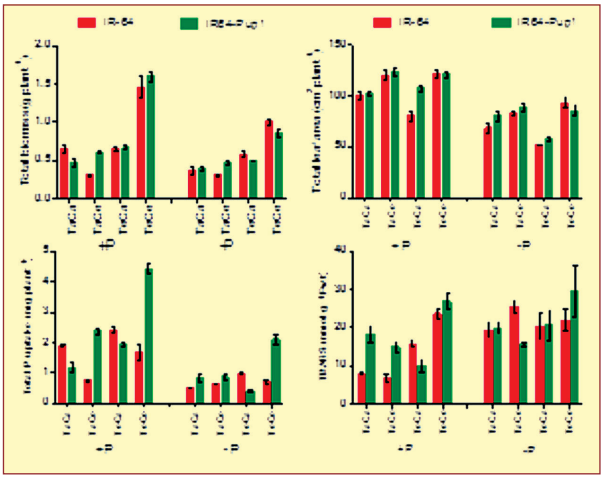
6.3.1.11 Stem reserve mobilization (SRM) in wheat under combined heat and drought stress

Stem reserve mobilization efficiency was analyzed in diverse set of 44 wheat genotypes under four field conditions namely, timely sown irrigated, timely sown rainfed, late sown irrigated and late sown rainfed. Traits such as stem reserve mobilization (SRM), stem reserve efficiency (SRE), harvest index (HI), leaf senescence duration (LSD), leaf senescence rate (LSR), growing degree days (GDD), grain weight (GW), specific weight (Sp. wt), Height (Ht) and grain weight percentage (GWP). Results showed that both SRM and SRE are significantly highly correlated with stem specific weight under irrigated, drought, heat as well as combined heat and drought field conditions.

6.3.2 Impact of Climate Change on Crop Physiology

6.3.2.1 Influence of elevated CO_2 × temperature on phosphorus nutrition in rice seedlings

The interactive effects of elevated CO_2, temperature and low P on plant growth, antioxidant system and P starvation signaling components in two rice varieties, IR 64 and IR 64-Pup1, were studied under controlled conditions. The treatments were low (2 µM) and sufficient (500 µM) P, temperature D/N 28°C/18°C (ambient; aT) and 35°C/20°C (elevated; eT), and CO_2 400 ppm (ambient, aCO_2) and 700 ppm (elevated, eCO_2). eCO_2 × T enhanced biomass as well as P uptake in low P plants. The total leaf area reduced with low P and low P × eT whereas eCO_2 enhanced leaf area under low P. eCO_2 improved root length, while eT increased root diameter. Together CO_2 × T interaction caused an increase in root surface area. The levels of TBARS, an indicator of lipid peroxidation, increased considerably under low P and eT resulting in higher membrane injury under low P × eT. The expression of OsmiR399a and OsmiR399b were up-regulated by low P × CO_2 × T, while the expression of their target gene, *OsPHO2*, was considerably down-regulated. Both miR827 and its target *NLA-SPX* exhibited lower expression under eCO_2 × T interaction whereas eCO_2 enhanced their expression. Expression of low P induced *OsPHR1* was strongly enhanced by eCO_2 as well as CO_2 × T.

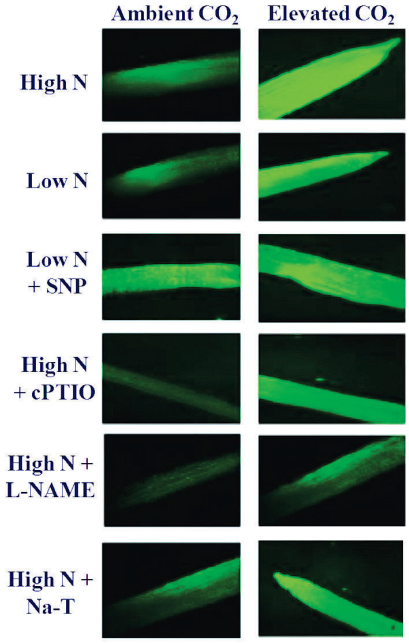


Influnce of elevated CO_2 and temperature on biomass, leaf area, P uptake and membrane damage in rice seedlings under low P

Up-regulation of signaling components and down-regulation of their corresponding targets resulted in higher P uptake under the interaction of elevated CO_2 × T. Thus, a concomitant rise in CO_2 levels and temperature enhanced the activity of P starvation signaling components that resulted in better P uptake.

6.3.2.2 Impact of elevated CO_2 on nitrogen metabolism and nitrate signalling in wheat

The protein concentration of wheat grain often decline as a result of exposure to elevated CO_2 (EC). An experiment was conducted to determine the effect of rising CO_2 levels on changes in mechanism of N assimilation, nitrate uptake, nitrate and nitric oxide signaling and plant growth in two wheat genotypes differing in N assimilation in two wheat varieties. Exposure to EC enhanced the plant biomass, leaf area



Effect of elevated CO_2 on nitric oxide (NO) production in roots of wheat seedlings. Photographs of NO production shown as green fluorescence of DAF- FM DA in representative roots

and contents of photosynthetic pigments. Activities of nitrate reductase and ammonia assimilating enzymes, glutamine synthetase and glutamate synthase were downregulated by exposure to EC. The transcription of genes involved in N assimilation and signaling were also downregulated under EC conditions. Plants grown under EC displayed enhanced production of

nitric oxide (NO) and more so when N availability was high. Based on exogenous supply of NO, inhibitors of NO production and NO scavenger, regulatory role of NO on EC mediated changes in root morphology and NR activity was revealed. The enhanced NO production under EC and high N levels, negatively regulated the NR and HATS at both transcriptional and post translational levels. Plant growth under EC resulted in alteration of N assimilation and signaling depending on the level of N supply.

6.4 GENETICS

6.4.1 Wheat

6.4.1.1 Identification of QTLs linked to drought and heat stress tolerance

Backcross-derived populations were phenotypes under drought and heat stress conditions. A total of 44 QTLs were detected in the mapping population of GW 322 x HI 1500 for drought stress tolerance. Nine QTLs were detected in the mapping population of WH 730 x HD 2733 for heat stress.

6.4.1.2 Development of double haploids (DHs) in wheat

Fifteen doubled haploid (DH) plants were developed using *Imperata cylindrica* mediated chromosome elimination technique. The cross between *I. cylindrica* with F_1s and parents highlighted that the frequency of DH production was more in parents than in F_1s. Eleven DH developed so far were genotyped with molecular markers for the presence of *Lr34*.

6.4.1.3 Molecular characterization of introgression lines carrying leaf rust resistance

Three cytologically stable *T. militinae* (AtAtGG, 2n=4X=28) derived introgression lines (ILs) viz., TMD 6-4, TMD7-5 and TMD11-5 with wide spectrum rust resistance were used for molecular characterization. About 1200 SSRs were used for genotyping these ILs. The extent of introgression in ILs TMD6-4, TMD7-5 and TMD11-5 was 2.8, 8.3 and 8.6%, respectively. The set of 'informative markers' in the Molecularly Tagged Chromosome Regions (MTCR) of *T. militinae* origin can also be used in future for tagging of genes associated with traits of economic importance. The transferability of *Triticum aestivum* SSRs to *T. militinae* was 96.4% for A genome, 95.8% for B genome and 84.3% for D genome.

6.4.1.4 Molecular mapping of leaf rust resistance

A dominant gene for leaf rust resistance was mapped to the long arm of chromosome 3B (*LrS2427*) in Selection 2427, a bread wheat introgresed line with *Ae. speltoides* as donor parent. *LrS2427* seems to be a novel gene as none of the known seedling leaf rust resistance genes so far have been located on chromosome 3B. Selection 2427 showed a unique property typical of gametocidal genes that when crossed to other bread wheat cultivars, the F_1 showed partial pollen sterility and poor seed setting suggesting an accidental co-transfer of gametocidal genes with *LrS2427* from Selection 2427. However, *LrS2427* did not show any segregation distortion and assorted independently of putative gametocidal gene(s), its utilization will be difficult due to the selfish behaviour of gametocidal genes. In order to exploit wild resources, CIMMYT has developed a series of synthetic hexaploid wheat by combining the accessions of D genome donor *Triticum tauschii* and *T. durum*. Characterization of leaf rust resistance in Synthetic 45 by multi-pathotype tests showed a high degree of seedling resistance to 20 diverse pathotypes of leaf rust pathogen and APR against two most prevalent pathotypes, 77-5 and 104-2. Inheritance studies showed that resistance in Synthetic 45 was governed by a single recessive gene. Molecular mapping indicated that the resistance gene is located on short arm of chromosome 1D with 6.1 cM distance to *Xwmc432* and 10.6 cM to *Xcfd15* with 4.6 cM distance among the two markers. The gene identified in Synthetic 45 has been designated as *LrSyn45*.

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

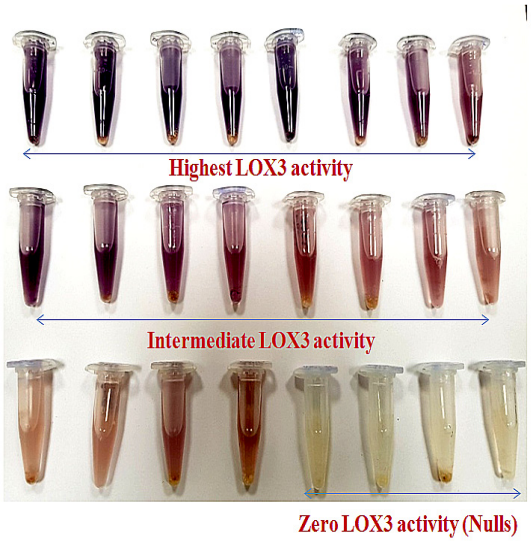
Locally adapted variety NP 4 does not carry any *Lr* gene or suppressor factor for leaf rust resistance,

and is early maturing, slow rusting, lodging-tolerant, non-shattering, heat and drought tolerant and bold seeded cultivat. Earlier, 9 differentials carrying *Lr1, Lr2a, Lr2c, Lr3a, Lr9, Lr10, Lr15, Lr17a* and *Lr20* were developed in NP 4 background and registered. Now, the NILs carrying leaf rust genes *Lr13, Lr18, Lr19* and *Lr26* were developed by backcrossing NP 4 line with Thatcher lines carrying these genes. The lines viz., HI KK 10 (NP4+*Lr13*) (IC0624491, INGR17034), HI KK 11 (NP4+*Lr18*) (IC0624492, INGR17035), HI KK 12 (NP4+*Lr19*) (IC0624493, INGR17036) and HI KK 13 (NP4+*Lr26*) (IC0624494, INGR17037) carrying leaf rust resistance genes were registered with NBPGR, New Delhi.

6.4.2 Rice

6.4.2.1 Identification of rice genotypes with non-functional lipoxygenase 3 (LOX3) enzyme

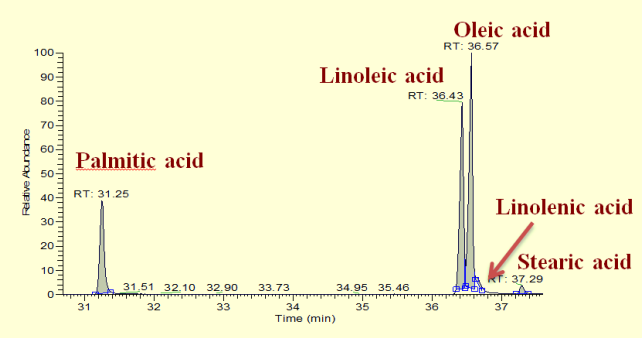
A set of 250 rice germplasm accessions were screened for LOX activity by KI starch assay method. Genotypes with functional LOX3 produce dark purple color in the assay, while those with non-functional LOX3 give no colour. Based on the assay, accessions were characterized into different LOX activity groups and identified 12 genotypes with complete absence of LOX activity. These genotypes could be the probable nulls for LOX gene with absence of functional LOX3 enzyme, hence can be further utilized towards the development of cultivars with improved storage.



Evaluation of rice germplasm accessions for their LOX3 activity

6.4.2.2 Fatty acid profiling in rice bran

A set of 140 recombinant inbred lines derived from the cross of Pusa Basmati 1121 and Pusa 1342 were phenotyped for fatty acids in rice bran. Significant differences were observed between the parents for all the major fatty acids viz., 14:0, 16:0, 18:0, 18:1, and 18:2. Genomic regions governing fatty acid composition will be identified further.



Fatty acid profiling in rice bran

6.4.3 Maize

6.4.3.1 Identification of genes for waterlogging tolerance

Analysis of root transcriptome of waterlogging tolerant inbred (HKI 1105) using RNA sequencing revealed 21,364 differentially expressed genes (DEGs) that regulate energy-production, programmed cell death (PCD), aerenchyma formation and ethylene responsiveness under waterlogged stress conditions. High up-regulation of *invertase* (49-fold), *hexokinase* (36-fold), *expansin* (42-fold), *aspartic protease A3* (19-fold), *polygalacturonase* (16-fold), *respiratory burstoxidase homolog* (12-fold), and *hydrolase* (11-fold) were observed. SNPs were mapped to the DEGs regulating aerenchyma formation, ethylene-responsive factors, and glycolysis under stress.

6.4.3.2 Post-transcriptional regulation of genes for drought tolerance

A set of 13 drought-associated miRNA families consisting of 65 members and regulating 42 unique

target mRNAs were subjected to structural and functional characterization. The largest number of members (14) was found in the Zm-miR166 and Zm-miR395 families. Twenty-three major drought-responsive cis-regulatory elements were found in the upstream regions of miRNAs. Many drought-related transcription factors, such as GAMYB, HD-Zip III, and NAC were associated with the target mRNAs. Nearly 35% and 31% of miRNAs were up-regulated in HKI 1532 (tolerant) and V 372 (sensitive), respectively. The up-regulation of target mRNAs was as high as 14.2% in HKI 1532, but was only 2.38% in V 372. A low level of negative regulations of miRNA associated with a higher level of mRNA activity in the tolerant genotype helped to maintain crucial biological functions thereby leading to drought tolerance.

6.4.3.3 Development of MAGIC populations

Development of MAGIC population in maize was undertaken using eight founder lines (UMI 1210, LM 17, CML 22, HKI 1105, LM 13, NAI 147, CPM 8 and CPM18). The inbreds had high per se yield, drought tolerance, MLB tolerance and borer resistance. These were crossed in systematic way and now the population is at 8 way cross. These will be further utilized in dissecting the trait of interest.

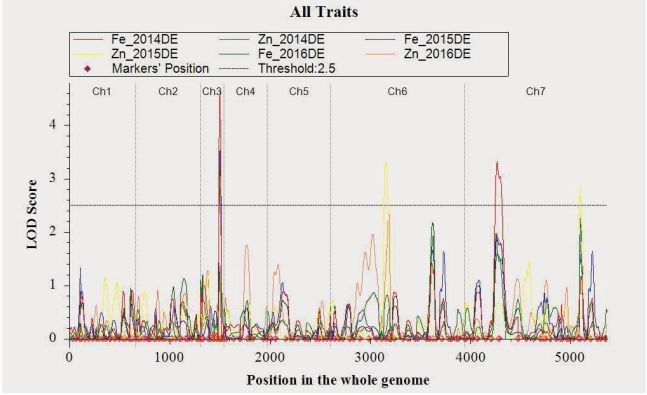
6.4.3.4 Development of bi-parental mapping population

Following crosses were attempted for developing mapping population to study the genetics of stress tolerance, viz., drought tolerant vs susceptible (CML 425 x SKV 239 and HKI 1105 x SKV 1142) and water logging tolerant vs. susceptible (HKI 1105 x SKV 38). Population is at F_2 stage and will be advanced to respective different family in coming season.

6.4.4 Pearl Millet

6.4.4.1 Mapping of QTL for the grain Fe and Zn

Two hundred ten RILs were phenotyped for grain iron and zinc content using AAS during 2014, 2015 and 2016 and genotyped with 142 polymorphic markers for QTL mapping. QTL for grain iron content was detected on chromosome 3 with a LOD score of 2.5 and a recombination frequency threshold of 0.5 and explained year-wise phenotypic variation of 9.59%, 8.30% and 7.26%, respectively. For grain zinc content, two QTLs in year 2015 and one QTL in year 2016 were detected on chromosome 6 and chromosome 7 with LOD score of 2.5 and phenotypic variance 6.81%, 9.28% and 6.44%, respectively. One more QTL for grain iron content was identified at chromosome 7 in the year 2014 which explained 25.64% phenotypic variation.



QTLs for iron and zinc identified in $F_{6:7}$ population of PPMI 683 x PPMI 627

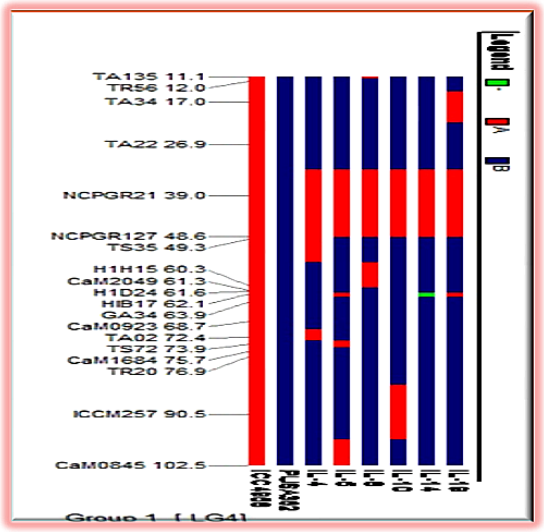
6.4.4.2 Inheritance of fertility restoration of the A_4 CGMS system

Inheritance of fertility restoration of the A_4 system of cytoplasmic genetic male sterility in pearl millet was investigated using four crosses involving two diverse male sterile lines and two diverse restorers belonging to A_4 cytoplasm. The F_2 and BC_1 populations of four crosses were planted in two environments (Delhi and Dharwad). Crosses ICMA 99111/DPR 7, ICMA 99111/DPR 8, ICMA 03999/DPR 7 and ICMA 03999/DPR 8 showed a segregation ratio of fertile: sterile as 15:1 and 3:1 in F_2 and BC_1 generations, respectively, for pollen fertility and seed set indicating involvement of the duplicate dominant epistasis for fertility restoration of A_4 CGMS system.

6.4.5 Chickpea

6.4.5.1 Development of drought introgression lines

Introgression lines of chickpea were developed harbouring the 'QTL hotspot' from the donor parent ICC 4958. Pusa 362, an elite *desi* chickpea cultivar was used as recurrent parent. Foreground selection was done using two SSR markers (NCPGR 21 and NCPGR 127). Twenty ILs (BC_2F_4) with 79-97% recurrent parent genome recovery were phenotyped for root traits and yield. Phenotyping for eleven root traits revealed that most of the ILs were better than the recurrent parent Pusa 362 for most of the root traits. Nine out of twenty ILs out yielded Pusa 362 under rainfed conditions. The introgression of the donor parent genome associated with the root trait QTL-hotspot region was depicted using Graphical Genotyping Software (version GGT



Recover of the RPG in introgressed progenies

2.0) which helped to select plants with maximum RPG recovery to eliminate the **linkage drag** on carrier chromosome. IL 5 (BG 3097) gave significantly higher yield as compared to Pusa 362 and was entered into coordinated trial.

6.4.5.2 Identifying transcription factor genes associated with yield traits

The *Kabuli* reference genome-based GBS and targeted gene amplicons resequencing-led high-throughput SNP genotyping in 326 *desi* and *Kabuli* accessions led to the identification of 1611 SNPs from 736 TF genes representing 30 TF gene family. Maximum of 551 and 484 SNPs were discovered from the 257 and 221 TF-encoding genes belonging to Zinc finger and DUF (domain of unknown function) TF gene families, respectively. Of these, 1497 and 114 SNPs derived from 683 and 53 TF genes were physically mapped across eight chromosomes and unanchored scaffolds of *Kabuli* genome, respectively. The eight chickpea chromosomes contained maximum frequency of SNPs in the TF genes belonging to zinc finger and ARF (auxin responsive factor) TF gene families.

6.4.6 Mechanism of MYMV Resistance in Mungbean

RNA-seq comparison between a resistant mungbean genotype (PMR 1) and a susceptible genotype (Pusa Vishal) challenged with the MYMV virus and mock inoculated, was carried out. The number of differentially expressed genes (DEGs) identified between resistant (inoculated) and susceptible (control) and susceptible (inoculated) and resistant (control) were 208 and 451, respectively. A number of defense-related genes/ pathways were significantly induced only in PMR 1, while photosynthesis and several metabolic pathways were affected in both genotypes with MYMV infection. Gene ontology enrichment analysis of the differentially expressed genes revealed key components during the viral infection, which included carbohydrate metabolic process (GO:0005975), protein kinase activity (GO:0032147), xyloglucan metabolic process (GO:0010411), phosphorelay signal transduction system (GO:0000160) and phosphatidylinositol-3-phosphate biosynthesis (GO:0036092).

6.4.7 Lentil

6.4.7.1 Association mapping for grain iron and zinc content

A set of 96 diverse germplasm lines were evaluated at three locations for Fe and Zn concentration. The genetic variation among genotypes of the association mapping (AM) panel was characterized using a genetic

distance-based and a general model-based clustering method. The model-based analysis identified six sub-populations, which satisfactorily explained the genetic structure of the AM panel. AM analysis led to the identification of three SSRs (PBALC 13, PBALC 206, and GLLC 563) associated with grain Fe concentration explaining 9% to 11% of phenotypic variation and four SSRs (PBALC 353, SSR 317±1, PLC 62, and PBALC 217) associated with grain Zn concentration explaining 14% to 21% of phenotypic variation. These candidate SSRs can be used in marker-assisted genetic improvement for developing Fe and Zn fortified lentil varieties.

6.4.7.2 Variation of salinity tolerance in cultivated and wild genotypes

One hundred and sixty two genotypes of different *Lens* species were screened for salinity tolerance in hydroponics at 40, 80 and 120 mM sodium chloride (NaCl) for 30 d. The germination, seedling growth, biomass accumulation, seedling survivability, salinity scores, root and shoot anatomy, sodium ion (Na+), chloride ion (Cl-) and potassium ion (K^+) concentrations, proline and antioxidant activities were measured to evaluate the performance of all the genotypes. Genotypic variation for salinity tolerance was observed among the genotypes screened under hydroponic and saline field conditions. Concentrations of Na^+ and Cl^- in plant tissues at 120 mM NaCl stress treatment were found to be significantly correlated with germination, root and shoot length, fresh and dry weight of roots and shoots, seedling survivability, salinity scores, K^+ and seed yield in the field. Root and shoot anatomy of tolerant line (PDL 1) and wild accession (ILWL 137) showed restricted uptake of Na^+ and Cl^- due to thick layer of their epidermis and endodermis as compared to sensitive cultivar (L 4076).

6.4.8 Mustard

6.4.8.1 Development of Recombinant Inbred Lines

Three mapping populations for mapping genes/QTLs for heat stress tolerance (Pusa Bahar x BEC 144, F_9), oil content (EJ 17 x BEC 144, F_6) and seed size (NPJ 161 x BEC 144, F_5) were advanced for developing RILs.

6.4.8.2 Screening and genomic analysis for seedling stage heat tolerance

Thirty promising genotypes were screened for heat tolerance in phytotron conditions. The expression analysis of transcription factors i.e. HSF3, HSF3B, HSP20 and gene DWF-4 involved in heat tolerance were analyzed between heat tolerant genotype Pusa Bahar and susceptible genotype Pusa Karishma. HSF3 and HSF3B expressions were higher in heat tolerant genotype as compare with heat susceptible genotype.

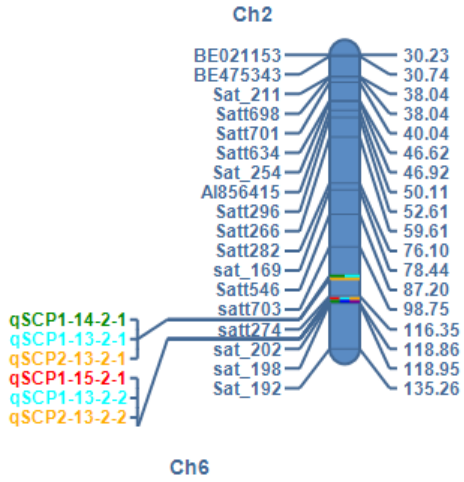
6.4.9 Soybean

6.4.9.1 Breeding for tolerance to waterlogging

A set of 145 soybean genotypes were phenotypes for waterlogging tolerance at germination stage. Two methods viz, i) sowing seeds in plastic cups and flooding it with water (PCM), and ii) dibbling seeds pre-soaked in water for required duration (SM) were used. Four treatment conditions (3, 5, 7, 9 days water-logging) along with one well-drained treatment were set for each method. Data was recorded on percent germination; shoot length (cm), root length (cm), fresh and dry weight (g) on the seventh day of draining/dibbling. Threshold treatment level was found to five days of waterlogging duration. The PCM method was statistically better than the SM method for evaluating pre-germination water logging tolerance in soybean. Most susceptible (Pusa12-13, DS 9712, VLS 93, G 2658) and most tolerant (WT 3, WT 8) genotypes were identified. Six crosses were made based on tolerance, yield, seed colour and mosaic resistance.

6.4.9.2 Seed coat permeability in soybean

Seed coat of wild type soybean (*G. soja*) is impermeable while that of cultivated type (*G. max*) is permeable. Two wild type soybean accessions viz., PI 424079 and PI 366120 were crossed with a cultivated variety (JS 335). Seed coat of the $F_{1:2}$ seeds of both the cross combinations were primarily impermeable (84-89%) indicating impermeability to be dominant over permeability. The $F_{2:3}$ seeds exhibited wider variability for seed coat impermeability (0-100%). Grouping and



QTL for seed coat permeability in soybean

Chi-square analysis of the data revealed that seed coat impermeability is controlled by at least one major gene. In order to map the genomic regions for seed coat permeability, a RIL population ($F_{2:6}$) developed from a cross between a wild type soybean (impermeable seed coat) and a cultivated variety (permeable seed coat) was used. A set of 207 polymorphic SSRs were used for genotyping 204 RILs. The seeds of the RILs were soaked in water for 6 h for phenotyping. Five QTL were mapped for the trait; however, a QTL on Chr.2 alone explained 62.92% of the phenotypic variations indicating to be a major QTL. Other 4 QTL had phenotypic effect in the range of 5.93-10.33%. The QTLs were validated in an unrelated F_2 population.

6.4.10 Cauliflower

6.4.10.1 Interspecific hybridization for transfer of black rot resistance

Interspecific hybridization between cauliflower cv. (black rot susceptible) × *Brassica napus* (resistant) was made and *in vitro* embryo rescue was used to produce F_1. The plants at BC_2F_1 stage of Cauliflower '' × *B. carinata* 'NPC-9', BC_1F_2 stage in Cauliflower 'DC 401' × *B. juncea* 'Pusa Vijaya' and Cauliflower 'DC 401' × *B. nigra* were inoculated with *Xcc* race 1, 4 and 6. Resistant plants with leaves resembling cauliflower, dwarf stature and late bolting were backcrossed to recipient parent of cauliflower and self-pollinated to produce advance generation. One hundred six RILs of *Brassica carinata* (NPC-17 × NPC-9) were advanced to F_7 generation for black rot resistant trait.

6.4.10.2 Diversification of CMS system

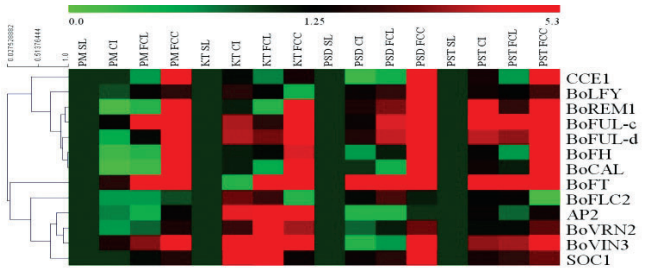
Introgresison of *Eru* CMS system in cauliflower was advanced to BC_4 generation with cauliflower. Inter-specific crosses were attempted between cauliflower and wild CMS sources such as *Trachystoma balli, D. siifolia, D. catholica, Moricandia arvensis* and *Erucastrum canariense, B. oxyrrhina* and CMS Anand and CMS *Brassica* in order to transfer sterile cytoplasm. In addition, a total of 95 CMS lines in Indian cauliflower were analysed using 13 morpho-metric traits and 11 mitochondrial SSR markers to establish the CMS system. Ten SSR markers (matK, rbcL, trnL, trnl-psbA, Yeflb, rpoC, rpob1, psbA-trnH, ITS5A,-ITS4 and ITS-2) showed polymorphism indicating differences in sources and genetic changes during introgression in different backgrounds.

6.4.10.3 Marker assisted breeding for downy mildew resistance

Eight four recombinant inbred lines ($F_{2:7}$) derived from a cross between Pusa Himjyoti x BR-207 were used for mapping downy mildew resistance. Bulk segregant analysis (BSA) and single plant analysis with SSR markers revealed that BoGMS0900 and BoGMS0486 markers are closest with 1.19 cM and 3.57 cM distance from the downy mildew resistance locus, respectively.

6.4.10.4 Expression profiling of curding and flowering genes

Expression profiling was carried out for genes involved in flowering, curd development, GA pathway, and MAD box genes in four genotypes of cauliflower viz., Pusa Meghna, Pusa Sharad, Pusa Shukti and KT 25. The heat maps of expression clusters revealed two major gene clusters viz,. Cluster 1) *CCE1, BoLFy, BoREM1, BoFUL-c, BoFUL-d, BoFH, BoCAL, BoFT* genes and Cluster 2) *BoFLC2, AP2, BoVRN2, BoVIN3* & *SOC1* genes.



Heat maps of expression pattern of different flowering related genes in cauliflower

6.4.11 Genetic Diversity in Bitter Gourd

Fifty one bitter gourd accessions were genotyped using 61 microsatellite SSR markers which produced a total of 99 alleles. The number of alleles per loci varied from 2 to 5 with an average of 3.3 alleles per locus. The highest number of alleles (5) was detected for the loci AVRDC BG-66, JY003, S-24 and S-32 and the lowest (2) in markers AVRDC BG-2, AVRDC BG-74, BG_SSR-8, McSSR-20 and McSSR-20. The allele frequency of the bitter gourd accessions varied from 0.35 at JY001 to 0.98 at BG_SSR-8 with a mean of 0.65 at each locus. The average Polymorphism Information Content (PIC) was 0.429. Expected heterozygosity or gene diversity (D) calculated according to Nei (1973) varied from 0.04 (BG_SSR-8) to 0.76 (S-24) with the average of 0.51. The number of genotypes obtained per loci ranged from 2 for BG_SSR-8, McSSR-20 and McSSR-20 to 8 for S-24.

6.4.12 Development of Tropical Gynoecious Indian Cucumber

Marker assisted selection (MAS) backcross breeding was performed for introgression of gynoecious trait (*F* locus) from G 421 (exotic gynoecious line) in to Pusa Uday background. Two SSR markers (SSR-13251 and SSR- 15516) and one gene based SCAR marker (CsACS1G) were used for foreground selection of *F* locus (gynocey) and a total of 121 markers were used for background selection spanning an average of 18 markers per chromosome. The recurrent parent genome (RPG) recovery ranged from 60.63% to 78.72% in BC_1F_3 generation from which 10 plants were selected based on the foreground, background and phenotype. These plants exhibited gynoecious habit,

Monoecious Pusa Uday (left) and Introgressed gynoecious Pusa Uday (BC_2F_6)

more later branches (4-5) and better fruit quality (L:D ratio >3.4). The BC_2F_3 population was also subjected to foreground, background and phenotypic selection. The MAS derived gynoecious lines those were validated in different growing seasons, and Improved Pusa Uday (BC_2F_6) is found to be promising with 100% female flower and quality similar to Pusa Uday.

6.4.13 Doubled Haploid Induction in Onion

Flower buds of 3.0-3.25 mm were found to have microspores in late uninucleate or early binucleate stage which is best suitable for haploid development. In the haploid induction using *in-vitro* gynogenesis, some of the doubled haploid plants were formed using colchicine as the doubling agent. These bulbs were sown in *rabi* and some of them were found to be fertile.

Doubled haploid onion bulbs that produced fertile flowers

6.4.14 ToLCNDV Resistance in Tomato

Using validated markers specific for *Ty-2* and *Ty-3* genes for ToLCV, *Ph-3* gene for late blight, genotyping was done in F_2, F_3 and F_4 populations. The same populations were phenotyped for ToLCNDV resistance under epiphytotic conditions. Based on the genotyping

and phenotyping, *Ty-3* gene in homozygous condition was found for resistance against TOLCNDV. To impart ToLCNDV resistance in tomato through CRISPR-Cas9 genome editing, guideRNAs were designed for targeting various genes of ToLCNDV genome like coat protein, IR, Rep, AV2 and AV3.

6.4.15 Genetic Diversity in Brinjal

Genetic diversity was assessed among 60 eggplants (*Solanum melongena L.*) genotypes including 9 wild species using 20 SSR markers. Fifteen markers were polymorphic with maximum numbers of alleles (6) for primer eme08D09, followed by emi03O22, eme03H04 and emf21N03 (4). The UPGMA dendrogram grouped 60 genotypes into three major clusters**.** Cluster I from bottom predominantly consisted of 4 wild species viz., *S. viarum, S. khasianum, S. sisymbrifolium* and *S. xanthocarpum* with small round fruits with hard pulp and the member of this group were less domesticated. The cluster II further was divided into IIA (*S. macrocarpum* and *S. integrifolium*) and IIB (*S. aethiopicum* and *S. insanum*), while the cluster III comprised of cultivated genotypes. Five mapping population viz., Sel-195 × Pusa Uttam, Pusa Shyamla × Pusa Bindu, Pusa Uttam × G-190, Pusa Bindu × Pusa Uttam, Sel-195 × Pusa Bindu for mapping QTLs for fruit size, fruit colour and were advanced.

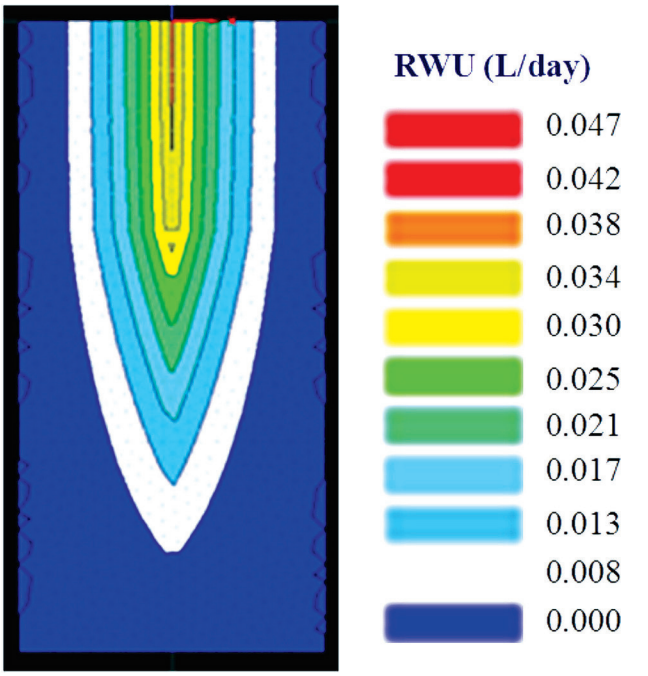
6.4.16 Promoter Characterization of dINO80 Gene in Drosophila

The *INO80* is a member of Chromatin Remodelling Complex and can functions as Enhancer of Polycomb and Trithorax protein (ETP). The 5kb upstream region of dINO80 was analyzed with software PROMPREDICT, EPDNew and Neural Network Promotor Prediction (NNPP from BDGP) and a fragment of 500 bp was identified which may contain the possible promoter for *dINO80*. The identified regions were cloned in promoterless vector pGL4.20 which has a luciferase reporter. These clones were used to tranfect S2 cells derived from late embryonic tissue.

6.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS, AND METEOROLOGY

6.5.1 Simulation of Soil Water Dynamics and Root Water Uptake in Wheat under Different Tillage and Irrigation Management using HYDRUS-2D Model

Field experiments were conducted during the years 2015-16 and 2016-17 on wheat cv. HD 2967 in a sandy loam soil at IARI, New Delhi to calibrate and validate HYDRUS-2D v 2.05 model for simulation of soil water dynamics and root water uptake in wheat under different tillage and irrigation management. The treatments comprised of three tillage practices as main plot factor [Conventional tillage (CT), Deep tillage (DT) and No tillage with residue (NT)] and three levels of irrigation as subplot factor [I_1: 1 irrigation (CRI), I_3: 3 Irrigations (CRI, Tillering, Flowering) and I_5: 5 Irrigations (CRI, Tillering, Jointing, Flowering, Milk)], which were evaluated in a split plot design with three replications. HYDRUS-2D v 2.05 model was calibrated with the field experiment generated soil moisture and



Simulated root water uptake by wheat at 108 days after sowing under deep tillage treatment with 5 irrigations

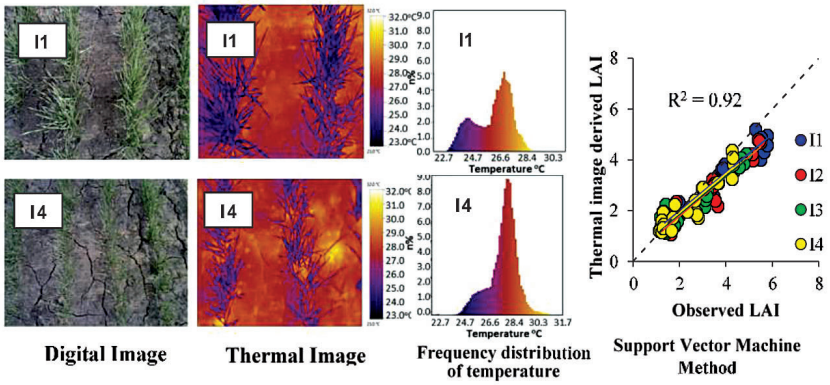
root growth data for the year 2015-16. The predictability of soil moisture content by HYDRUS 2D model was significantly improved after imposition of Inverse modeling option. When the model was run with the optimized van Genuchten parameters, the model could account for 49.4%, 65.1%, 48.3% and 55.9% variations in the observed soil moisture content at 0-15, 15-30, 30-45 and 0-45 cm soil depths. Soil water balance studies in both the years showed that cumulative root water uptake was highest in DT followed by CT and NT whereas cumulative evaporation under NT was higher than that of DT and CT. With increasing irrigation level, cumulative root water uptake increased but cumulative evaporation decreased in both the years. The deep percolation loss increased in both the years with the increase in irrigation level.

6.5.2 Determination of Soil Water Stress Coefficient by Different Methods for Computing Crop Transpiration under Bed Planted Pigeon Pea

Soil water-deficit stress occurs after few days of irrigation and thus affects root water uptake and transpiration rate. This stress effect can be quantified by soil water stress coefficient (Ks). Ks can be computed from simulated root water uptake (RWU) using HYDRUS-2D model. To check the reliability of model, a study was conducted under permanent raised bed with residue (PBB+R) and conventional tillage (CT) system in a pigeonpea-wheat cropping system. Soil water balance simulated for 100-125 DAS by HYDRUS-2D model showed higher cumulative root water uptake (CRWU) (1.72 cm), lower cumulative evaporation (CE) (0.34 cm) and higher soil water retention in PBB+R than in CT. Ks calculated from both the methods showed that under low soil moisture condition in root zone, Ks significantly reduced RWU whereas when root zone is sufficiently wet, Ks have very negligible effect. Model simulated actual transpiration rates were comparable with observed values whereas values computed from FAO method showed substantial deviation. This model may be adopted for evaluating different management practices in terms of improvement in soil water use.

6.5.3 Application of Thermal Imaging of Wheat Crop to Estimate Leaf Area Index

Thermal imaging can better distinguish two classes i.e., leaf and soil based on temperature, and hence thermal imaging was used to determine the canopy coverage. Thermal images were analyzed with five different supervised image classification techniques, namely, Maximum likelihood, Mahalanobis, Minimum distance to mean, Parallelepiped and Support Vector Machine methods using ENVI - image analysis software. Results showed that the best estimation of LAI was possible using Support Vector Machine method, due to its higher overall classification accuracy and Kappa coefficient. This is further supported by the statistical analysis based on the comparison with instrument observed LAI and digital image derived LAI. Thus thermal image analysis could be applied as a non-destructive and rapid method to characterize the crop canopy temperature and LAI of the wheat crop grown under moisture stress conditions.



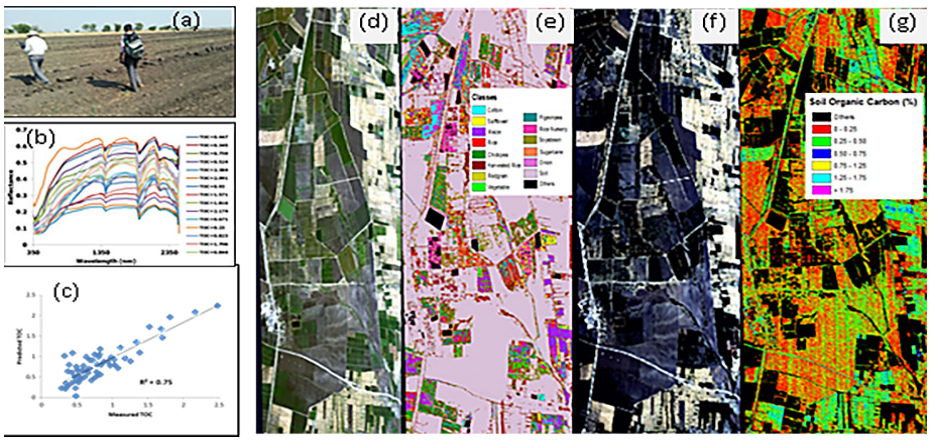
Thermal image based LAI estimation of a wheat crop grown under moisture stress condition

6.5.4 Global Sensitivity and Uncertainty Analyses of Web InfoCrop Wheat for Soil Parameters

Sensitivity and uncertainty analyses are critical for identifying the most sensitive parameters of the crop simulation models. The study was for the sensitivity and uncertainty analyses of the soil parameter inputs of the Web InfoCrop Wheat model under water deficit- and high temperature stress conditions for different agro-climatic conditions of India. Sensitivities of soil input parameters (15) were analyzed by crop simulations under the no stress (potential), water deficit- (limited irrigation), high temperature- (+3 °C above ambient), and their combined stress conditions for a period of 10 years across four sites in the wheat-growing regions of India. Amongst the soil input parameters (15) and outputs (10), the nutrient parameters such as NITRATE, ORG_CARB (Organic carbon), AMMONIUM were the most sensitive input parameters under the no stress (potential) and high temperature stress conditions. On the contrary, the parameters related to the soil moisture such as CLAY (Clay %), FLD_CAP (Field capacity), SATU (Saturation) and MOISTURE (initial soil moisture contents) were the most sensitive input parameters under water deficit stress conditions. Both the sensitivities and uncertainty of soil parameters under different crop production and environmental conditions influenced the outputs of the Web InfoCrop model significantly.

6.5.5 Mapping of Soil Organic Carbon under Different Agro-Ecosystems using AVIRIS-NG Airborne Imaging Spectroscopy

Total organic carbon of soil was assessed using AVIRIS-NG (Airborne Visible Infra Red Imaging Spectrometer - Next Generation) for mapping soil organic carbon on a regional scale. Synchronized soil sampling and spectral data collection was done at 7 sites in India during field campaign of AVIRIS NG through collaborative experiment of ISRO and NASA during December 2015 to February 2016. Soil samples collected from all the sites were processed and reflectance spectra were collected in laboratory condition using spectroradiometer (Fieldspec3, ASD, USA) along with contact probe followed by wet-lab estimation Total Organic Carbon (TOC). AVIRIS NG L2 surface reflectance image was used to retrieve soil spectra using geolocations of soil sampling points. Predictive models were developed using Partial Least-Squares Regression (PLSR) and Step-wise Multiple Linear regression (SMLR) between extracted soil organic carbon and AVIRIS-NG L2 surface reflectances in the sensitive band regions. A Jack-Knifing method was adopted to develop predictive models from 2/3rd data pairs followed by validation from 1/3rd data pairs. The result revealed that the estimation accuracy of PLSR (R^2 = 0.89, RMSE = 0.22) was better than SMLR (R^2 = 0.83, RMSE = 0.24). Location specific model developed were used further for generating soil organic carbon map using AVIRIS-NG L2 reflectance image.



Mapping of Soil Organic Carbon using AVIRIS-NG Airborne Imaging Spectroscopy: (a) Spectral data collection synchronizing with air born imaging, (b) spectral signature of soil with varying locations, (c) comparative evaluation of spectral based predictive model, (d) Natural color composite of air borne image of AVIRIS NG of National Seed Producing Farm, Sidhanur, Raichur, Karnataka, (e) classified map of the farm, (f) Soil mask of farm, and (g) Soil organic carbon map of the farm generated from the image of AVIRIS NG

A study was also undertaken to assess total organic carbon of soil using AVIRIS-NG over ICRISAT and Nagarjun Sagar, Hyderabad, India. After pre-processing the airborne image and classification for masking out areas under open soil, the relation between AVIRIS-NG L2 spectra from different soil geolocations of study area and measured TOC was developed using different mulitivariate regression (PLSR, MLR etc). PLSR based predictive model (R2 = 0.88, RMSE = 0.23) performed better than SMLR based model (R2 = 0.82, RMSE = 0.26) for predicting soil TOC. The validated model thus developed was applied on the AVIRIS-NG L2 reflectance image for mapping soil organic carbon at regional scale.

6.5.6 Quantitative Estimation of Wheat Leaf N Content Using VNIR Imaging Spectrometer

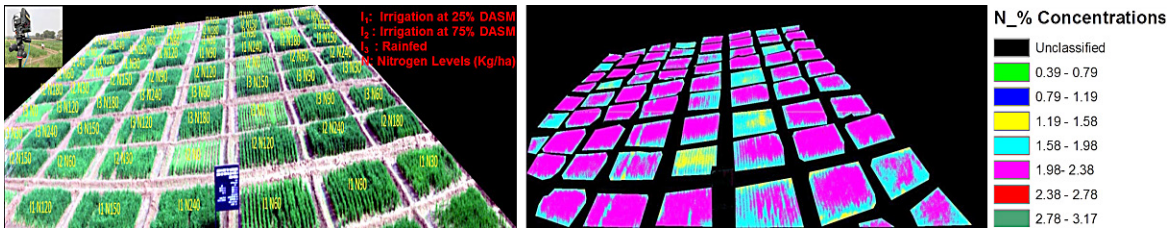
Wheat crop was grown at IARI farm with eight varying levels of nitrogen and three irrigation levels in three replications. Hyperspectral image was captured using nano-hyperspec camera (Headwall photonics, USA) in VNIR range (396-1003nm). Image acquired was preprocessed to covert to surface reflectance image. Multivariate models like PLSR and MLR were used for estimation plant leaf nitrogen. Significant bands (408, 425, 560, 564, 712 and 737nm) identified from PLSR analysis were used for developing MLR model. PLSR model found to have better predictability (R^2= 0.74 and RMSE 0.13) as compared with MLR (R^2= 0.68 and RMSE 0.14). Plant nitrogen map of wheat field was generated using developed predictive model which shows variation among field having different N treatment and also within the field. Thus this method can be used for high throughput and cost effective estimation of canopy N content of wheat crop.

6.5.7 Retrieval of Leaf Area Index from Airborne AVIRIS-NG L2 Reflectance Data

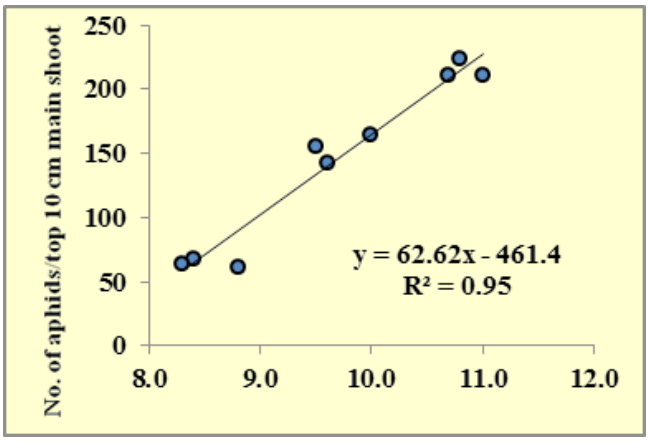
To retrieve LAI from AVIRIS NG L2 surface reflectance data of wheat crops over Buxar region, Bihar, synchronized spectral observation and LAI measurement were done using field portable spectroradiometer (Fieldspec3, ASD, USA) and plant canopy analyzer (LICOR, USA) during air borne AVIRIS –NG field campaign through collaborative experiment of ISRO and NASA during December 2016. Evaluation of retrieval was done on the basis of coefficient of determination (R^2), root mean squared error (RMSE), normalized root mean squared error (nRMSE) and ratio of prediction to deviation (RPD). The result showed coefficient of determination (R2) of 0.84 for LAI retrieval with RMSE of 0.26 and indicated good model efficiency.

6.5.8 Development and Evaluation of Composite Indices, Prediction Rules, Models for Risk Assessment of Biotic and Abiotic Stresses

A field experiment was conducted at IARI farm with mustard crop to find out the pattern of aphid population development under three thermal regimes. The sowing were done on 25th October (D_1), 7th November (D_2) and 8th November (D_3) in 2016 with three cultivars, namely, Pusa Vijay, Pusa Mustard 21 and Pusa Bold. The aphid infestation started in mustard from flowering stage onward in each treatment then reached a peak value around seed filling stage in D_1 and pod formation stage in D_2 and D_3. The highest aphid population (232) was observed in D_3 in Pusa Bold. In general, the late sown (D_3) crop was affected most, followed by D_2 and D_1 crops.



Spatial variable map of Plan N of wheat derived from imaging spectrometer



Aphid population on mustard as influenced by minimum (Tmin) at reproductive stage of mustard

Increase of aphid population (no. of aphids/top 10 cm main shoot) for delayed sowing due to temperature increase during reproductive stage was studied. It was found that mean maximum, minimum and mean temperature of reproductive stage had positive impact on aphid population. Maximum increase in aphid population took place due to increase of minimum temperature. Per degree rise in minimum temperature increased the aphid population by 63 aphids/ top 10 cm main shoot.

6.5.9 Characterization of Micrometeorology under Different Crop Environments

Experiments were conducted during *kharif* and *rabi* seasons at IARI, New Delhi to study microenvironments under different conservation treatments along with conventional treatment and their effect on biophysical parameters and yield of maize, wheat crop in maize-wheat cropping system and pigeonpea, wheat crop in pigeonpea-wheat cropping system. The field experiment was conducted with sowing of crop in seven treatments, conventional tillage (CT), narrow-bed without residue (PNB), narrow-bed with residue (PNB+R), permanent broad-bed without residue (PBB), permanent broad-bed with residue (PBB+R), zero tilled flat bed without residue (ZT), zero tilled flat bed with residue (ZT+R) arranged in a randomized block design (RBD) with three replications. Results showed that the microenvironment was improved under different conservation practices. Stomatal conductance, photosynthesis rate, transpiration rate, biomass, plant height, water potential, relative water content, leaf area, different yield attributes and grain yield was found higher value under conservation treatments than conventional treatment. Better crop growth, yield and RUE in conservation treatments over conventional treatment could be due to the additional nutrient by crop residue, improved soil physical properties and water regimes, better water extraction, aeration and nutrient use in conservation treatments. System productivity had higher value in pigeonpea-wheat cropping system than maize-wheat system. Among all treatments, PBB+R showed better microenvironment for crop growth and gave higher grain yield, WUE, RUE and HUE than the other treatments. Thus, PBB+R management practice could be adopted by farmers for improving crop productivity in the maize-wheat and pigeon pea-wheat cropping systems in semi-arid region of Indo-Gangetic area.

6.5.10 Weather based Agromet Advisory Services

Weather based agro-met advisory bulletins were prepared in Hindi and English and issued on every Tuesday and Friday. Agromet advisory bulletin give weather forecast and warning in advance regarding rainfall variation, its amount and other weather variables including pest/disease problems, etc. so that farmers can decide about crop management, application of nutrients, irrigation scheduling, sowing, harvesting, etc. These advisories were uploaded on the Institute website (www.iari.res.in), IMD website (www.imdagrimet.gov.in) and farmer portal (http://farmer.gov.in) in both Hindi and English. These advisories along with crop status were sent to IMD, Pune for preparation of National bulletins. The bulletin is passed on to the farmers on the real time through SMS / telephone / E-mail. The bulletins are 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 2017-18, total 102 agro-advisory bulletins were prepared in Hindi as well as in English. SMS were sent to the farmers through m-Kisan portal. Feedback received from the farmers from different villages of NCR Delhi showed that agromet advisory bulletin is useful since they receive advises on appropriate field operations and management practices depending on suitability of weather conditions. It helps in reducing cost of cultivation, saving of input resources and increases in net profit. Farmers who followed the agromet advisories are 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. Weather forecast and agromet advisory bulletin is fruitful for farmers, through this they can select high yielding varieties of different crop and vegetables, other farming practices such as sowing, weeding, irrigation, fertilizer, pesticides spray (time & doses) can be done at right time. Through this they can benefited from the monsoon, its status and day to day weather conditions which is helping to do proper farm practices at proper time.

6.6 NATIONAL PHYTOTRON FACILITY

The controlled environmental facilities of the National Phytotron Facility (NPF) was hugely used by scientists and students from IARI and other ICAR institutes including University of Delhi (South Campus), Jawaharlal Nehru University, New Delhi and others to conduct critical experiments related to climate change, transgenic crops, gene expression and regulation, physiology of nutrient use efficiency, plant-pathogen interaction, biochemical and genetic interventions for crop improvement, etc. During the year 2017-18, 141 new experiments were accommodated along with a few previous on-going experiments. Bulk of these experiments were from the in-house projects of the ICAR institutes (52.48%) followed by post-graduate researches (39.01%) and the paid experiments from out-funded projects and non-ICAR institutes (8.01%). An amount of ₹ 3,35,123/- was collected at NPF as users' fee of the glass house and growth chambers. The NPF was visited by a number of domestic and foreign visitors who expressed happiness in functioning and maintenance of the facility. Various experiments conducted in the NPF aroused interest among the visitors, the student visitors in particular.

7. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

Government of India's focus is to double or enhance farmers' income. School of Social Sciences is focusing on assessing the impact of various programmes on reducing rural poverty, impact assessment, investment, energy sector and its requirements, reforms in agricultural market, including e-market/*mandis* and changing scenario of trade and innovations in access to credit, etc. Reaching the unreached is possible by developing innovative extension models. Emphasis is on global current issues i.e., climate change, nutritional security, agri-nutri linkages and entrepreneurship development. Capacity building of various stakeholders was done with focuss on entrepreneurship development and gender empowerment. Various IARI technologies were assessed and transferred in public-private partnership mode at various locations across the country.

Krishi Unnati Mela 2018 and M*era Gaon Mera Gaurav* programmes are well supported by the School of Social Sciences. Agricultural Technology Information Center (ATIC) as single window service and Institute's KVK at Shikohpur, Gurugram are working as per the mandate and serving the farming communities.

7.1 AGRICULTURAL ECONOMICS

7.1.1 Determinants of Agricultural Growth

The macro-economic variables like public investments, credit, farm mechanization, total factor productivity, diversification have greater influence on agricultural growth. Recent changes in level and composition of public expenditure and investments especially under *Rashtriya Krishi Vikas Yojana* (RKVY) at all India level and for major states have been analyzed. The expenditure under RKVY has increased over the years. The expenditure per project under RKVY was lower in the southern and north-eastern regions while the same regions have higher project completion percentages (more than 70 %) since the inception of the programme. In contrast to this, the results showed the opposite situation in the northern and western regions i.e., higher expenditure per project and lower project completion percentage. This may be due to the implementation and completion of the projects with lower expenditure which is easier compared to the projects with higher expenditure.

Agricultural credit is considered as an enabling input that influences agricultural growth primarily through use of variable inputs as well as via investments in fixed capital. The total flow of institutional credit to the agriculture sector is ₹ 7,11,621 crores in 2013-14 which is five times more than the credit amount in 2004-05, this may be due to the policy initiative of doubling agricultural credit within three years. The credit elasticity of agricultural GDP for this period was estimated at 0.31 indicating that a 10 percent increase in institutional credit flow to agriculture at current price is associated with a 3.1 percent increase in agricultural GDP of the following year.

A mechanization index based on the ratio of cost of use of machinery to the total cost has been estimated for major crops using cost of cultivation data pertaining to triennium ending 2014-15. The manual labour cost is more than machine labour charges in the operational cost of wheat, even though the level of mechanization (49.6 %) for this crop is the highest in the country. Energy and crop yield analysis clearly indicated that energy use in high productivity states is seven times more than the low productivity states.

Improving total factor productivity (TFP) of pulse crops is important to achieve food and nutritional security in India. A study on consumption pattern

of pulses and TFP growth of major pulses (chickpea, pigeon pea, green gram and black gram) in India for the period of 1994-95 to 2012-13 indicates that per capita consumption of pulses has declined over the years. The chickpea and green gram have exhibited improvement in TFP in most of the states, but pigeon pea and black gram have not shown any TFP improvement in most of the states considered.

Diversification plays a crucial role in sustaining agricultural productivity and farm income. The agricultural production in India is very much skewed, as 50 per cent of gross cropped area comes under cereal crops which leads to low degree of diversification. Over the period of 1999-00 to 2013-14, the share of cereal in total value of output of agriculture and allied sector has been reduced to 18.84 per cent in 2013-14 form 27.53 per cent in 1999-00. For the same period, share of livestock, fruits and vegetables in total value of output has been increased from 28.55 per cent to 32.27 percent, 5.55 per cent to 9.74 per cent and 8.95 per cent to 9.74 per cent respectively. Concentration ratio (CR4) has declined from 73.6 per cent to 69.6 per cent for the study period which indicates shift of Indian agriculture from cereal based production pattern to other high value based production pattern. However, Simpson Index for diversification (SID) indicates that, the average national SID for all agricultural enterprise is 0.83. The previous cropping pattern, trend factor, per capita NSDP, farm size, irrigation and cropping intensity are the major factors determining level of diversification at the macro level. The higher farm size and irrigation have negative impact toward diversification.

7.1.2 Agricultural Sustainability of Major Indian States

Achieving sustainability of food production system is of paramount interest. The study constructed indices for environmental, economic and social dimensions of agricultural sustainability for 17 major states of India, and finally aggregated them into a single index value of agricultural sustainability for three point of time, viz., 1991, 2001 and 2011. During the period of 1991-2011, there was an improvement in the values of agricultural sustainability in all the states in terms of index values. However, out of 17 states, negative changes were recorded by 9 states in environmental sustainability index, 3 in economic sustainability index and no state in social sustainability index. As on 2011, the agricultural sustainability was the highest in Himachal Pradesh, Jammu & Kashmir and Kerala; and the lowest in Bihar, Uttar Pradesh and Gujarat. Among the component indices, sharp deterioration of environmental quality with respect to agriculture is a cause of concern, notably for Punjab and Haryana. In economic sustainability index, Punjab and Haryana topped the list. In terms of social outcomes, all the states posted positive changes, with faster gains emanating from peninsular and hilly states of India.

7.1.3 Agricultural Market Reforms and Economic Growth

Various agricultural reforms initiated by the government like agricultural produce market committee (APMC), minimum support price (MSP), *e-mandi* were studied for their economic benefit. An agricultural Marketing Infrastructure Index was developed for each state according to APMC reform considering variables like number of regulated markets, market area covered by each regulated market, etc.. Uttar Pradesh received the highest index value, followed by Maharashtra, Madhya Pradesh and West Bengal. The infrastructure values were in general higher for states in the third and fourth category that is the ones that have partially or fully adopted APMC reforms and lower in the preceding ones.

The study on impact of *e-Mandi* on price realization and farmers income was carried out in Karnataka. Majority of the stakeholders are satisfied with the different provisions of *e- mandi.* Eighty percent of the farmers feel that introduction of electronic tender system has made the operations of the market more transparent helping in better price realization. Three-fourths of farmers feel that the system has helped in faster completion of tender process and the trade transaction leading to faster payment settlement. But still some of the components are not up to the

satisfactory level like participation of outside traders from different APMC, lack of proper grading system and poor provision of online payment system which hinders the farmers to realize better prices and income.

Minimum support price is an important component of administered price policy of Government. Awareness about MSP of the crop can influence the choice of marketing channel preferred by farmers. Study on farmer's awareness about MSP of crops grown by them using NSSO data, (70th round) shows that only 23.72 and 20.04 per cent of rural agricultural households in India are aware of MSP of crops grown by them. It was found that MSP awareness is high in those states only where procurement network is strong. Hence, the Government's objective of treating MSP as safety net will only be fulfilled, if announcement of MSP is coupled with active procurement.

7.1.4 Agro-Processing Industry and Farmers' Linkages

The study on farmer –processor linkage in mango processing industries in Tamil Nadu shows that establishment of mango processing industries in the region has helped farmers in having assured markets. Farmer-processor linkage results in highest share of producers in consumer rupee (62.65 %). If farmer market his produce through this channel, the net returns will be to the tune of ₹ 5.81 /kg of produce. The linkage between mango processing firms and farmers has resulted in an increase in income to the tune of 49 percent on average basis.

7.1.5 Impact of Improved IARI Agricultural Technologies

IARI recent wheat varieties, HD 2967, HD 3086, HD 3059 are popular in all the major wheat growing states. The wheat varietal composition would indirectly reveal the importance of the IARI varieties. The wheat varieties prevalent in the major wheat growing states i.e., Bihar, Haryana, Madhya Pradesh, Punjab and Uttar Pradesh during the period 2010-16 have been studied using the Shannon Index. The diversity has drastically fallen in the states of Haryana, Punjab and Uttar Pradesh.

The varietal newness index by estimating proportion of area sown to varieties not sown in earlier periods was analysed. The index was highest for Bihar followed by Haryana and Madhya Pradesh in the year 2015. The varieties released from IARI also contributed significantly to the newness index in major states like Punjab (HD 2967, HD 3086, HD 3059) Haryana (HD 2967 and HD3059), Bihar(HD 2285 and HD 2967), Uttar Pradesh(HD 2967, HD 3043, HD 3059, and HD 3090) and in Madhya Pradesh(HD 4713, HD 2189, HD 2851).

The impact of IARI *basmati* rice variety (PB 1121) has been evaluated through estimation of the area replaced and yield and price gain. The total gain due to IARI *basmati* variety PB 1121 is estimated to be ₹ 8,97,904 crores. Punjab alone accounts for 49 per cent of the total gain followed by Haryana (34%) and Uttar Pradesh (17 %). Overall the yield increase accounts for 51 per cent of the incremental gain.

The impact of IARI wheat variety (HD 2967 & HI 1544) has also been evaluated to be ₹ 7239 crores in the major wheat growing states of Punjab, Haryana, Uttar Pradesh and Madhya Pradesh. The IARI wheat variety HD 2967 accounts for 59 per cent of the total gain.

The economic surplus approach was used to evaluate the impact of mustard variety Pusa Mustard 30. Pusa Mustard 30 is expected to generate a total surplus of ₹ 12,394 million per year. The analysis indicates high potential benefits for the PM 30 under niche marketing. The impact of carrot variety Pusa Rudhira has been studied by taking the cost in development of the variety. Pusa Rudhira variety gave internal rate of return of 34 per cent which is substantially high. The profitability of protected cultivation of gerbera was analysed using the primary data from the farmers of Dehradun district of Uttarakhand. The feasibility analysis revealed that the B:C ratio ranged from 1.33 to 1.43 across the discount rates for 10 per cent and 5 per cent. The IRR was estimated to be 35 per cent. The benefits of solar energy use in Rajasthan was studied. The use of solar energy for irrigation lead to a saving per farm of ₹ 8000 to ₹ 47321. The per hectare savings ranged from ₹ 1280 to ₹ 10433.

The study on feasibility of adoption of drip and sprinkler irrigation in north west Rajasthan shows that the farmers invested ₹ 1.65 lakhs for adoption of drip irrigation of which 70 per cent was the subsidy they received. The average area benefited was 4.8 ha. While for installation of sprinkler irrigation ₹ 0.81 lakh was invested for which about 48 per cent was the subsidy received.

A comparison of incidence of fertilizer subsidy on different farm categories was done for the year 2006-07 and 2011-12. The ratio of subsidies to all farm groups and the per ha fertilizer subsidy received by different farm groups indicated better values for marginal and small famers compared to the larger ones. Between 2006-07 and 2011-12 even though the per ha subsidy increased for all the farm categories, marginal farmers were able to improve the ratio of subsidies received per ha to all farm groups from 1.23 to 1.44.

7.2 AGRICULTURAL EXTENSION

7.2.1 Development of Innovative Extension Model

IARI-Post Office Linkage Extension Model. An institutional mechanism for upscaling IARI Post Office Linkage Extension Model has been developed with Department of Posts, Government of India. The quality seeds of improved IARI varieties viz., Pusa 1612, Pusa 2511 and PB1121 of paddy (2.3 t) in 46 districts of 12 states; HD 2967, HD 3059 and HD 3086 of wheat (2.76 t) in 9 districts of 6 states; Pusa Mustard 26, Pusa Mustard 30, Pusa Mustard 31 and Pusa Vijay of mustard (0.156 t) in 3 districts of 2 states; Pusa 991 and Pusa 992 of pigeonpea (0.085 t) in 3 districts of two states; Pusa Shivalik of lentil (0.7 t) in 14 districts of 5 states, Pusa Vishal of green gram (1.0 t) in 30 districts of 7 states; Pusa Pragati of vegetable pea (0.45 t) in 15 districts of 6 states; and 0.02 t of vegetables (onion, *palak*, *methi*, carrot, tomato and radish) in 4 districts of 3 states were disseminated through branch post masters of the post offices. Seed Producers' Association named "*Dev Bhumi Krishi Evam Bahuuddeshiyo Swayat Sahkarita Baswaskheri*" has been promoted at Haridwar district of Uttarakhand for enhancing access to quality seeds. Seed multiplication of IARI improved wheat variety HD 2967 has been undertaken in *Rabi* 2017-18.

Climate change adaptation. Survey was undertaken in Ganjam district of Odisha to analyze the farmers' perception about climate change and adaptation strategies in coastal areas. Over the last 10 years the main changes perceived by the farmers were temperature increase in summer (weighted mean 2.43), more occurrence of floods (weighted mean 2.15), delay in onset of rainy season (weighted mean 2.11), and short duration of winter season (weighted mean 2.0), The main impacts of climate change on agriculture perceived by the farmers were reduction of area under Betel vine (weighted mean 2.61), increase of agricultural labour cost (weighted mean 2.37), and increase of pest attack particularly BPH in rice (weighted mean 2.06), The commonly adopted strategies were line transplanting of paddy (63 %), flood/drought resistant varieties like flood-resistant Swarna Sub-1 and drought-resistant Sahabhagi (59 %), farm mechanization (mainly Rotavator) (43%), and indigenous variety which are more resistant to pest attack (38 %).

ICT led extension. Perception of extension scientists about the efficacy of video extension was studied through online using survey tool Google Forms. Sixty seven per cent of the scientists drawn randomly from NARS including ICAR Institutes, State Agricultural Universities, *Krishi Vigyan Kendras*, and MANAGE perceived that the existing extension personnel in the organization had to be trained in video production. Fifty seven per cent of them opined that the video should be of 10-20 minutes duration. Sixty one per cent of the scientists expressed that the genre (style) of video should be of 'demonstration at field'. Analysis of the video skills of the scientists revealed that majority of them (75 %) could write video scripts, but they lacked video editing skill (79 %), and video shooting skill (54 %). Survey of 120 farmers of Sitapur district, Uttar Pradesh, 30 farmers of Jhansi district, Uttar Pradesh, and 30 farmers of Datia district, Madhya Pradesh was

conducted to analyze the extent of use of video as extension tool to deliver the agricultural information to the farmers. The farmers expressed that the agricultural programme of Doordarshan should be re-telecast after 9.00 p.m. and during the breaks of the agricultural programmes, glimpses of local cultural music, songs, etc. might be telecast to make the programme more attractive. They suggested that the programme should be telecast fifteen days in advance of the actual field operation.

7.2.2 Maximizing Farm Profitability through Entrepreneurship Development and Farmer Led Innovations

Now there is a need to focus on strategies to raise farmers' income with entrepreneurship development and integration of farmer led innovations for sustainable agricultural development.

7.2.2.1 Agricultural entrepreneurship education and awareness

Entrepreneurial motivation, education and awareness regarding various available opportunities and suitable technological options were conducted in the project villages Fatehpur Biloch and Manjhawali villages of Faridabad district and Swamika village of Palwal district in Haryana. Value addition, seed production, protected cultivation of vegetables and flowers, fruit production and primary processing were promoted as entrepreneurial ventures in the project villages based on the situational assessment. Motivation enhancement, entrepreneurial orientation, skill training and awareness of marketing strategies were conducted in the project villages.

7.2.2.2 Adoption of specialty and secondary agriculture

Different adoption behaviour of the farmers was documented in project villages with a sample of 150 farmers. The findings revealed that 48.39 per cent farmers showed low adoption behaviour in respect of specialty and secondary agriculture with more farmers adopting the protected cultivation technologies in Manjhawali village followed by Fatehpur Biloch village. More farmers of Fatehpur Biloch expressed interest in adopting but were vary of high investment from their side. Post action interventions, in Swamika, majority of the farmers (51%) were found to be practicing traditional techniques of *in-situ* moisture conservation and cultivated crops which required less water. Only 28 per cent farmers brought any kind of crop diversification and 13 per cent farmers adopted any kind of tolerant or resistant varieties. The findings revealed that socio-economic factors like awareness, education, extension personnel contact, number of members in family, economic motivation and innovativeness were positively correlated with their adoption behavior at 5 per cent level of significance.

7.2.2.3 Farmer led innovations

Four case studies of farmer led innovations (FLIs) were conducted during the period under report. FLIs were either reconfiguration of existing resources giving incremental adjustments or innovations generated to solve an immediate problem. All innovators studied expressed dissatisfaction with the pre-existing economic returns of the farming, thus pushing them to innovate or to find newer way to solve a problem. Indicators for identification of FLI and its scalability have been standardized and are widely being used for identification and recognition of innovative farmers.

7.2.2.4 Interaction of farm innovators-researchers and supporting institutions

A two days Farm Innovators Meet entitled " Farm Level Stresses and Innovations" was organized on October 7-8, 2017 in collaboration with ATARI, Pune and KVK, Baramati. Eighty farm innovators from three states, Maharashtra, Andhra Pradesh and Telangana, research managers and researchers deliberated to develop a strategy of up scaling and out scaling farmer innovations.

7.2.2.5 Impact of training and mentoring interventions

Training interventions were conducted after assessing training needs of farmers and farm women.

Pre and post training data revealed enhanced motivation, aspirations, entrepreneurial orientation, and also creating a facilitative entrepreneurial climate in the form of effective business linkages among various stakeholders.

Enterprise uptake. In Manjhawali and Swamika villages, farm women were proactive in forming SHGs whereas more intense efforts of convincing on part of researchers were needed in Fatehpur Biloch for mobilizing farmers/ farm women to take up group entrepreneurship. In collaboration with NABARD, two farmer interest groups (FIGs) were mobilized in Fatehpur Biloch. Seed production, nursery raising, protected cultivation, value addition-soybean milk, tofu, potato chips, *dal badi*, etc., dry flower technology based products, flower cultivation, *ata chakki*, animal feed, oil mill, enterprise of ground spices, mushroom cultivation, etc., were various enterprises launched by trained farmers and farm women.

Economic benefits. The economics of poly house cultivation for crops like tomato, cucumber, etc. were calculated for trained farmers, and they realized their investment after harvesting of first crop itself. The B:C ratio ranged from 1.33 to 1.43. Therefore, it is recommended that the Government's programme to promote protected cultivation in the region should be given boost.

7.2.2.6 Study of backward - forward linkages of various agri-enterprises

Backward - forward linkages of various agri-enterprises were done. Two different marketing channels were identified for Gladiolus and Tuberose whereas three different marketing channels were found for tomato, cauliflower and cabbage in the project villages of Faridabad district. Social network analysis of linkages was done for FLI and agripreneurship promotion. Pattern and impact of linkages between agro-processing industry and farmers' groups were studied. Even the low quality produce, which would fetch very low price if sold in open market, can also be sold at the same price to processing firms.

7.2.2.7 Establishing convergence of various stakeholders for agripreneurship development

The participation of various stakeholders i.e., non governmental organizations (NGOs), government departments (Agriculture, Horticulture), bankers (Syndicate Bank, Corporation Bank), established entrepreneurs (in value addition, post harvest processing of flowers and seed production) and researchers, was also elicited in each village. Efforts for facilitation in strengthening the existing marketing linkages and exploration of new marketing avenues were also initiated. The impact of awareness programme was assessed, and low level of awareness was found regarding various schemes which implied that all the stakeholders along with the service providers should be actively engaged in public awareness and capacity building campaign for farmers

7.2.3 Enhancing Nutritional Security and Gender Empowerment

Nutritional security has been the prime concern of Indian government since its freedom. Recent evidence is that of National Nutrition Mission, which was launched on the occasion of International Women's Day at Jhunjhunu in Rajasthan. Despite all efforts of government, still the challenge of achieving nutritional security remains unfulfilled.

7.2.3.1 Association between food security and nutritional status in India

Economic prosperity and rousing figures on agricultural production does not reflected in nutritional status of India, as it is home for more than two third of malnourished children of the world and substantial proportion (47%) of Indian women in reproductive stage are anemic. In this context, the food security status across the Indian states was examined by constructing index comprising of 17 indicators developed by Economist Intelligence Unit, which represents food availability, affordability, and quality and safety. The information from multiple government sources and research reports were stitched together to develop a comprehensive Food Security Index for 2015-16. By extracting National Family Health Survey-4 (2015-16) data, body mass index and anemia based indicators

were analyzed to study the nutritional status of both children and adults across the states. The multivariate linear regression model was employed to explore the association between food security and nutritional outcome of the population. Empirical evidences suggests that one per cent increase in food security index would significantly decline the incidence of stunting and underweight, by 0.5 and 0.6 per cent, respectively, among children and about 0.4 per cent in case of adults underweight, after controlling for state dummy.

7.2.3.2 Food consumption pattern, knowledge and nutritional status

The food consumption pattern, nutritional status and knowledge level on nutrition have been collected from rural households of Raebareli, Sitapur, and Banda districts, Uttar Pradesh through a structured interview schedule to know the dietary habits and to understand the agriculture and nutrition linkages.

In Raebareli district, on an average, medium dietary diversity was noticed (5.45) among households in the study villages. Simpson Index of dietary diversity was 0.74. Women are coming under underweight category. Majority of the respondents were coming under low knowledge category. Income and own-farm produce share in staple food items were the major driving forces of dietary diversity.

The studied villages of Hamirpur were characterized by low parental education, limited access to nutritionally rich diets, low dietary diversity, very poor hygiene and sanitation. As compared to 17.34 percent of male, 37.18 per cent of the female were found to be in underweight category. A majority (75.83%) of the households had average dietary diversity (0.68-0.74). As found through a multiple regression analysis, occupational type, per day per capita income, alternate source of income and gender of head of the household were the major variables influencing household dietary diversity.

The problem of under nourishment was less with male groups than female groups in all the districts. Women and children, especially girls were more vulnerable. In general, across all the districts, medium dietary diversity (IDDS) was majorly noticed and it was found that mostly food was consumed about 50 per cent less than the recommended dietary allowance. In conclusion, dietary diversity is poor and efforts to improve nutritional status must address the issue of nutrition education, dietary diversity and nutrition sensitive agriculture.

In addition to it, healthiness index was prepared for the selected respondents of Ribhoi district, Meghalaya, and Ludhiana district of Punjab. Healthiness index of two states was compared. The respondents were categorized into low, medium and high healthiness index. The results revealed that most of the respondents belonged to medium category healthiness index in both the states. Food consumption score was also calculated and it was found that both the states' respondents were significantly different.

7.2.3.3 Behavioral intentions using TPB theory for organic food consumption

Theory of planned behavior (TPB) is considered as one of the most useful framework in explaining human behavior in the wide range of fields and more specifically it has great applicability in the field of environmental/ social psychology. The data were collected with the help of well-structured pre-tested schedule to understand the urban people intentions/behavior towards organic food by using TPB framework. The target population of the study were educated consumers of the urban area (Delhi). Total sample size was 1047. The results revealed that three variables, namely, Attitude, Subjective Norms and Perceived Behaviour Control accounted for 92.10 per cent of the variation in behavioural intention. Only 16 per cent respondents had high level of knowledge about organic food, followed by 59 per cent in medium category and 25 per cent in low level of knowledge. Most of the respondents had low to moderate level of knowledge about organic food.

7.2.3.4 Extension strategies for strengthening agri-nutri linkages

It is to be noted that self-sufficiency in food production has not been translated into nutritional security, indicating missing link between agriculture

production and nutritional security. It signifies that similar to that of "Green Revolution, there is a need for "Nutrition Revolution" for achieving nutritional security. To address these issues within the context of Indian Council of Agricultural Research (ICAR), the Division of Agricultural Extension, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, organized a workshop on "Extension Strategies for Strengthening Agri-Nutri Linkages" on September 21, 2017. The workshop was attended by representatives from Ministry of Agriculture and Farmers Welfare, ICAR Institutes, MSSRF, CYMMIT and SAUs. This workshop emphasized on strengthening the policies to build better chances of nutrition linkages, coordination of agriculture and nutrition scientists in a convergent mode and making the platform beneficial for the farmers. And also emphasized that there is a need for a paradigm shift in approach from production centric to nutrition centric agriculture.

An Agri-Nutri (A2N) smart village model is being validated in project villages of Baghpat district, Uttar Pradesh and Sonipat district, Haryana. A2N model is a framework which includes the various agriculture interventions, for capacity building programmes, for nutri-sensitive agriculture rich crops and varieties, farmers-scientists interface, exposure visits, streaming of videos on healthy practices as well as on nutri-rich varieties, minimal processing techniques of pulses, fruits and vegetables, etc. This model will act as a simple indicator to understand the balance and integration between agriculture and nutrition.

7.3 TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Outscaling Agricultural Innovations for Enhancing Farm Income and Employment

The project is in operation at four villages, namely, Khajurka (Palwal, Haryana), Kutbi (Muzaffarnagar, U.P.), Rajpur (Aligarh, U.P.) and Beenjpur-Raghunathpura cluster (Alwar, Rajasthan).

During *Rabi* 2016-17, demonstrations on location specific improved varieties of wheat, mustard, pea and carrot were conducted. Wheat varieties HD 2967, HD 3086 and HD 3059 performed well at all the model village locations. HD 3059 is suitable under late sown conditions and farmers prefer the variety due to high yield and resistance to yellow rust disease. The average yield of HD 3086 was 5.51 t/ha, which was 43.83 per cent higher than local check. In case of HD 2967, average yield of 5.08 t /ha was recorded. In sugarcane-wheat cropping system, late sown variety HD 3059 gave an average yield of 4.20 t/ha, which was 15.06 per cent higher than local check. In the village Rajpur, mustard varieties Pusa Vijay, Pusa Mustard 30 and Pusa Bold were assessed at farmers, field and recorded higher yields of 1.85, 2.00, and 1.88 t/ha, respectively, with economic gain of ₹ 41518/- (Pusa Vijay), ₹ 42527/- (Pusa Bold) and ₹ 46400/- (Pusa Mustard 30). Carrot variety Pusa Rudhira gave yield of 23.20 t/ha with average net return of ₹ 124350/- per ha.

Monitoring of demonstration of wheat var. HD 2967 at Khajurka village, Palwal (Haryana)

During *Kharif* 2017, a total of 125 assessment trails were conducted in all model villages on paddy varieties PB 1460, PB 1509, PB 1121 and Pusa 1592 covering an area of 48 ha. It is observed that in Khajurka, Palwal (Haryana) the highest yield of improved PB 1460 (5.22 t/ha) was recorded at farmers' field followed by PB 1509 (5.00 t/ha), PB 1121 (4.52 t/ha) and Pusa 1592 (4.07 t/ha). Majority of the farmers preferred PB 1460 due to presence of awn in paddy grain, high yield and due to the good market price it fetches. The economic impact assessment of paddy in the Khajurka location showed that Paddy PB 1460 fetched the highest net return i.e., ₹ 99040/- per hectare followed by PB 1509 (₹ 95250/-), PB 1121 (₹ 86475/-), and Pusa 1592 (₹ 53384/-). The grain quality was also good in terms

of maturity, cooking quality, good aroma and weight. In Raipur village, highest yield of Pusa 1592 i.e., 5.14 t/ha was recorded in demonstration plot followed by PB 1509 (4.52 t/ha), PB 1460 (4.45 t/ha), and PB 1121 (4.44 t/ha). In Kutbi village, four varieties of paddy were assessed which gave higher yield than the local check. The highest yield of PB 1509 i.e. 5.42 t/ha was recorded in demonstration plot followed by Pusa 1592 (4.71 t/ha), PB 1460 (4.61 t/ha) and PB 1121 (4.35 t/ha) with economic gain (net return) of ₹ 76030/-, ₹ 46272/-, ₹ 81204/- and ₹ 74365/-, respectively. Okra variety Pusa A-4 was also introduced in Rajpur and it fetched net profit of ₹ 155000/- per hectare.

In Beenjpur village, pigeon pea, bottle gourd and okra were assessed and gave higher yield than local check. Bottle gourd (Pusa Naveen) was highly preferred by farmers due to high yield and resistance from bacterial blight. Pigeon pea was newly introduced in Beenjpur location and yield of 1.28 t/ha with economic gain (net return) of ₹ 23020/- per hectare were reported in demonstration plot. Bottle gourd (Pusa Naveen) gave yield of 21.69 t/ha with net return of ₹ 123456/- per hectare in the demonstration fields.

Village Knowledge Resource Centers have been established in all the villages to facilitate the farmers to have access to latest information and knowledge and keep themselves abreast of the improved agriculture technologies, food processing and value addition, adaptability to climate change, development schemes, subsidies, etc. These knowledge resource centers are well equipped with farm libraries having a good collection of farm friendly literature, booklets, leaflets, journals, magazines, periodicals dealing on various aspects of agriculture, horticulture, animal husbandry, etc.

Around 100 farmers in each village have been linked with mobile SMS services for regularly communicating agro-advisory from the Institute.

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.

7.3.2.1 Collaborative programme with ICAR institutes and SAUs

During Rabi 2016-17, a total number of 373 demonstrations were conducted on wheat, mustard, carrot, cauliflower, pea, spinach and brinjal, covering an area of 82.45 ha across 17 locations.

Wheat

- The wheat variety HD 2932 was found marginally superior to the varieties release by the University (UAS 304). Wheat HD 3090 may be suitable variety for the region (UAS, Dharwad).
- HD 3059 is highly suitable under late sown conditions for maize/rice-*toria*-wheat cropping system and farmers prefer the variety due to its high yield, and resistance to yellow rust disease which is prevalent in local varieties of that area. Area under HD 2967 increased from 2592.80 ha to 22300.00 ha between 2013-14 and 2016-17 (KVK, Kathua). The wheat variety HD 2967 has spread over 50 per cent in area (KVK, Saharanpur).
- Majority of farmers achieved higher yield from variety HD 2967 in comparison to local variety. The farmers were highly satisfied with HD 2967 (IIVR, Varanasi).
- Wheat varieties HD 3086 and HD 2967 were well accepted by the farmers, due to less lodging in rains or heavy winds at maturity (DRMR, Bharatpur).
- The increase in yields of HD 2967 and HD 3118 was up to 27.76 per cent and 21.1 per cent, respectively, in comparison to local check HUW 468 (2.9 t/ha), (BAU, Ranchi).

- The yield performance of HD 2967 was good in respect of growth, tillering and grain quality. The area is showing an increasing trend of seed replacement by the variety in the district. The variety is in high demand among the farmers and it is replacing other timely sown varieties in the district, very quickly (IVRI, Izatnagar).

- No pest or disease is reported in HD 3086 except repeated minor attack of aphid. Early growth (144 days) and tillering is very good against local check. Farmers appreciated the growth, tillering and yield of HD 3086 and kept the produce for seed purpose. As reported by some farmers the performance of this variety is better than HD 2967 (IVRI, Izatnagar).

- The yield performance of wheat variety, HD 3059 was good in respect of growth, tillering and grain quality (IVRI Izatnagar).

- Farmers are happy with the high production potential of both HD 2967 and HD 3086 varieties. Higher yield could be realized by the farmers. Farmers also reported that HD 3086 yielded additional two quintals of straw which is useful for the dairy animals (NDRI, Karnal).

Mustard

- Mustard variety NPJ 113 was found suitable under multiple cropping system and moisture stress conditions (KVK, Kathua). Good yield was obtained in Pusa Sag 1 even in late sown conditions (IIVR, Varanasi). Mustard PM 30 gave an average yield of 0.46 t/ha which was 12.19% higher than the local check (BAU, Ranchi).

Palak

- Pusa All Green, assessed at different locations recorded good yield and was preferred by farmers due to its taste and marketability. Since it is a multi-cut variety and it could yield upto 20.0 tonnes per hectare (UAS, Dharwad). All Green demonstrated at farmer's field were superior to the local check (KVK, Saharanpur). Farmers appreciated the variety Pusa All Green for its broad leaf size, glossy appearance, dark green colour, profuse growth and tillering. Its market acceptability was more than that of the local variety. Its production is more due to quick re-growth (IVRI, Izatnagar). Farmers preferred Pusa Bharti to local due to diffused plant growth and attractive leaf color (IIVR, Varanasi).

Carrot

- Pusa Vrishti gave good average yield of 12.0 t/ha as compared to farmer practices (11.0 t/ha). But the consumers prefer red coloured varieties and at few places the length of carrot was less than their expectations. The farmers were not satisfied with this new variety of carrot (IIVR, Varanasi).

Cauliflower

- Cauliflower variety Pusa Paushja was appreciated by farmers. The yield was very good and liked with respect to attractiveness, light yellow tinge, medium curd size and taste (IIVR, Varanasi).

During *Kharif* 2017, a total of 176 demonstrations on paddy, pigeon pea, *palak*, bottle guard, carrot, cauliflower, *bhindi* and brinjal covering an area of 45.28 ha were conducted at ICAR Institutes / SAUs.

Palak

At UAS, Dharwad, *palak* variety, Pusa All Green is preferred for uniform green tender leaves, fast sprouting, no pests and deceases incidence, higher leaf yield compared to local variety (Harit Sona). It has high potential for adoption in the area.

Paddy

- In Kathua region, which was predominantly covered by coarse rice varieties earlier, now has 42 percent of its area covered by IARI *Basmati* varieties, Pusa Basmati 1121 has become very popular. PB 1509 being of short duration, having low water requirement was found to be suitable under rice-*toria*-wheat sequence. It has spread from 10 ha in 2015 to 58 ha during *Kharif* 2017. However, *basmati* rice varieties did not get good market price.

A success story of paddy variety Pusa Basmati 1121 seed production in Kathua was also published.

- At Kangra, under CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur paddy variety PB 1460 gave 17.40 per cent higher yield and was about 7-10 days early in maturity than local check Kasturi. Since Kangra is a rainfed area, some incidence of blast appeared.
- At KVK, Saharanpur under Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, paddy PB 1 and Pusa 1592 performed well and resulted in increase of yield of 30.02 percent and 17.91 percent, respectively, over local check. Less disease infestation was found in Pusa 1592.
- At IIVR, Varanasi locations, paddy variety Pusa 2511 was preferred for pleasant aroma, taste and higher yield but poor milling is a problem in local mills. It was sold at higher price than other existing cultivars. Paddy variety Pusa 1592 was appreciated by farmers due to its short duration and good cooking quality, and had higher demand in farming community. Paddy variety Pusa 1612 gave an yield advantage of 5.7 percent over local check (Sarju 52), 3.68 t/ha.
- At MPKV, Rahuri, paddy variety Pusa 2511 was assessed at two locations; Pune and Nashik. At both the locations, the variety was preferred for long grain (9 mm), good aroma and higher price as compared to checks.

Pigeon pea

- At IIVR, Varanasi pigeon pea variety Pusa 992 was appreciated for being of short duration that fits well for *Rabi* crops.

7.3.2.2 Collaborative programme with voluntary organizations

In collaboration with 29 voluntary organisations during *Rabi* 2016-17, a total of 549 demonstrations, covering an area of 150 hectares over 25 locations, on wheat, mustard, spinach, *saag*, carrot, brinjal, *methi* and pea, were conducted. The feedback from farmers is as follows:

Wheat

Among wheat varieties assessed HD 2967 is the most popular variety of this area and villages adopted upto 70 percent saturation (PRDF, Gorakhpur). The variety HD 2967 is highly rated for having high productivity, high tillering, best quality for *chapati* and is suitable for Bundelkhand region. (DRI, Chitrakoot). About 88 per cent of the area under wheat cultivation in Punjab is of IARI varieties HD 2967 and HD 3086. HD 3086 is most suitable for low temperature environment under cold conditions and higher yield obtained when sown after mid-November (Young Farmer Association -YFA , Rakhra). HD 3086 has edge over HD 2967 in respect of shape and size of grain and productivity (Gramin and Shahri Vikas Sansthan - GSVS, Mathura). All the wheat varieties HD 2967, HD 3086 and HD 3059 performed well in the area with increase in yield, ranging from 8-16 per cent, in comparison to local check variety (Foundation for Agriculture Research Management and Environment Remediation - FARMER, Ghaziabad). HD 3059 is found suitable for late sown conditions (end of December). Productivity-wise, it has edge over local variety Halna (Gramin and Shahri Vikas Sansthan - GSVS, Mathura). Wheat variety HD 2967 performed better with no disease and pest infestation. The grains of the variety did not shed even after 10 days of maturity (Krishi Vigyan Kendra - KVK, Holycross, Hazaribagh). There was 39 per cent increase in yield of HD 2967 over local check (Bhanu Foundation). HD 2967 variety gave 10-15 per cent higher yield in early sowing (October 15-31, in Muzaffarpur, Bihar location), compared to timely sown in November (VARDAN, Chhapra, Bihar). The average yield of the variety HD 3118 was 2.68 t/ha in comparison to 2.20 local check, Sonalika. Due to higher market rate of this variety, farmers could get gross return of ₹ 17080/- per hectare as compared to ₹ 4900 of local check (Shamayita Math, Bankura, WB). The yield of wheat varieties HS 507 and HS 490 was higher in trial demonstration in high rainfall lower valley area and yield was less in upper mid-hills (Nagwain area), which receives less rains (Society for

Technology Development - STD, Mandi). Low yield and less tillering of HD 2932, HI 1500 and HI 1531 as compared to improved local variety GW 496, although these varieties require less irrigation. HI 1500 and HI 1531 were prone to lodging due to taller plants. In variety HD 2932 less tiller, small spikes were recorded compared to GW 496. Farmers preferred high yielding variety which requires 6 to 7 irrigations (CinI Dahod). Wheat varieties HD 2967 and HD 3086 gave excellent performance with respect to vegetative growth, uniform seed, uniform growth, yield attributes, grain as well as straw yields. These varieties matured late by 10-15 days as compared to control varieties.

Pea

Pea variety Pusa Pragati gave 26.5 percent higher yield than local varieties and fetched higher market price (Himalayan Environmental Studies and Conservation Organisation - HESCO, Dehradun). The variety gave an average yield of 7.30 t/ha which was 12.2 per cent higher than local check. The bold grain and long pod were best traits reported. (Voluntary Action for Research Development and Networking - VARDAN, Chhapra, Bihar). Yield of pea was 10 percent less than local check (5.5 t/ha) because of poor germination, although the size and quality of pod was better (Society for Technology Development - STD, Mandi). Good pod size, very promising variety and good fruiting gave an average yield of 3.86 t/ha which was 51.89 per cent higher than the local check (Participatory Rural Development Foundation - PRDF, Gorakhpur). It was of short duration, suitable for green pod with average 6 to 7 grains per pod. It was a new introduction in the area, yet had high market demand (CinI Dahod).

Palak

- *Palak* variety Pusa Bharti gave an average yield of 20.5 t/ha which was 10.8 per cent higher than local check. It was preferred for soft and green leaves (VARDAN, Chhapra, Bihar).
- *Palak*, Pusa All Green gave an average yield of 18.0 t/ha which was 12.5 per cent higher than local check (STD, Mandi).

Carrot

- Carrot variety Pusa Rudhira gave an average yield of 25.6 t/ha which was 13.78 percent higher than local check. It was preferred for good colour, shape and size (VARDAN, Chhapra, Bihar).

Pusa Sarson Sag

- The variety of *sarson sag*, Pusa Sag 1 was new introduction in the area. It gave an average yield of 2.45 t/ha. Although it has soft and green leaves but there was less market demand (VARDAN, Chhapra, Bihar).

Mustard

PM 30 is less yielding than other locals (*Gramin and Shahsri Vikas Sansthan* - GSVS, Mathura).

During *Kharif* 2017, in collaboration with Voluntary Organisations, 336 demonstrations were conducted on different varieties of paddy, pigeon pea, brinjal, bottle gourd, okra, spinach, carrot, cauliflower, amaranths and ashgourd in an area of 108.57 ha. Major feedbacks are presented as under:

Paddy

- At Participatory Rural Development Foundation - PRDF, Gorakhpur, Pusa 2511 gave higher average yield of 4.74 t/ha among Paddy varieties assessed followed by Pusa 1612 (4.52 t/ha). Pusa 2511 has become popular scented variety of paddy but lodging was observed at maturity stage. The seed of PRH 10 was also produced in one acre of land through A and R lines. The results of application of half quantity of urea due to application of BGA were also encouraging.
- At Vivekananda Institute of Biotechnology - VIB, West Bengal, the yields of assessment trials of paddy varieties Pusa 2511 and Pusa 1612 were 6.00 and 6.20 t/ha, respectively. Farmers liked the variety Pusa 2511 for its aroma, long slender grain and high yield potential. The farmers are getting higher price of about ₹ 50,000 per tonne in comparison to other varieties ₹ 35,000 per tonne.

- Paddy variety PB 1460 gave average yield of 4.50 t/ha with average net return of ₹ 75160/- per ha at FARMER, Ghaziabad location.
- At HESCO, Dehradun, paddy (PB 1460), was assessed. Farmers preferred paddy variety PB 1460 for higher yield, superior cooking quality and better marketability.
- At KVK, Hazaribagh, paddy varieties Pusa 2511 and Pusa 1612 performed well with average yield of 4.56 t/ha and 4.86 t/ha, respectively.
- At Bhanu Foundation, paddy varieties Pusa 2511 and Pusa 1612 were preferred for good taste and scent and were in high demand among perched rice (*chiwura)* makers.
- At Shamayata Math, West Bengal, farmers preferred IARI paddy varieties Pusa 2511 and Pusa 1612 due to their good scent and cooking quality. Yield potential and market value is higher than local variety. A large number of farmers are interested to cultivate these varieties due to their short duration, requirement of less number of irrigations compared to local variety.
- At CinI Dahod, Paddy var. Pusa 2511 is preferred by the farmers for its traits like more tillering, long spikes, high production, long grains, good fragrance and taste after maturity of the crop and also removal of paddy husk and high market rate as compared to local variety.

Pigeonpea

- At HESCO, Dehradun, pigeon pea varieties (Pusa 991 and Pusa 992) were assessed. Both pigeon pea varieties yielded about 38 percent higher than the local check (1.04 t/ha).
- At CINI Dahod, pigeon pea varieties Pusa 991 and Pusa 992 were preferred for their short duration, dwarfness, heavy flowering, suitable for inter crop with maize, and good cooking quality and taste.

Bhindi

- At HESCO, Dehradun, *bhindi* variety Pusa A4 was assessed. The average yield of A4 was 10.03 t/ha as compared to 8.0 t/ha of local check.
- At KVK, Chomu, *bhindi* (Pusa A4) was severely affected by yellow mosaic virus.

Bottle Gourd

- At KVK Chomu, bottle gourd variety (Pusa Naveen) gave an average yield of 22.50 t/ha and farmers liked the variety in respect to yield attributes, uniform size of gourd.
- At KVK, Hazaribagh, the yield obtained from bottle gourd (Pusa Naveen) was 31.00 t/ha with B:C ratio of 2.75:1. Farmers found good marketability of bottle gourd, Pusa Naveen for its fruit size (av. wt. 750 g) and shape (cylindrical & straight fruit).

Marigold

- At KVK, Hazaribagh, Marigold (Pusa Narangi) with deep orange colour flower is in high demand and the flower size (approximately 5-6 cm diameter) was preferred in market for higher profitability. .

7.3.3. Participatory Seed production of Improved Varieties of IARI

Under participatory seed production of improved varieties of wheat during *Rabi* 2016-17, seeds of wheat vars. HD 2967 (90.00 t) and HD 3118 (2.50 t) was produced at PRDF, Gorakhpur; and at YFAP, Rakhra, seeds of wheat vars. HD 2967 (23.17 t) and HD 3086 (38.3 t) was produced.

During *Kharif* 2017, 12 t of PB 1509, 61.6 t of Pusa 44 and 15.1 t of Pusa 1121, 14.4 t of PB 1401 paddy seeds was produced at Rakhra, Punjab.

7.3.4 Front Line Demonstrations on Wheat (in collaboration with IWBR):

During *Rabi* 2016-17, 15 FLDs on wheat at Samaypur village, of Ghaziabad district (UP) were conducted on newly released wheat variety HD 3086 and use of bio-fertilizer (Azotobacter + PSB) in HD 3086.

Performance of FLD – IWBR (Wheat) during *Rabi* 2016-17

Technology	Variety	No. of dem.	Area (ha)	Yield demo. plot (t/ha)	Av. yield (t/ha) of check plot	% increase over check
Newly Released wheat variety	HD 3086	7	2.80	5.13	4.61 (PBW 550, BW 343)	11.49
Use of bio-fertilizer (Azatobactor +PSB)	HD 3086	8	4.00	5.28	5.10 (HD 3086)	3.81
	Total	**15**	**6.80**			

7.3.5 *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 program is to provide farmers with required information, knowledge and advisories on regular basis by adopting villages.

7.3.6 *Krishi Unnati Mela 2018*

The national agricultural fair– *Krishi Unnati Mela 2018*, with a major theme of doubling farmers' income by 2022, was organized at the campus of Indian Agricultural Research Institute (IARI), New Delhi from March 16 to 19, 2018. It was a collaborative venture of Indian Council of Agricultural Research (ICAR)/ Department of Agricultural Research & Education (DARE) and Department of Agricultural Cooperation (DAC), Ministry of Agriculture and Farmers' Welfare. The *mela* was inaugurated by Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh. Hon'ble Union Ministers of State for Agriculture and Farmers' Welfare Shri Parshottam Rupala, Shri Gajendra Singh Shekhawat and Smt. Krishna Raj also graced the occasion. In his keynote address, Shri Radha Mohan Singh stated that India is moving towards a Digital and Mobile revolution and even far-flung villages have access to mobile phones and dissemination of information on research and development in agriculture will be easy in near future.

The 10th National Conference of Krishi Vigyan Kendras-2018 was also organized during the *mela* (March 16-17, 2018). The theme of the conference

Dr. T. Mohapatra, Secretary, DARE and Director-General, ICAR welcoming Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh during *Krishi Unnati Mela 2018*

was "Technology for Doubling Farmers' Income". The conference was inaugurated by Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR). Shri Chhabilendra Roul, Additional Secretary (DARE) & Secretary (ICAR), Dr. A.K. Singh, Deputy Director General (Agricultural Extension) & Director, IARI also graced the occasion.

The occasion was graced by Hon'ble Prime Minister of India, Shri Narendra Modi who visited the *Krishi Unnati Mela*, 2018 on March 17 and addressed a huge gathering of the farmers, agricultural scientists and other participants. Hon'ble Prime Minister inaugurated the *Jaivik Kheti* portal and laid the foundation stone of 25 KVKs, besides launched an e-marketing portal for organic products. He gave away the *Krishi Karman* Awards and *Pandit Deen Dayal Upadhyaya Krishi Protsahan Puraskar*. Addressing the gathering, Hon'ble Prime Minister said that such *Unnati Melas* play a key role in paving the way for New India. He appreciated that he had the opportunity to simultaneously speak to two sentinels of New India – farmers and scientists. He said farmers and scientists have to work together to transform agriculture. While appreciating the spirit and the hard work of farmers and their achievements in agriculture, he mentioned present problems of agriculture, which reduced farmers' income while increasing the input cost and expenditure. Speaking about the progress made, Hon'ble Prime Minister said that more than 11 crore soil health cards have been distributed so far. Cent per cent replacement of conventional urea with neem coated urea has also resulted in lowering expenditure on fertilizer, apart from raising productivity. He said the *Pradhan Mantri Krishi Sinchai Yojana* envisions water for every farm. Rupees 80,000 crore are being spent to complete pending irrigation projects. He said the *Kisan Sampada Yojana* is helping in strengthening the supply chain from the farm to the market and is creating modern agriculture infrastructure.

Hon'ble Prime Minister informed the gathering that, several Model Acts related to farmers' welfare have been prepared and State Governments have been urged to implement them. Government is working to ensure that farmers get improved seeds, adequate power supply, and easy market access. The farmers Unions and Organizations would be given relief on income tax, on the lines of cooperative societies. Now the minimum support price (MSP) will be raised to one and a half times the production cost of all notified crops. Comprehensive steps are being taken for

Hon'ble Prime Minister of India, Shri Narendra Modi addressing the audience at *Krishi Unnati Mela 2018* at IARI *Mela* ground

Agriculture Marketing Reforms to connect rural retail markets with wholesale and global markets. He said that in the recent Union Budget, the concept of *Grameen* Retail Agriculture Markets has been envisaged. Twenty two rural *haats* will be upgraded with necessary infrastructure, and integrated with APMC and the e-NAM platform. The Prime Minister also emphasized the importance of Farmer Producer Organizations and mentioned that Farmer Producer Marketing Reform is being added in this programme, with the e-marketing portal for organic products. According to him, along with the Green Revolution and White Revolution, we must stress on Organic Revolution, Water Revolution, Blue Revolution, and Sweet Revolution. He said that the Krishi Vigyan Kendras (KVKs) will play a key role in this regard. The Prime Minister mentioned the role of honey-bees as an important source of additional income for farmers. At the same time, he spoke about the benefits of harnessing solar power in agriculture. He informed the gathering about the *Go-Bar Dhan Yojana* for creating compost, bio-gas, etc. from bio-waste. The Prime Minister warned about the deleterious effect of crop residue burning, and benefits of recycling them by incorporation into soil biomass as manure or mulch. The Government is working to ensure the availability of adequate credit in agriculture. The Prime Minister encouraged the organization of *krishi mela* of this kind and said that such events should also be held in far-flung areas. However, he also called for impact analysis of such events.

The *Jaivik Mahakumbh* pavilion was a special attraction to showcase techniques for organic crop production. A *Sahakar Sammelan* was also organized to boost cooperative societies in agriculture. Apart from this, 9 sessions of farmers-scientists interaction (3 seminars per day) were also organized on important issues. Exclusive seed selling counters were also put up in the fair. Theme pavilions focused on ways to enhance farmers' income by dissemination of ideas and novel inventions such as micro-irrigation, neem-coated urea, soil check/Soil Health Card, reducing cost through less use of fertilizer, effectiveness of crop insurance scheme and new avenues of income generation, such as animal husbandry, bee-keeping, poultry farming, etc. More than 800 stalls of the Central and State Governments and various private agencies were set up. Farmers had a glimpse of improved farming through live demonstrations.

On 18th March during Valedictory Ceremony, Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh felicitated 6 farmers with IARI-Fellow Farmer Award' and 44 progressive farmers with 'IARI-Innovative Farmers Award' which included four women farmers from different states of India. Hon'ble Ministers of State for Agriculture & Farmers Welfare, Shri Parshottam Rupala and Smt. Krishna Raj; Shri Surya Pratap Shahi, Agriculture Minister of Uttar Pradesh; Shri Tarun Shridhar, Secretary, DADF; Dr. Trilochan Mohapatra, Secretary, DARE & Director-General, ICAR; Dr. A.K. Singh, Director, IARI & DDG (Agriculture Extension), ICAR; Dr. Ashok Dalwai, Chief Executive

Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh presenting fellow farmer award during *Krishi Unnati Mela 2018*

Hon'ble Ministers of State for Agriculture & Farmers Welfare, Shri Parshottam Rupala honouring farmer with IARI Innovative Award

Officer, National Rainfed Area Authority, Ministry of Agriculture and Farmers Welfare; Dr. J.P. Sharma, Joint Director (Extension), IARI and other dignitaries were also present during valedictory ceremony. Shri Radha Mohan Singh delivered the valedictory address and also launched a new mobile app called PUSA m KRISHI® for farmers in order to take the technology to farm. In his address, he reiterated the central role of new and innovative farm technologies in doubling income of farmers. He said that modern technologies and crop varieties must reach to farmers without any time lag and must be demonstrated on farmers' fields for winning the confidence of farmers. The government is working towards increasing the usage of technology by the farmers under various schemes like *Pradhan Mantri Krishi Sinchai Yojana*, Soil Health Card Scheme and Traditional Agriculture Development Scheme (*Paramparagat Krishi Vikas Yojana*), etc. with a vision of doubling farmer's income by 2022. More than one lakh farmers from across the country visited the fair and gained useful knowledge and information.

7.3.7 Participation in Off-campus Exhibitions

The Institute organized / participated in sixteen national/international agricultural exhibitions for display /sale of IARI technologies, products, services and publications.

- International Agri-Horti Expo and Food Technology Expo, 2017 at Pragati Maidan, New Delhi from July 14-16, 2017.The event was organized by NNS Media Group.
- Exhibition during conference on "Digitalization of Agriculture for Enhancing Farm Income" on September 8, 2017 at India Habitat Centre (IHC), New Delhi.
- 'North-East Calling' during DoNER event on September 9-10, 2017 at Vigyan Bhawan, New Delhi.
- *Kisan Mela* at YFA Campus, Rakhra on September 16, 2017.
- Agricultural Exhibition from September 22-25, 2017 at Mathura on the occasion of birthday anniversary of Pandit Deendayal Upadhyaya.
- "All India Farmer's Fair and Agro Exhibition" at SVPUA&T, Modipuram, UP from October 7-9, 2017.
- Exhibition organized by Ministry of Rural Development during 'Nanaji Deshmukh 100th Birth Anniversary Event' from October 10-11, 2017 at IARI *Mela* Ground, New Delhi.
- World Food India organized by a Ministry of Food Processing Industries on November 5, 2017 at New Delhi.
- International Trade Fair 2017, at Pragati Maidan from November 14-27, 2017.
- National Sheep and Wool Fair organized by ICAR-Central Sheep & Wool Research Institute, Avikanagar, Rajasthan on December 8, 2017.

IARI was awarded 1st prize for best display of technologies.

- Exhibition organized on the occasion of 4th ASEAN-India Ministerial Meeting on Agricultural and Forestry, 2018 on January 11-12, 2018.
- 24th *Sarson Mela* on February 3, 2018 at ICAR-DRMR, Bharatpur.
- National Conference on "Agriculture 2022-Doubling Farmers' Income" organized by Ministry of Agriculture & Farmers' Welfare from February 19-20, 2018 at NASC, Pusa, New Delhi.
- North Zone Regional Farmers' Fair organized by ICAR-IIVR, Varanasi and DAC&FW, New Delhi on February 23-25, 2018 at Trade Facilitation Centre, Varanasi.
- *Kisan mela* organized by Young Farmers Association, Rakhra, Patiala on March 10, 2017.
- *Krishi Mela* organized by ATMA, Nagaur, Rajasthan on March 25, 2018.

A view of IARI exhibition stall at Avikanagar, Rajasthan

7.3.8 Agricultural Technology Information Centre (ATIC)

National Agricultural Research System has generated a 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 also provides mechanism for feedback from the users (farmers) to the Institute.

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

In ATIC crop *cafeteria*, live demonstrations of *Kharif* paddy varieties Pusa Basmati 1509, Pusa Basmati 1637, Pusa Basmati 1121, Pusa 1612, Pusa 2511, Pusa 1401 (PB 6), *moong* var. Pusa Vishal were laid out. In *Rabi*, live demonstrations of wheat varieties HD CSW 18, HD 3086, HD 2967, DB 02, and HD 3043; Nutri-garden with 15 vegetable varieties and fruit orchards (lemon, guava, mango, *ber*, kinnow and grapes) were demonstrated for the visiting farmers.

For awareness of farmers, herbal block has also been developed in crop *cafeteria* which includes medicinal plants of Aloevera, Ashwagandha, Satavar, Coleus, Giloe, Mushkdana, Sadabahar, Mint, *Tulsi* (Basil), Lemon grass, Java citronella, etc.

Delegates from Yezin Agricultural University, Myanmar with IARI team at ATIC

New infrastructure developed at ATIC:

1. 20 LED display boards of IARI technology have been fixed in ATIC building corridor.
2. One POS machine has been fixed in ATIC for cashless transaction.

A total number of 39,480 farmers/entrepreneurs, development department officials, students, NGO representatives, etc. from 20 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 (62.5%) visited ATIC to purchase / enquire seeds / varieties followed by plant protection (22.5%), and farm publication and others agro-advisory services (15 %). A majority of them were from Uttar Pradesh (29 %) followed by Haryana (21.5%), Delhi (13 %), Rajasthan (12.5%), Punjab (11%) and others (13%). Besides, 11,975 farmers from 19 states were able to get information on various aspects of agriculture through Pusa *Agricom* (A toll free Help Number-1800-11-8989) Pusa Help-line (011-25841670, 25841039, 25846233, 25803600) and *Kisan Call Centre* 1800-180-1551 (IInd level). Pusa seeds of worth ₹ 98,30,035/- and farm publications for ₹ 63,070/- have been sold to the farmers during the year, out of which cashless transaction was ₹ 10,63,150/- (10.81%).

Four issues of Hindi farm magazine "*Prasar Doot*" were published by the centre during the reporting period. Besides, more than 1200 farmers and others got farm advisory services through e-mails during the period.

7.3.9 *Krishi Vigyan Kendra*, Shikohpur, Gurugram

7.3.9.1 On- farm testing

On-farmer testing (OFTs) 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 within their farming system perspective with their active participation and management. OFTs aims to address the problems that are important and faced by a majority of the farmers in the area. The problems are diagnosed based on the data and information generated through different methods and interactions with the farmers and field level extension functionaries, farmers group meetings, field surveys and field visit, etc. During 2017-18, 7 on-farm testings were conducted on different problems identified in the region.

On-farm testings organized at farmer's field during 2017-18

S.No.	Title of OFT	Problem identified	Technology assessed
1.	Integrated Nutrient Management (INM) in Wheat	Low productivity of wheat due to inadequate nutrient application	Soil test based + INM (FYM + Azatobactor + PSB + 75% NPK)
2.	Integrated Weed Management (IWM) in Wheat	A lot of weed flora have come in wheat crop resulting in reduced crop yield	Carfentrazone + Sulphosulfuran 45g/ha
3.	Management of Diamond back moth (DBM) in cauliflower	Diamond back moth is the major problem in cauliflower cultivation resulting in low production of cauliflower	2 spray of Emamectin benzoate (5% SG) @ 0.50 g/liter of water and 2 spray of neemarin @ 5 ml/liter of water solution alternatively
4.	Management of *Fusarium* wilt in Summer Squash (Chappan Kaddu)	Fusarium wilt in summer squash is major problem in resulting in low crop yield	Seed treatment with carbendazim (50WP) @ 2.5 g /kg seed
5.	Use of Revolving Stool to Reduce Drudgery in Women during Milking Operation	Muscular disorder due to incorrect posture during milking operation	Revolving stool developed by G. B. Pant University Agriculture & Technology, Pantnagar
6.	Management of Nematode in Summer Squash (*Chappan Kaddu*)	Nematode is a major problem in summer squash resulting in low yield of crop	Soil treatment with neem seed kernal powder @ 500 kg + 2.5 kg *Trichoderma harzianum*/ha. Seed soaking with *Trichoderma harzianum* @ 5 g/liter water solution per kg seed for one hour
7.	To Test the Efficiency of the Mineral Mixture & Vitamin AD3E on reproduction performance in buffaloes	Poor reproductive performance in buffaloes	Supplementation of mineral mixture along with deworming and use of vitamin AD3E

7.3.9.2 Front line demonstration programme

A total of 196 demonstrations were conducted (*Rabi*, 2016-17 and *Kharif*, 2017) covering an area of 78.00 ha. during the period under report. The improved varieties and latest recommended package of practices were demonstrated under the programmes.

Results of FLDs organized at the farmers' fields during *Rabi* 2016-17

Crop	Variety	No. of demo.	Area (ha)	Yield kg/ha				Increase in yield %	BC ratio
				Demonstrations			Local		
				Max.	Min.	Avg.	Avg.		
Mustard	RB 50	50	20.00	2140	1570	1962	1840 (Laxmi)	6.63	2.58
	RB 50 (CFLD)	50	20.00	2165	1625	1968	1840 (Laxmi)	6.96	2.46
Wheat	HD 2967	13	5.00	6585	5735	6120	5760 (WH 711)	6.25	4.59
	HD 3086	13	5.00	6370	5525	5840	5760 (WH 711)	1.39	4.40
Barley	BH 393	10	4.00	6850	5500	5725	5280 (PL 426)	8.43	4.64
	Total	**136**	**54**	--	**--**	**--**	**--**	**--**	**--**

Results of FLDs organized at the farmers' field during *Kharif* 2017

Crop	Variety	No. of demo.	Area (ha)	Yield kg/ha				Av. cost of cultivation (₹)	Av. gross income (₹)	Av. net income (₹)	B.C. ratio
				Main produce			By produce				
				Max.	Min.	Av.					
Mungbean	MH 421	25	10	865	640	710	--	14500	36778	22278	2.54
Pigeon Pea	Pusa 991	25	10	1875	1640	1735	5000	62000	96798	70798	3.72
Cauliflower	Pusa Meghna	10	4.0	10925	9430	10420	-	30500	166720	136220	5.47
Total		**60**	**24**								

7.3.9.3 Entrepreneurship development in rural youth and women under ARYA project

Realizing the need to create interest and confidence in Indian rural youth by making agriculture more profitable, ICAR launched a project titled "Attracting and Retaining Youth in Agriculture". The objective of the project is to attract and empowers the youth in rural areas to take up various agriculture and allied sector enterprises for sustainable income and gainful employment. Initially, the project has been implemented in 25 districts by KVKs as ARYA centers and KVK, Shikohpur is one of them. Under this project, KVK has given training to 74 rural youth and women in the year 2016-17 and 64 youth and women in the year 2017-18 in 4 areas viz., value addition, protected cultivation, goat farming and mushroom production, out of which 70 participants have adopted the vocation and established their own enterprise. The details of the activities done under ARYA project:

Activities done under ARYA project

S. No.	Enterprise	No. of youth trained	No. of youth started their enterprise	Details of the enterprise
1.	Value Addition	34	34	3 SHGs formed. One group (14 women) established *masala* enterprise where as the other 2 groups (20 women) working on value addition of cereals, pulses and millet and earning 4-5 lakh annually per SHG
2.	Protected Cultivation	16	16	Established poly house at their own place and growing seedling and sapling of flowers & vegetables
3.	Goat Farming	10	10	5 female goats and 1 male goat was given to each farmer
4.	Mushroom Production	14	10	4 Mushroom units have been established at farmers place where buttom mushroom was grown and a gross income of ₹ 32,100/- to ₹ 1,90,000/- was earned in 2017-18 depending on the size of unit established

7.3.9.4 Agricultural extension activities and farm advisory services of KVKs

In addition to OFTs, FLDs and trainings, various other extension activities were also conducted during 2017-18, to cover more farmers, farm women and rural people to disseminate the technologies. A total of 2553 such activities were conducted.

"World Soil Day" celebrated at KVK, Shikohpur

7.3.10 Transfer of Technologies through IARI Regional Stations

7.3.10.1 Regional Station, Pusa (Bihar)

Wheat Frontline Demonstrations

To reduce the yield gap between lab-to-land, 16 frontline demonstrations were laid out during the year under report in Lakhinandlalpur, Mahmadpur and Rajapur Dihuli villages of Muzaffarpur districts of Bihar. The demonstrations conducted were on use of bio-fertilizers- *Azatobactor* and PSB on latest wheat variety HD 2967 (6), zero-tillage technology (5), and new improved wheat variety (5). The performance of different demonstrations conducted was very encouraging.

Besides these activities, the regional station Pusa participated in *Kisan Mela* at DrRPCAU Pusa, Bihar on December 3-5, 2017, *Agri-Expo Kisan Mela* on January 11-13, 2018 at ICAR Research Complex, Patna, Bihar., *Kisan Mela* on February 22, 2018 at ICAR Research Complex Patna, Bihar, *Krishi Unnati Mela* on March 16-19, 2018 at IARI, New Delhi, *Kisan Mela* (Agricultural Exhibition cum Farmer - Scientist Interaction Meet) at Motihari, Bihar on April 13-15, 2018

7.3.10.2 Regional Station, Karnal (Haryana)

Seed village programme. Seed village programme sponsored by DAC, Ministry of Agriculture, and Govt. of India was continued during *Rabi* 2016-17 and *Kharif* 2016 for farmer-to-farmer horizontal spread of seeds of popular varieties of different crops. In *Rabi* 2016-17, 21.2 ha area was taken under wheat cvs. HD 2967/HD 3086 and in *Kharif* 2017, 52.8 ha area under paddy cv. PB 1121 for seed production to increase the availability of quality seeds in their villages itself.

Basmati beej diwas. '*Basmati Beej Diwas*' was organized on March 3, 2018. *Pusa Beej* of two new *Basmati* varieties PB 1728 and PB 1637 and other popular varieties of *Basmati* paddy viz., PB 1509, PB 1121 and non-*Basmati* variety Pusa 44 of worth ₹ 13.23 lakh was sold to hundreds of farmers from Haryana, Punjab and western Uttar Pradesh.

Dr. A.K. Singh, DDG (Agricultural Extension), ICAR & Director, IARI (third from right) visited Seed Processing and Storage facility at R. S., Karnal during *Basmati Beej Diwas*

Off campus exhibitions/melas. Participated in the following *Krishi Mela*-cum-Exhibitions to display the technologies, products and publications of the institute. Stalls were visited by hundreds of farmers including women farmers.Vegetable kits were also sold to farmers.

- "Seed Day & *Rabi* Workshop" held at ICAR-IIW&BR, Karnal on October 10, 2017.

- National seminar on "Improved Production Technologies, Usage and Processing of Onion, Garlic & Potato in Haryana" on November 29-30, 2017 held at NHRDF, Karnal.
- "*Rabi Kisan Mela*" held at ICAR-CSSRI, Karnal on March 10, 2018.

7.3.10.3 Regional Station, Indore (M.P.)

A total of 28 demonstrations of 11 wheat varieties during 2016-17 in 13.8 hectares area of Indore and Dhar districts of M.P. using recommended package of practices were conducted. Increase in yield was recorded as 2.0 t/ha or 50%. Best performing varieties were: HD 2987 (yield- 4.8t/ha and 71 per cent yield increase over check), HI 1605 (yield- 5.1 t/ha and 67 per cent yield increase over check) and HI 8627 (yield- 4.2t/ha and 62% yield increase over check).

Extension activities during 2017-18

Particulars/Activity	Number
Preparation of display exhibits viz., Posters and Banners, etc	25
Farmers group meetings organized (Field)	50
Kisan Mela / Field Day organized	1
Field Visits	46
Short trainings for farmers/ extension officers and NGO's, etc	7
Visitors groups (Farmers/ Extension officers and NGO's)	59
Extension literature distributed to farmers, visitors & trainees	13,700
Participation in agricultural exhibitions / *Krishi Mela*	7
Number of farmers trained in "Wheat Production Technology"	3450
Answered farmers' phone calls	920
News articles in National papers	7
TV/ Radio Programmes/ Bytes	8
Popular articles	9

7.3.10.4 Regional Station, Shimla (H.P.)

Twelve front line demonstrations on wheat variety HS 562 and 3 FLDs on barley varieties BHS 380 and BHS 400 were conducted in different villages of Himachal Pradesh.

Field / farmer's day

- Participated in *Kisan Mela* and conducted *Kisan Gosthi* in association with Ambuja Cement Foundation, Darlaghat on January 16, 2018. More than 450 farmers participated. Distributed extension folders, strawberry and temperate fruit planting materials.
- Conducted Field Day cum *Kissan Gosthi* on "Production Technology of Temperate Fruit Crops" on January 17, 2018 at IARI Horticulture Research Farm, Dhanda. Seventy farmers/orchardists have participated.
- Farmers day organized at Shyamla Ghat, H.P. on May 11, 2017 by the Deptt. of Horticulture, H.P. More than 60 farmers had participated and extension folders distributed. Delivered lectures to the farmers regarding research achievements of the regional station.
- Field day organized in Kinnaur district of Himachal Pradesh under TSP in collaboration with NBPGR, Phagli at Nichar Block, Kinnaur district ,H.P. on August 23-24, 2017. Fifty farmers participated.
- Organized training program cum Field Day on the topic *Seb Ke Javik or Ajavik Vikaron Ka ekikrit Prabandhan* at Sumara and Nako Panchayat of Pooh block and Batseri Panchayat during October 3-8, 2017. Total 167 farmers participated in the training program. Training manual prepared in Hindi was distributed among trainee farmers. Seeds of recent wheat variety HS 507 (Pusa Suketi)and barley varieties BSH 400 (Pusa Kiran), BSH-352 (Pusa Himadri) were also distributed to farmers.
- Conducted Farmers Day under MGMG on July 26, 2017 at IARI, Horticulture Research Farm, Dhanda.

Twenty farmers/orchardists have participated. Talks were on strawberry cultivation, and strawberry planting materials distributed.

- Conducted one day training under MGMG on February 23, 2018 at Chailey,H.P. More than 70 farmers/orchardists have participated. Delivered talks on temperate fruit cultivation, and apple planting materials distributed.
- A *Kisan Diwas*, involving farm women from Kyar village was organized at Tutikandi Centre on March 15, 2018 to create awareness about recent high yielding varieties of wheat and barley developed for Northern Hills Zone.

A view of Farmers Day under MGMG at IARI Regional Station, Shimla

7.3.10.5 Regional Station, Kalimpong, West Bengal

IARI Regional Station, Kalimpong conducted numerous extension and technology transfer activities in the adopted villages under MGMG programme. Total 36 training programmes, 24 demonstrations and 50 awareness programmes covering 485 farmers were conducted. Improved technologies of IARI paddy varieties (PS 5, P 1612), mustard (PM 26, PM 31, Pusa Vijay) varieties and plating materials of Darjeeling mandarin were promoted under the programme. The scientists of the station regularly conducted field visits (28) and farmers meetings (30), and provided required advisory services on different aspect of cultivation.

Demonstration of grafting technique of Darjeeling Mandarin under MGMG at Darjeeling (West Bengal)

7.3.10.6 Regional Station, Wellington

IARI Regional Station, Wellington conducted front line demonstrations (FLD's) in 20 ha area for popularizing wheat cultivation in non-traditional areas of Tamil Nadu and Karnataka using two bread wheat varieties CoW3 and HW 5216, and one *dicoccum* variety HW 1098 in entire *dicoccum* wheat growing areas in Maharashtra, Karnataka and Tamil Nadu. The Station also conducted two wheat field day at Hosur and Ooty.

IARI Regional Station, Wellington released wheat varieties, NP 200, NP 201, HW 641, HW 971, HW 2004, HW 1085, HW 2044, HW2045, MACS 6145, HD 2888, COW(W)1, HW 5216, COW2, COW3 and HW1098 were raised in the field for demonstration as technology developed.

During *rabi* 2017-18, demonstrations on four Indian mustard varieties (PM 25, PM 28, PM 30 and PM 31) were carried out at three different places (Tumakuru, Raichuru and Kodaikanal) in Karnataka and Tamil Nadu. The crop expressions were very impressive at Tumakuru with a seed yield of 1.18 t/ha for Pusa Mustard 25, 1.53 t/ha for Pusa Mustard 28, 1.6 t/ha for Pusa Mustard 30, and 1.18 t/ha for Pusa Mustard 31.

7.3.11 NEH Programme of the Institute

Under this programme, paddy varieties Pusa 1612 and Pusa Sughandh 5; pigeon pea cultivars Pusa 991 and Pusa 992; green gram cultivars Pusa Vishal, Pusa 672 and Pusa 9531; vegetable varieties, Pusa A 4

(bhindi), Pusa Pragati *(*pea*),* Pusa Bharti *(palak)* Ridhi, Madhvi, Red Pusa (Onion), Pusa Swati (turnip), *Pusa Sag* (mustard *saag);* and oilseeds PM 25, PM 26 and PM 28 (mustard) were demonstrated at farmers field in coordination with selected KVKs of the NEH region. The use of the pheromone traps for insect and pest control in crops was also demonstrated to the farmers. In addition, training was imparted to the scientists, technical staff and farmers on cultivation practices of different improved crop cultivars and processing of horticultural crops of the region at KVK, Dimapur, Nagaland.

7.3.12 An Android App "NEMATODEINFO"

An android app "NEMATODEINFO" on nematode problems of rice-wheat crops was released in National Symposium of the Nematological Society of India in January 2017. The farmers are able to download the app on their handsets. Photographs of the nematode damage symptoms can be matched with the symptoms under field conditions. Our scientists are also using and have recommended/provided information to the farmers under MGMG.

8. EMPOWERMENT OF WOMEN IN AGRICULTURE AND MAINSTREAMING OF GENDER ISSUES

Rural women are playing an increasingly vital role in agricultural development, and their contribution to the farm based activities, particularly the animal production and management is widely recognized. They have immense potential to deliver significantly to increase farm output and enhance family income and well-being. Empowerment of rural women through capacity building in farm and non-farm alternative occupations holds a key towards realizing their full potential to realize the intended goals of sustainable food, nutritional and livelihood security. A number of interventions were implemented to address the women empowerment and gender issues for creating awareness about scientific farming, seed production, nutritional security and developing entrepreneurial skills.

8.1 WOMEN 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. Twenty five women during *Rabi* 2016-17 and *Kharif* 2017 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 Wheat cvs. HD 2967, HD 3086 and Paddy cvs. PB 1121, PB 1509. By active participation in the trainings, their level of knowledge for importance of quality seed has increased.

8.2 EFFECTIVENESS OF SHGs FOR GENDER EMPOWERMENT

There SHGs formed during the year 2014-15 are maintaining their enterprises and working towards its growth in terms of number of products prepared, quantity of production, annual turnover and their own profit share. The annual turnover of Arzoo SHG has raised to approximately 20 lakhs with a net profit of 20-30 percent (amounting to ₹ 4-6 lakhs annually). The success of the group's work has inspired them to name their enterprises as "Khushboo Masala Udhyog". Last year, the group planned to grow some of the spices on their own and for that purpose they formed one more SHG with the name of "Ozone" which is mainly formed to take up the farming activity.

Another group "Kshitz" has increased its sale up to ₹ 4-5 lakh per annum and one more SHG of 10 women named "Pragati" was added to the group. The women members of SHG benefited in the form of income enhancement by taking small enterprise and supplementary income generating activities thereby creation of some assets and raise in social status. The SHG work as a small bank through its micro financing activity, awareness about various developmental schemes, funds availability for various work and linkage with various institutions. The earning of SHG has increased the lending capacity of the group to its members and thus enhanced the micro credit system among the community. Social taboos like women should not come in front of men and go out to work and attend meeting was overcome, which resulted in women empowerment.

8.3 BIOTECHNOLOGY-LED SOCIO-ECONOMIC EMPOWERMENT OF FARM WOMEN

The project is under operation in five villages of Tappal Block of Aligarh district having different agro ecological conditions. Nineteen SHGs of farm women were linked to lead bank of Aligarh where they could save their group contributions and incomes.

Till November 2017, ₹ 6,39,079/- were saved in the bank. SHGs promoted the concept of mutual trust, understanding and support. Inter-loaning has started among group members for various farming and family purposes.

In all, 1,110 demonstrations proved the increase in yields i.e., wheat up to 12.19 percent; paddy up to 11.36 percent; mustard up to 14.47 percent; and *moong* up to 18.75 percent; biofertilizers like Rhizobium and PSB improved the soil fertility, crop productivity and production. Use of bed planter saved 25% water requirements of the crop, thus saving the cost of irrigation. At RBTIAU facilities of bakery unit, information kiosk, drudgery reducing implements and farm publication are made available.

At the CATAT, about 48 capacity building activities were conducted including drudgery reduction and livestock management.

Concept of biogas was popularized and few plants were constructed in beneficiaries' house. Use of slurry not only improved the crop performance, but also uses of chemical fertilizers were reduced with reduced number of irrigations. Biogas was also utilized as cooking fuel thus reducing the use of LPG cylinder resulting in saving money.

8.4 VOCATIONAL AND FARM TRAININGS FOR TECHNOLOGICAL INTERVENTION

The KVK, Shikohpur is playing a vital role in empowering rural women of Gurugram district by organizing various need based self-employment and income generating activities, and other extension programmes for creating the awareness about scientific farming and disseminating the technology in wide area. The important programmes and activities organized for rural women during the period April, 2017 to March, 2018 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 demonstrations for disseminating improved farm technologies
- Celebration of "Women in Agriculture Day"
- T.V. talks, advisory services on phone, publication of literature on technical know-how on food processing and dairy management, etc.
- Formation of women Self Help Group in villages, and motivating them to start their own enterprise and linking them to the market.

A number of training programmes by the Institute's Division of Agricultural Extension were organized under broad area of nutritional security for rural women; nutrition awareness programmes and National Nutrition Week were organized at farmers fields. Community Agri-Nutri Centre was established at Lachoda village, Bagpat district of U.P. Near about 1000 demonstrations were conducted on wheat (NB-02), vegetables, summer *moong*, *bajra* (Pusa Composite 443 & 701) in Sonipat district (Haryana) and Bagpat district (UP).

Interaction with rural women during a training on "Nutritional Security for Rural Women" at Lachoda village, Bagpat district of U.P

8.5 TRAINING NEEDS ON GENDER MAINSTREAMING AND SENSITISATION

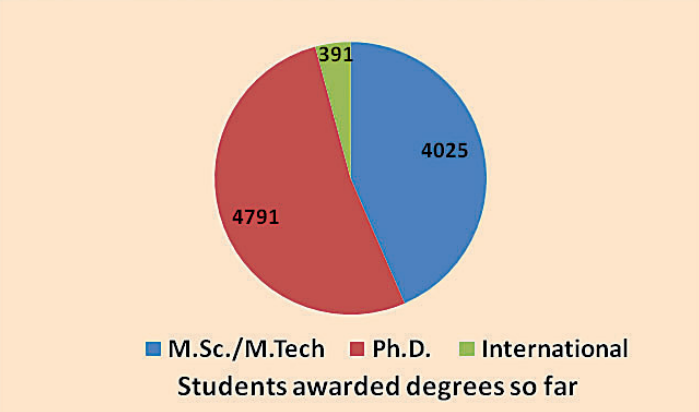
Fifty one extension personnel (trainers) involved in organising training as training managers and trainers were interviewed using a structured interview

schedule for estimation of training needs related to training on gender concepts.

The data on the training needs were collected by assigning on a five point scale as per Likert technique i.e., from very much needed to not at all needed. Scores of 5, 4, 3, 2, and 1 were allotted against the selected training areas. Training Need Index (TNI) was calculated and the results were ranked accordingly. Each task we face requires a corresponding set of skills for effective performance. A successful effective gender empowerment training program requires good gender empowerment and training skills by the organizers and trainers for sensitizing and creating effective learning environment. An attempt was made to identify the learning style of extension personnel by using Kolb learning style inventory. Findings is useful in examining best match between each learning style and training style of trainers for effective instructional strategy. The Converging learning style is associated with decision skills like quantitative analysis, use of technology, and goal setting. Diverging learning style is associated with valuing skills: relationship, helping others, and sense making. The Accommodative learning style encompasses a set of competencies that can best be termed acting skills: leadership, initiative, and action. Assimilating learning style is related to thinking skills: Information gathering, information analysis, and theory building. Majority extension personnel followed diverging learning style (53%) followed by accommodator (38%), converger (6%) and assimilator style (3%).

9. POST GRADUATE EDUCATION AND INFORMATION MANAGEMENT

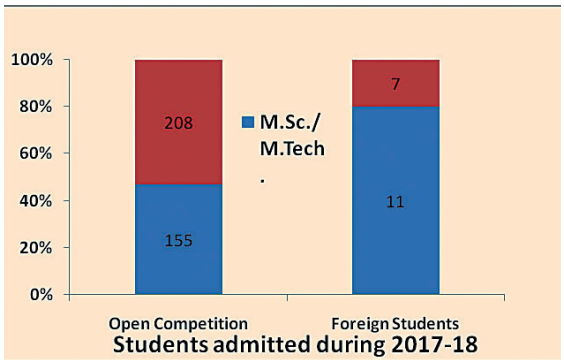
The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence of more than 113 years in research, teaching and extension. The Post Graduate School of IARI continues to provide national and international leadership in Human Resource Development by awarding Post Graduate degrees in 26 disciplines. So far, 4025 M.Sc., 47 M.Tech. and 4791 Ph.D. students have been awarded degrees including 391 international students. The Institute has received accreditation from the National Assessment and Accreditation Council of UGC (3.51/4.00, A+; 2016-2021) as well as National Agricultural Education Accreditation Board of ICAR (2015-2020). Based on the National Institutional Ranking Framework (NIRF) India Rankings 2018 by the Ministry of Human Resource Development (MHRD), IARI has been awarded the status of 'Special Mention Institution'.



9.1 POST GRADUATE EDUCATION

9.1.1 Admission during the Academic Session 2017-18

The PG School continues to attract students seeking admission to 26 disciplines in all five streams of admission, namely, Open competition, Faculty up-gradation, ICAR in-service nominees, Departmental candidates and Foreign students. The admissions to the Ph.D. programme are based on the national level entrance examination conducted in different parts of the country, followed by an interview and academic track record. While the admissions to the M.Sc. programme are based on an 'All-India Entrance Test' conducted by the Education Division of ICAR. The foreign students are admitted through DARE and are exempted from the written test and interview. During the academic year 2017-18, 155 students (including 4 from physically challenged and 3 from under privileged states categories) were admitted to M.Sc.; 9 students to M.Tech. and 208 students (including 5 physically challenged, 7 ICAR in service, 9 under faculty up-gradation scheme and 2 under departmental scientific scheme) to Ph.D. courses. For PG outreach programme at sister institutes, 12 students for CIAE, Bhopal and 16 students for IIHR, Bengaluru were admitted. In addition, 18 international students (11 M.Sc. & 7 Ph.D.) from 6 foreign countries were admitted. At present, the total number of students on roll is 1106 (302 M.Sc., 16 M.Tech. and 788 Ph.D.), which include 41 international students (18 M.Sc. & 23 Ph.D.) from 13 foreign countries.



9.1.2 CONVOCATION

The 56th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 9, 2018. Hon'ble President of India, Shri Ram Nath Kovind, was the Chief Guest. Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh presided over the function. Dr. T. Mohapatra, Secretary, DARE & Director General, ICAR, former Director Generals of ICAR and former Directors of IARI also graced the occasion. The Chief Guest presented the medals and awards to the students, while the Chairman presented the degrees to the students and awards to the faculty. The Chief Guest released IARI publication and 19 IARI varieties of different crops. In his convocation address, the Chief Guest highlighted the importance and priorities in the field of agricultural research and education. Dr. A.K. Singh, DDG (Agricultural Extension), ICAR and Director, IARI (Additional charge) presented his report on the significant research achievements of the Institute during 2017-2018, while Dr. R.K. Jain, Dean & Joint Director (Education), IARI presented vote of thanks.

During the Convocation, 237 candidates (133 M.Sc., 7 M.Tech. and 97 Ph.D.) were awarded degrees, including 14 (12 M.Sc./M.Tech. and 2 Ph.D.) international students. One student each in M.Sc. (Ms. Priti Priyadarshani, Agricultural Extension) and Ph.D. (Ms. N. Anuradha, Genetics & Plant Breeding) were awarded the Best Student of the Year Awards. Five students each in M.Sc. and Ph.D. received IARI Merit Medals. Dr. V. K. Baranwal, Professor of Plant Pathology and Dr. T.K. Behera, Professor of Vegetable Science jointly received the Best Teacher Award 2017 for their achievements in academics. The twentieth Sukumar Basu memorial award for the biennium 2015-16 was awarded to Dr. V.K. Singh, Head, Division of Agronomy, IARI, New Delhi for his outstanding research contributions towards "Site-specific Nutrition Management System and Integrated Farming System (IFS) model for small holders". The XVIII Hari Krishna Shastri Memorial Award for the year 2017 was awarded to Dr. (Ms.) Radha Prasanna, Principal Scientist, Division of Microbiology, IARI, New Delhi for her outstanding research contribution in the field

A Ph.D student receiving IARI Best Student of the Year Award from Hon'ble President of India, Shri Ram Nath Kovind during the Convocation

of "Exploring Cyanobacteria Capabilities as Plant Growth Promoting and Biocontrol Agents". The IV Dr. A.B. Joshi Memorial Award for the biennium 2017-18 was awarded to Dr. P.K. Agrawal, Assistant Director General (NASF), ICAR for his outstanding research contributions in "Quality Protein Maize (QPM) Breeding and Institution Building".

9.1.3 Special Lectures

Dr. B.P. Pal Memorial Lecture. 24th Dr. B.P. Pal Memorial Lecture was delivered by Prof. P K Joshi, International Food Policy Research Institute (IFPRI), South Asia Regional Office, NASC Complex, Pusa, New Delhi on May 26, 2017 on the topic 'Transforming Indian Agriculture - Challenges, Opportunities and Way Forward'. Dr. Gurubachan Singh, Chairman, ASRB, New Delhi presided over the function.

Teachers' Day Lecture. The Teachers' Day Lecture-2017 was delivered on September 5, 2017 by Dr. K.M. Paknikar, Director, Agharkar Research Institute, Pune on "Bioinspired Innovation in Nanotechnology". Dr. H.S. Gupta, former Director, IARI and Chairperson of the function, highlighted the new initiatives in agricultural education in India.

Lal Bahadur Shastri Memorial Lecture. The 48th Lal Bahadur Shastri Memorial Lecture was delivered by Dr. Girish Sahni, Secretary, DSIR & Director General, CSIR on February 8, 2018 on "The Joy, Tribulations and Opportunities in Scientific Innovation: Personal Insights". Dr. T. Mohapatra, Secretary DARE & Director General, ICAR presided over the function.

Dr. Girish Sahni delivering 48th Lal Bahadur Shastri Memorial Lecture

9.1.4 International Exposure

The excellence of IARI is recognised 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 Ministry of External Affairs (MEA), Government of India. Post-Graduate Courses of Yezin Agricultural University (YAU), Myanmar were revised and the courses with revised course curriculum being offered from the academic session 2017-18. Revised Post Graduate Handbook of YAU has been printed. Three new postgraduate programmes (M.Sc. & Ph.D.) (Agricultural extension Education; Molecular Biology & Biotechnology; and Food Engineering & Technology) have been initiated from the first semester of the academic session 2017-18. IARI faculty has delivered twelve courses during the 1st semester of the academic session 2017-18.

9.1.5 Addressing Plagiarism

To maintain academic integrity, 1526 documents in the form of thesis and manuscripts prior to submission were subjected to web based software 'Turnitin' and similarity reports were generated.

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 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 also initiated. Currently, this digital repository has about 1,20,000 articles including 65,000 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. A unified library instance for 63 SAUs/ DUs/ CAUs has been created and hosted at IARI integrated with implementation of day-to-day library operation software 'Koha'. Migration of data from local server (corresponding university) to centralized server (at IARI data center) is under progress.

9.2.2 Acquisition Programme

9.2.2.1 Books

During the period under report, the library procured 922 publications which includes 128 in Hindi, 725 in English and 69 Advances & Annual Review costing ₹ 99,66,844. The Library also acquired 50 gift publications, 241 theses and purchased 358 e-books, uploaded on IARI server and accessible through IARI Intranet.

9.2.2.2 Serials

The Library procured 2471 journals/serials through subscription, gifts and exchanges. It subscribed to 73 foreign journals, 235 Indian journals & Advances and Annual reviews and 250 newsletters. Exchange relationship was maintained with 65 institutions globally and nationally by sending 152 annual reports, ICAR journals and society publications. One hundred fifty seven annual scientific/technical reports/bulletins of different institutions were received in the Library during the reported period. The expenditure on serial acquisition from unified budget/library strengthening was ₹ 1,65,31,991 on foreign journals and ₹ 7,79,147 on Indian journals.

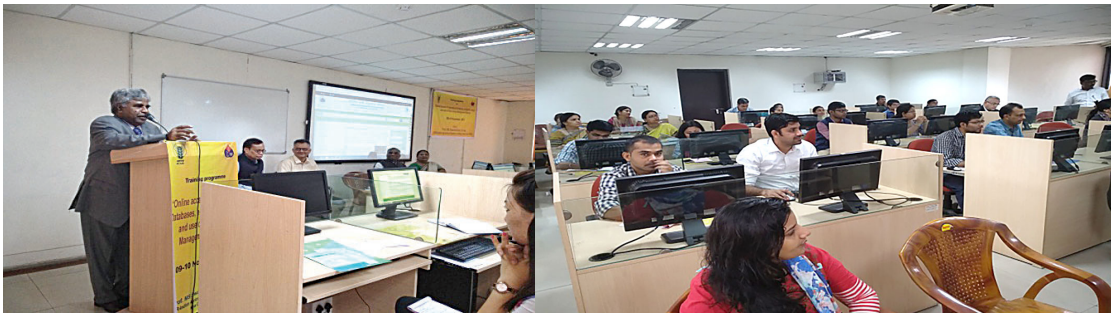
9.2.3 Document Processing

In all, 1149 documents consisting of 593 books, 212 post-graduate IARI theses, 40 ICAR awarded theses and 304 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 1500 to 2000 documents. During the reported period, 384 new members (40 staff and 344 students) were registered. During the period under report, 1713 publications were issued and 1750 publications returned to its members through "KOHA" library management software. Fifteen documents were issued under Inter Library Loan System to various institutions. About 460 no dues certificates were issued. Membership of DELNET (Developing Library Network) was renewed to provide Inter Library loan (reference services) to scientific community.



Workshop of users community on on-line journals, e-books and international databases

9.2.5 Workshop

The Library organized a workshop on the theme "Workshop of users community on on-line journals, e-books and international databases" during November 9-10, 2017. The main object of the workshop was how to use on-line journal/International databases in modern digital era.

9.2.6 Krishikosh

Krishikosh provides ready software platform to implement all aspects of the open access policy, similar to 'Cloud Service' for individual institution's self-managed repository with central integration. These two products of E-Grant (i) Krishikosh and (ii) IDEAL are used by all SAUs/DUs/CUs & ICAR Institutes. Up to March, 2018, the library uploaded 4612 theses, 5431 journals, 4835 books and 650 other publications.

9.2.7 Access of Online Journals

Apart from CeRA consortium library subscribed the 54 online journals, users can access these full text journals through LAN.

9.2.8 Access of E- books

Library procured 362 E-books from various publishers like Taylor and Francis, Arts and Science academy E- books (Online) on perpetual basis, access is available on LAN also.

10. PUBLICATIONS

An important mandate of the Institute is to generate scientific information, add value to information and share the information nationally and internationally. Publications are an important component of the information system. During the year, 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	620
b)	Symposia/conference papers	366
2. Books/Chapters in Books		
a)	Books	39
b)	Chapters in books	272
3.Popular Articles		328

10.2 IN-HOUSE PUBLICATIONS

10.2.1 Regular Publications

- IARI Annual Report 2016-17 (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)

- Post Graduate Research and Human Resource Development at IARI (2007-2016) (Vol. I&II) (ISBN 978-93-83168-30-9)
- Climate Resilient Agro-technologies for Enhanced Crop and Water Productivity under Water Deficit Agro-ecologies (ISBN 978-93-83168-31-6)
- Integrated Crop Management Practices for Enhancing Productivity, Resource-use Efficiency, Soil Health and Livelihood Security (ISBN 978-93-83168-32-3)
- Advances in Compost Production Technology (ISBN 978-93-83168-33-0)
- Sustainable Agriculture through Biocompost (ISBN 978-93-83168-34-7)
- Arise…….Get Set……Go! (ISBN 978-93-83168-35-4)
- Fellow and Innovative Farmers-2018, (Bilingual) (ISBN 978-93-83168-36-1)
- Integrated Farming Systems for Farmers Empowerment and Entrepreneurial Development (TB-ICN: 173/2017)
- Seed Production, Processing, Quality Assurance and Marketing (TB-ICN: 174/2017)
- Anthocyanin - A Premium Functional Superfood Supplement (TB-ICN: 175/2017)
- Seed Production in Field and Vegetable Crops (*Kharif*) (TB-ICN: 176/2017)
- Training Manual on Seed Law Enforcement (TB-ICN: 177/2017)

- Vitamin-E - A Premium Superfood Supplement (TB-ICN: 178/2017)
- Quality Seed Production of Vegetables for Higher Productivity and Profitability (TB-ICN: 179/2017)
- Integrated Farming System Model for Livelihood Security of Small and Marginal Farmers (TB-ICN: 180/2018)
- Seed Production and Quality Evaluation (TB-ICN: 181/2018)
- Phytic Acid –A Challenge to Nutritional Security and Environmental Health (TB-ICN: 182/2018)
- Seed Production in Winter Field Crops and Vegetables (TB-ICN: 183/2018)
- Breeding, Molecular and Biochemical Analysis of Vegetable Crops (TB-ICN: 184/2018)
- Molecular Breeding for Higher Productivity, Quality, Food Colorants, Nutraceuticals and Bioactive Health Compounds in Vegetable Crops (TB-ICN: 185/2018)
- Practical Manual on Basic Concept of Physics (TB-ICN: 186/2018)
- Pusa Vegetable Varieties for Nutrition & Health (TB-ICN: 187/2018)
- Hydroponic Technology for Horticultural Crops (TB-ICN: 188/2018)
- Genomics-assisted Breeding for Crop Improvement (TB-ICN: 189/2018)
- VSC-502: Principles of Vegetable Breeding (TB-ICN: 190/2018)
- Agri-Nutri Smart Village for Food and Nutritional Security (TB-ICN: 191/2018)

10.2.3 fu;fer i:dk'ku ¼fgUnh½

- ❖ पूसा सुरभि (वार्षिक) (ISSN : 2348-2656)
- ❖ वार्षिक रिपोर्ट 2016–17 (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 rduhdh i:dk'ku ¼fgUnh½

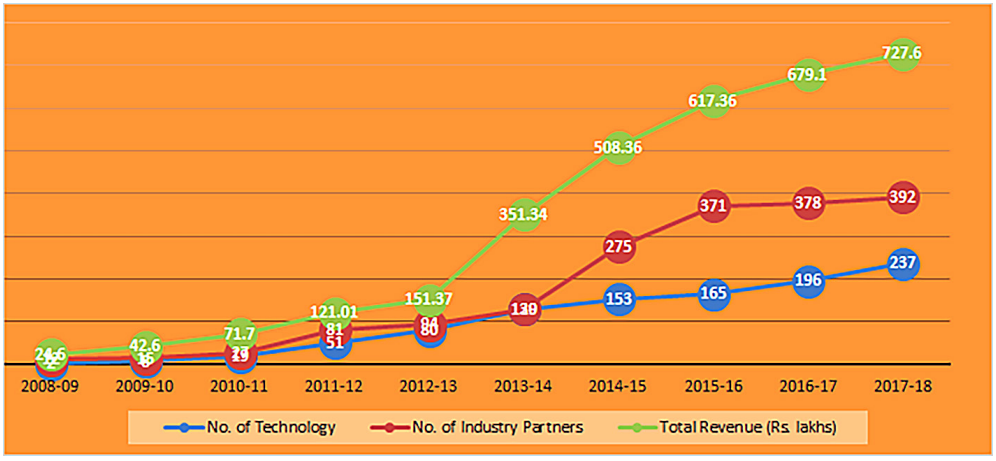
- ❖ बदलते मौसम के परिवेश में एकीकृत फसल उत्पादन तकनीक (ICN : H-166 /2018)
- ❖ शीतकालीन फसलों व सब्जियों का बीज उत्पादन (ICN : H-167 /2018)

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 under report, the Unit has organized following activities:

11.1 TECHNOLOGY COMMERCIALIZATION

During the financial year 2017-18, under Lab to Land Initiative, thirty one (31) innovative technologies of IARI were transferred to 14 industry partners resulting in a revenue generation of ₹ 48,00,000/-. These technologies included the rice variety, Pusa 1637; wheat varieties, HD CSW 18, HD 3117 and HD 3086; mustard varieties, Pusa Mustard 25, 26, 27, 28,



Technology commercialization from 2009 to 2018

A view of memorandum of agreement (MoA) between IARI and Himalayan Maharani, New Delhi for Pusa Soyanut and *Aonla* Candy Technology

A view of MoA with M/s Farm Implement (India) Pvt. Ltd. for Pusa Compost Turner cum Mixture & Pusa Compost Sieving Machine

29, 30 and 31; extraction technologies for Anthocyanin from black carrot; VAM biofertilizer technology & compost inoculant biofertilizer technology; Pusa Compost Turner cum Mixture; Pusa Compost Sieving Machine; and vegetable varieties and hybrids. Moreover, vegetable basket of 21 vegetable varieties and 25 vegetable varieties & hybrids were licensed to two companies.

11.2 INTELLECTUAL PROPERTY RIGHTS

One new Patent application has been filed and eight earlier filed applications have been granted. Eight trademark applications have been filed and one copyright has been granted in August 2016 and One copyright application filed; Four NBA Form – III applications and one (1) Form – II application were submitted. The details are as follows:

Patent application filed			
S. No.	**Application/ registration no.**	**Name of innovation/technology/process**	**Date of filing/ grant**
1.	201711016288	Side view image capturing device	May 9, 2017
Patents granted			
1	1988/DEL/2004 (283378)	Urea molasses mineral block machine	May 18, 2017
2	2218/DEL/2006 (284264)	A novel bio-pesticidal formulation with improved shelf-life and the method for its preparation	June 15, 2017
3	257/DEL/2012 (290155)	Development of slow release nano formulations of bioactive molecules and method of preparation thereof	November 30, 2017
4	3745/DEL/2012 (290085)	Anti-oxidant and anti-bacterial di-aryl-indazol-3-ols and their method of preparation thereof'	November 29, 2017
5	258/DEL/2012 (290363)	A product and process for the decontamination of pesticide residues from vegetables by using safe reagent	December 7, 2017
6	2150/DEL/2004 (291334)	Light heat and water resistant neem meliacin concentrates and product with controlled release	January 2, 2018
7	2051/DEL/2011 (292080)	Nanoencapsulated hexaconazole: a novel fungicide and the process for making the same	January 24, 2018
8	2032/DEL/2008 (292555)	Pusa 5sd-a bio-formulation of *Trichoderma harzianum* (iari p-4) for seed treatment	February 9, 2018
9	1710/DEL/2009 (292524)	A novel formulation of the plant growth promoting rhizobacteria with enhanced shelf-life and the method of its preparation	February 2, 2018
10	2416/DEL/2004 (293925)	Preparation of liquid pesticidal concentrates of neem meliacin(s)	March 8, 2018
11	577/DEL/2009 (294901)	Development of scar marker for identification of *Chaetomium globosum*-a potential biocontrol agent	March 16, 2018
12	420/DEL/2012 (2194416)	Nano copper-a copper based formulation to combat bacterial blight of pomegranate, rice and bean	March 16, 2018
13	3746/DEL/2012 (295150)	Development of polymeric formulations of bioactive molecules and method of preparation thereof	March 28, 2018

Trade Marks filed				
1	3689084	IP Spectra: IP Facilitation Centre for Agro based MSME's	Word mark (Class 41)	November 28, 2017
2	3689085	IP Spectra	Logo (class 45)	November 28, 2017
3	3689086	IP Spectra: IP Facilitation Centre for Agro based MSME's	Word mark (class 44)	November 28, 2017
4	3689087	IP Spectra: IP Facilitation Centre for Agro based MSME's	Word mark (Class 45)	November 28, 2017
5	3689088	IP Spectra	Logo (Class 44)	November 28, 2017
6	3689089	IP Spectra	Logo (Class 41)	November 28, 2017
Plant variety protection filed				
1	REG/2017/1869		Pusa Double Zero Mustard 31 (PDZ-1)	September 18, 2017
Copyright granted				
1	SW-9322/2017		Design of 'Micro - irrigation System'	August 18, 2017

11.3 AGRIBUSINESS INCUBATION

A. ITMC Meetings

During the reported period, two Institute Technology Management Committee (ITMC) meetings were organized by the unit to evaluate research outcomes of the technologies, management of IPR portfolios, forage the inventions that need to be protected under IPR and to contrive the terms and conditions for commercialization of new varieties and technologies developed by IARI.

B. IP Spectra (IP Facilitation Center for MSMEs)

In just one year of its establishment, IP Spectra has been ranked eleventh amongst all IP facilitation centers in India for its excellence in the field of IP services. IP Spectra organizes 'Free IP clinic service for MSMEs' – IP CARE' to give an overview of IP and to sensitize and spread awareness on 'How to Protect Intellectual Property'. IP Care gives an opportunity to members of the institute, inventors, startups, entrepreneurs, young farmers and students to discuss their ideas and IP matters with IP experts of the unit.

C. Business Incubation

Under the scheme "Support for Entrepreneurial and Management Development of SMEs through Incubators" for incubates support, the four incubates have received grant-in-aid support from Ministry of MSME. Stellargene Technologies was supported with Biotechnology Ignition Grant of ₹ 50 Lakhs from BIRAC and Sense it out Technologies with NIDHI-PRAYAS Grant of ₹ 10 Lakh.

Glimpse of ADP organized by ZTM&BPD Unit

11.4 CORPORATE MEMBERSHIP

During the year under report, 77 new corporate members with 77 renewals of existing memberships were registered, generating a revenue of ₹ 6,97,000/-.

11.5 OTHER ACTIVITIES

A. Agripreneurship Development Program (ADPs)

During 2017-18, three agripreneurship development program (ADPs) were organized on (i) Rapid Degradation of Agro Residues with Low Cost Input, June 12-17, 2017 (10 trainees participated), (ii) Soil Health Management, October 30 – November 4, 2017 (14 trainees participated) and (iii) Hands-on Training on Prior-Art Search, November 15-18, 2017 (9 trainees participated).

B. Marketing and Promotion Campaign

During the year 2017-18, 14 e-maketing campaign for technologies of IARI and Zonal Institutes i.e., EPN Technology for White Grub Management, Biofertilizer Technology, Biopesticides Technology, Agricultural Chemicals Technology, Nano Fertilizer Technology, new *basmati* rice varieties Pusa 1718 and Pusa 1728, new wheat varieties HD CSW 18, HD 3117 and HD 3086 and mustard seed varieties has been launched. More than 5900 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 4200 cold calls were made to various agro-based companies and corporate members for promotion of new technologies developed by IARI, New Delhi. B2B meetings with more than 800 companies were organized to showcase the potential technologies of IARI.

C. Marketing and Networking Platform

- ZTM&BPD Unit provided the platform to its six incubates to showcase their technologies, products, services and varieties in the exhibition on the theme "Technology and Rural Life" by ICAR-IARI, New Delhi on the occasion of birth centenary celebration of Nanaji Deshmukh on October 11, 2017 at IARI, New Delhi.
- ZTM&BPD Unit, facilitated and provided space to eight incubatees of ZTM&BPD Unit, to put up their stalls in the Agriculture Pavillion at 37th India International Trade Fair during November 14- 27, 2017 to promote and market their products and services.
- ZTM & BPD Unit's four incubates i.e., M/s. Kad Bio-resource Pvt. Ltd., M/s. Ananya Seeds Pvt. Ltd, M/s. Silage Agro Pvt. Ltd., and M/s. W. S. Telematics Pvt. Ltd., showcased their innovative products and technologies in the Festival of Innovation and Entrepreneurship, held during March 19-23, 2018 at Rashtrapati Bhawan, New Delhi.

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. The Institute is helping in the establishment of two IARI like Institution of excellence in Jharkhand and Assam. Students are being admitted to these institutions, namely, M.Sc. at IARI-Assam and IARI–Jharkhand in 5 disciplines viz., Agronomy, Genetics, Soil Science & Agricultural Chemistry, Vegetable Science and Water Science & Technology from the academic year 2015-16.

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 1.4.2017 to 31.3.2018 is given below:

Name of funding agency	Number of projects
Within India DBT, DST, NCPAH, APEDA, MSME, CSIR, DAC, Directorate of Horticulture, IMD, BRNS, NHB, NMSA, MIDH, PPV&FRA, SAC and ICAR	162
Outside India International Centre for Agriculture Research in Dry Areas (ICARDA), Harvest Plus Consortium-IFPRI, Bill & Melinda Gates Foundation-IRRI, Michigan State University-GCFSI, UNDP, US-India Education Foundation	6
Total	**168**

13. AWARDS AND RECOGNITIONS

- ICAR - Indian Agricultural Research Institute registered and received the ISO 9001: 2015 Quality Management System Certificate for providing Education, Research and Training in the field of Agriculture by Equalitas Certifications Limited. Certificate No. : Q-18031001.
- Dr. Ravinder Kaur, Principal Scientist, Water Technology Centre and team received (i) Skoch (Platinum) Transformational Innovation Award and (ii) Skoch Order-of-Merit Award. Dr. Ravinder Kaur, also received (iii) Savitribai Phule Excellence Award, (iv) World Soil &Water Conservation Award, and (v) elected National Environmental Science Academy Fellow.
- Dr. Chinnusamy Viswanathan, Head, Division of Plant Physiology was elected NAAS Fellow.
- Dr. Vinod, Professor, Division of Genetics was elected NAAS Fellow.
- Dr. Sakuru Venkata Sai Prasad, Head, IARI Regional Station, Indore was elected NAAS Fellow.
- Dr. Sanjay Kumar Singh, Head, Division of Fruits & Horticultural Technology was (i) elected NAAS Fellow, and (ii) received Bharat Ratna Dr. C. Subramaniam Award.
- Dr. S.P Datta, Professor, Division of Soil Science and Agricultural Chemistry was (i) elected NAAS Fellow, and (ii) received Bharat Ratna Dr. C. Subramaniam Award.
- Dr. V.K.Singh, Head, Division of Agronomy was (i) elected NAAS Fellow, and (ii) received Sukumar Basu Award.
- Dr. R. Roy Burman, Principal Scientist (Team Leader), Dr. J.P. Sharma, Joint Director (Extension), Dr. S.K. Dubey, Principal Scientist, Dr. K. Vijayragavan, Former Joint Director (Extension) (Associates), IARI, New Delhi were awarded with Hari Om Ashram Trust Award 2014-15 for Social Sciences.
- Dr. B.S. Dwivedi, Head, Division of Soil Science and Agricultural Chemistry received (i) Hari Krishna Shastri Memorial Award, and (ii) S.S. Ranade Memorial Award.
- Dr. K. Annapurna, Head, Division of Microbiology was selected for Endeavour Executive Fellowship - Australia Awards 2018.
- Dr. A. Sarangi, Principal Scientist, Water Technology Centre received Bharat Ratna Dr. C. Subramaniam Award.
- Dr. V.K.Vikas, Scientist (Senior Scale), IARI Regional Station, Wellington was elected NAAS Associate and selected for Endeavour Research Fellowship 2017, Australia.
- Dr. M.G. Mallikarjuna, Scientist, Division of Genetics received Jawaharlal Nehru Award of ICAR for his outstanding PG research in Crop Sciences category.
- Dr. (Ms.) Reshma Gills, Scientist, Agricultural Extension received Jawaharlal Nehru Award of ICAR for her outstanding PG research in Social Sciences category.
- Dr. Sangeetha Chopra, Principal Scientist, Agricultural Engineering selected for Fulbright Nehru Academic and Professional Excellence Fellowship 2017-18.
- Dr. Neeru Bhooshan, Incharge, ZTM & BPD Unit received National IP Award 2017.

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.) & Revised Estimates (R.E) for the year 2017-18 under Unified Budget

(Rs. In lakhs)

S. No.	Head	B.E 2017-18				R.E. 2017-18			
		Other than NEH & TSP	NEH	TSP	Grand Total	Other than NEH & TSP	NEH	TSP	Grand Total
Grants for creation of Capital Assets (CAPITAL)									
1	Works								
	A. Land				0.00				0.00
	B. Building								
	i. Office building	300.00			300.00	300.00			300.00
	ii. Residential building	170.00			170.00	100.00			100.00
	iii. Minor Works				0.00				0.00
2	Equipments	170.00			170.00	180.00		20.00	200.00
3	Information Technology				0.00				0.00
4	Library Books and Journals	217.00			217.00	286.00			286.00
5	Vehicles & Vessels				0.00				0.00
6	Livestock	1.00			1.00	1.00			1.00
7	Furniture & fixtures	40.00			40.00	31.00			31.00
8	Others			20.00	20.00				0.00
	Total – CAPITAL (Grants for creation of Capital Assets)	**898.00**	**0.00**	**20.00**	**918.00**	**898.00**	**0.00**	**20.00**	**918.00**
Grants in Aid - Salaries (REVENUE)									
1	Establishment Expenses								
	Salaries								
	i. Establishment Charges	19231.00			19231.00	19824.15			19824.15
	ii. Wages				0.00				0.00
	iii. Overtime Allowance	2.75			2.75	2.75			2.75
	Total – Establishment Expenses (Grant in Aid - Salaries)	**19233.75**	**0.00**	**0.00**	**19233.75**	**19826.90**	**0.00**	**0.00**	**19826.90**

Grants in Aid - General (REVENUE)									
1	**Pension & Other Retirement Benefits**	14231.00			14231.00	20202.00			20202.00
2	Traveling Allowance								
	A. Domestic TA / Transfer TA	85.00			85.00	80.00			80.00
	B. Foreign TA				0.00	5.00			5.00
	Total – Traveling Allowance	**85.00**	**0.00**	**0.00**	**85.00**	**85.00**	**0.00**	**0.00**	**85.00**
3	Research & Operational Expenses								
	A. Research Expenses	150.00			150.00	643.00			643.00
	B. Operational Expenses	260.00			260.00	997.00			997.00
	Total - Research & Operational Expenses	**410.00**	**0.00**	**0.00**	**410.00**	**1640.00**	**0.00**	**0.00**	**1640.00**
4	Administrative Expenses								
	A. Infrastructure	6000.00			6000.00	2735.00			2735.00
	B. Communication	50.00			50.00	50.00			50.00
	C. Repairs & Maintenance								
	i. Equipments, Vehicles & Others	150.00			150.00	300.00			300.00
	ii. Office building	150.00			150.00	900.00			900.00
	iii. Residential building	225.00			225.00	650.00			650.00
	iv. Minor Works	225.00			225.00	400.00			400.00
	D. Others (excluding TA)	645.00			645.00	1245.00			1245.00
	Total - Administrative Expenses	**7445.00**	**0.00**	**0.00**	**7445.00**	**6280.00**	**0.00**	**0.00**	**6280.00**
5	Miscellaneous Expenses								
	A. HRD	35.00			35.00	35.00			35.00
	B. Other Items (Fellowships, Scholarships, etc.)	500.00			500.00	480.00			480.00
	C. Publicity & Exhibitions	2.25			2.25	2.25			2.25
	D. Guest House – Maintenance	30.00			30.00	75.00			75.00
	E. Other Miscellaneous	135.00	40.00	10.00	185.00	135.00	40.00	10.00	185.00
	Total - Miscellaneous Expenses	**702.25**	**40.00**	**10.00**	**752.25**	**727.25**	**40.00**	**10.00**	**777.25**
	Total Grants in Aid - General	**22873.25**	**40.00**	**10.00**	**22923.25**	**28934.25**	**40.00**	**10.00**	**28984.25**
	Total Revenue (Grants in Aid - Salaries + Grants in Aid - General)	**42107.00**	**40.00**	**10.00**	**42157.00**	**48761.15**	**40.00**	**10.00**	**48811.15**
	Grand Total (Capital + Revenue)	**43005.00**	**40.00**	**30.00**	**43075.00**	**49659.15**	**40.00**	**30.00**	**49729.15**
	Loan and Advances	**66.00**	**0.00**	**0.00**	**66.00**	**69.64**	**0.00**	**0.00**	**69.64**

15. STAFF POSITION

(As on 31.03.2018)

	Category	No. of posts	
		Sanctioned	**Filled**
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	6	2
2)	Principal Scientist	65	35
3)	Senior Scientist/Scientist (S.G.)	170	123
4)	Scientist	337	345
	Total	**578**	**505**
B.	**TECHNICAL STAFF**		
1)	Category III	19	10
2)	Category II	279	170
3)	Category I	339	269
	Total	**637**	**449**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	18	18
2)	Group B	243	208
3)	Group C	163	100
	Total	**424**	**326**
D.	**SKILLED SUPPORT STAFF**	**1012**	**758**

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 2017-18, 9 physically challenged students (4 M.Sc./M.Tech and 5 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 Official 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 exofficio members of OLIC and Deputy Director (OL) is its member-secretary. During the period under report, the meeting of this Committee was organized regularly in each quarter and necessary suggestions and instructions were given for promoting the use of Hindi in various official/research activities and the effective implementation of Official Language. To ensure follow up action on the decisions taken in these meetings, sub-committees were also constituted in different Divisions, Regional Stations and the Directorate.

17.1.1 Inspection of Progressive Use of Official Language

As per the recommendations of the OLIC and to achieve the targets fixed in the annual programme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, an OL Inspection Committee was constituted under the chairmanship of Dr. Indra Mani 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 gave valuable suggestions for making the desired progress of (OL) implementation in the concerned Division/Section/Centre, etc., and submitted inspection reports.

17.2 AWARDS AND HONOURS (*RAJBHASHA*)

- The Institute was awarded the First Prize for doing maximum writing work in Hindi for the year 2015-16 under the ICAR *Rajrishi Tandon Rajbhasa Puraskar Yojna*.
- The Institute was also awarded the Second prize for its Annual *Rajbhasha Patrika* 'Pusa Surbhi' for the year 2016-17 under the *Rajbhasha Patrika Puraskar Yojna of* Narakas, North Delhi.

17.3 PROGRESSIVE USE OF HINDI IN OFFICIAL WORK

In order to encourage the staff members in different categories to do maximum work in Hindi, several steps were taken by the Institute during the year 2017-18:

- Five-days workshop cum training program on Hindi typing in Mangal (Unicode) font, was organized for administrative staff of the institute from July 31, 2017 to August 4, 2017.
- One-day workshop on the topic *Rajbhasha ke Niti Niyamon ka Vyavharik Prayog* was organized for newly appointed assistants of the institute on December 28, 2017.
- One day workshop was organized on March 24, 2018 for scientific and technical staff of the institute on 'Unicode system, phonetic and voice typing in Hindi on Computers'.

17.4 AWARD SCHEMES/COMPETITIONS

During the year 2017-18, 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 officers and employees of different categories of staff participated in these activities. The following activities were organized:

17.4.1 Award Scheme for Doing Maximum Official Work in Hindi

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India was implemented as per the directives of the Department and 6 employees of the institute were given cash awards for doing their maximum official works in Hindi during the year.

17.4.2 *Hindi Patra Vyavahar Pratiyogita*

Hindi Patra Vyavahar Pratiyogita were organized amongst the different Divisions and Sections of Directorate separately and a Division and a Section each were awarded mobile shield (*chal bajanti*) for doing maximum work in Hindi during the year 2017-18. The Division of Biochemistry, amongst the divisions and CATAT Unit amongst the sections/units were given the mobile shields.

17.4. 3 Awards for Popular Science Writing in Different Journals/Magazines

A competition for Popular Science Writing was organized for scientists/technical officers of the Institute, and winners were awarded first (₹ 7000), second (₹ 5000), third (₹ 3000) and four consolation (₹ 2000 each) prizes for their published Hindi articles in different journals/magazines.

17.4.4 Dr. Ram Nath Singh Award

Dr. Ram Nath Singh Award was given jointly to three scientists of the Institute for writing books in Hindi. The award carries a cash prize of ₹ 10,000/- and a certificate.

17.4.5 Power Point Presentation in Hindi

A Power Point Presentation Competition was organized on November 9, 2017 on the topic entitled 'Ethical Research' for Scientists and Technical Officials. Cash Awards were given to the successful participants.

17.5 *RAJBHASHA SAMMELAN*

A *Rajbhasha Sammelan* on the topic *Sarkari Karyon Main Rajbhasha Ka Prabhavi Prayog* was organized on April 12, 2017 in collaboration with NARAKAS (North Delhi) in Dr. B.P. Pal auditorium of the Institute. Dr. Satya Narayan Jatia, Honorable MP and vice-president of Committee of Parliament on Official language, was the chief guest of the function. A total of four sessions related to importance of Hindi as the official language and policy rules of the official language Hindi were kept in this conference. Dr. Jatia delivered the inaugural Lecture, and also reciting one of his poem at the conference. More than 150 participants from all the offices under NARAKAS (North Delhi) and IARI regional stations/divisions participated in the conference.

Honorable Member of Parliament Dr. Satya Narayan Jatia delivering the inaugural lecture at the *Rajbhasha Sammelan*

17.6 *HINDI CHETNA MAAS*

The Institute celebrated *Hindi Chetna Maas* from September 1 to 30, 2017. Dr. K.V. Prabhu, Joint Director (Research) & Chairperson, OLIC inaugurated the *Hindi Chetna Maas* on September 1, 2017. On this occasion, a Hindi Essay Writing competition was organized. During *Chetna Maas*, various other Hindi competitions

like essay writing, noting & drafting, 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.

17.6.1 Hindi Annual Prize Distribution Function

Hindi Annual Prize Distribution Function was organized on January 21, 2018. Shri Hari Babu Shrivastawa, Director, LESTAK, DRDO, New Delhi, was the Chief Guest. Dr. A.K. Singh, Director, IARI (additional charge) & DDG (Agricultural Extension), ICAR presided over the function. Dr. K.V. Prabhu, Joint Director (Research) and Chairman, Institute Official Language Committee was also present. The Chief Guest gave away the prizes to the winners of different competitions conducted during *Hindi Chetna Maas*. Shri Keshav Dev, Deputy Director (OL) presented the annual Hindi progress report of the Institute. Institute's Annual *Rajbhasha Patrika* ' Pusa Surbhi', was also released on this occasion.

The chief guest, Shri Hari Babu Shrivastav (third from left) releasing institute's *Rajbhasha Patrika* 'Pusa Surbhi' on the occasion of 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	Number of trainees
Division of Agricultural Engineering		
Training on Precision Agriculture Technologies	September 18-23, 2017	18
Training on Processing and Value Addition of Fruits and Vegetables for Women Farmers of J&K State	October 24- 29, 2017	9
Division of Agricultural Economics		
CAFT training on "Technological and Policy Options for Enhancing Farmers' Income"	September 23 - October 13, 2017	25
CAFT training on "Quantitative Methods for Agricultural Policy Analysis"	January 23 - February 12, 2018	25
Division of Agricultural Extension		
CAFT Training on Extension Strategies for Nutrition Sensitive Agriculture to Address Sustainable Development Goal.	September 2-22, 2017	15
CAFT Training on Advances in Instructional Technologies for Enhancing Teaching-Learning and Training Competencies	October 13 - November 2, 2017	18
CAFT Training on Innovations in Agricultural Extension for Enhanced Technology Application and Stakeholders Empowerment in Context to Changing Agrarian Needs	January 5-25, 2018	14
Agricultural Knowledge Management Unit		
Training on "Implementation of KOHA Platform for Library Management in NARES" at Professor Jayashankar Telangana State Agriculture University, Hyderabad	November 17-18, 2017	55
Training on "Applications of Information Technology in Agriculture" for technical staff of IARI	December 4-8, 2017	25
Awareness programme on 'Krishikosh' and 'KOHA' for the faculty, scientists and students of Sri Venkateswara Veterinary University, Tirupati, at Sri Venkateswara Veterinary University, Tirupati.	January 4, 2018	400

Training on Strengthening of Digital Library in NARES using KOHA Platform" at Indira Gandhi Krishi Vishwavidyalaya, Raipur	January 11, 2018	430
Training on "Strengthening of Digital Library in NARES using KOHA Platform" at CCSHAU, Hisar, Haryana	March 6, 2018	25
Training on " Tools & Techniques in Bioinformatics"	March 12-14, 2018	25
Division of Agricultural Physics		
21st IIRS Outreach Programme on 'Remote Sensing & GIS Applications in Water Resources Management'	May 22 – June 9, 2017	14
23rd to 27th IIRS Outreach Programme on "Basics of Remote Sensing, GIS & GNSS"	August 22 – December 4, 2017	19
29th IIRS Outreach Programme on "Hyperspectral Remote Sensing and its Applications"	February 19 – March 14, 2018	51
Division of Biochemistry		
Training on "Tools and Techniques for Analysis of Biomolecules"	September 5-18, 2017	14
CAFT on Recent Techniques and Tools for Nutritional Quality Assessment and Enhancement of Food Crops	January 23– February 12, 2018	18
Centre for Environment Science and Climate Resilient Agriculture		
Training workshop on "Advances in Simulation Modelling and Climate Change Research towards Knowledge Based Agriculture" for ICAR-scientists	November 16 – December 6, 2017	31
Centre for Protected Cultivation and Technology		
Protected Cultivation Technologies	December 28 - 29, 2017	25
Protected Cultivation of Horticultural Crops	January 15 - 17 2018	25
Skill Development Programme for Greenhouse Operators	February 12 – March 13, 2018	30
Division of Entomology		
Training on "Identification of Insect Pests/Vectors/their Damaging Symptoms and Management"	November 21- December 14, 2017	14
Division Floriculture & Landscaping		
Empowerment of Rural Women through Value Addition in Flower Crops	August 22 - 24, 2017	50
Landscape Gardening and Hi-tech Nursery Management for the officers of Directorate of Floriculture, Srinagar (Kashmir)	November 20 - 24, 2017	7
Commercial Floriculture for the officers of Directorate of Floriculture, Jammu, Srinagar (Kashmir), and Odisha Forest Department Cooperation, Bhubaneshwar	January 4 - 8, 2018	12
Division of Microbiology		
Production Technology of Blue Green Alga-Spirulina	July 18 - 21, 2017	30

Basic Microbiological Techniques for Studying Microbes	July 24 – 31, 2017	12
Division of Soil Science and Agricultural Chemistry		
Training on "Instrumentation Techniques for Analysis of Soil, Plant and Water"	October 4 - 13, 2017	17
14th Advanced Level Training on Soil Testing, Plant Analysis and Water Quality Assessment	December 8 - 28, 2017	16
Division of Vegetable Science		
Training on Quality Seed Production of Vegetable Crops for Enhancing Productivity and Profitability	November 6 - 13, 2017	26
Winter School on "Molecular Breeding for Higher Productivity, Quality, Food colorants, Nutraceutical and Bioactive Health Compounds in Vegetable Crops"	February 13 - March 5, 2018	23
Water Technology Centre		
Summer School on "Advances in Water management Practices for Enhancing Water Productivity in Agriculture"	October 25- November 14, 2017	15
Training on "Augmentation & Conservation of Rainwater through Rainwater Harvesting and Impact Analysis Assessment Methodology"	January 18 - 19, 2018	8
Skill Development Training Programme for Green House Operator	February 12 - March 13, 2018	29
Fundamental Concepts and Methodology for Agricultural Water Management	February 19 - 24, 2018	21
Regional Station, Indore		
Pre-season Surveillance SAARC Tool Box	December 7, 2017	12
Training for Farmers on "Wheat Production Technology"	December 20, 2017 - January 9, 2018 January 23- March 16, 2018	210
Training on "Recording of Data in Coordinated Wheat Trials and Nurseries"	March 5 - 7, 2018	20
Regional Station, Pusa, Bihar		
Integrated Crop Production Technologies under Changing Climate Scenario	January 23 – March 5, 2018	20
Recent Management Practices in Pulse Production	February 16 - 22, 2018	20
Regional Station, Karnal		
Farmers Training for Members of *Krishi Vistar Avum Mahila Uthan Sammiti*, Karnal	January 25, 2018	26
Farmers Training on "Seed Production in Winter Field Crops and Vegetables"	March 6 - 8, 2018	20
Farmers Trainings (6) under Seed Village Programme during *Rabi* - *Kharif* seasons on Different Aspects of Quality Seed Production	*Rabi* 2016 - 17 & *Kharif* 2017	200
Regional Station, Katrain		
Two Farmers Training on "Off-season Cultivation of Temperate Vegetables"	July 27 - 29, 2017 August 9 - 11, 2017	60

Training on "Modern Breeding Strategies for Higher Productivity, Quality and Bio-active Health Compounds in Temperate and Exotic High Value Vegetables"	October 4-13, 2017	15
Farmers' Training on "Temperate Vegetable Seed Production Technology"	January 17 - 18, 2018	25
Regional Station, Kalimpong		
Two trainings on "Advance Organic Cultivation of Horticultural Crops"	May 25-29, 2017 June 7-11, 2017	60
Production Technologies of Mustard and Wheat Cultivation	November, 28, 2017	50
Package of Practices of Mustard and Wheat Cultivation	November, 29. 2017	45
Scientific Cultivation Practices of Mustard and Wheat	November, 29, 2017	30
Cultivation of Leafy Vegetables for Nutrition Security	December 7, 2017	35
Master training programme on "Quality Improvement of Large Cardamom and Ginger"	December 15, 2017	50
Production Technologies of Vegetable Cultivation	December 16, 2017	40
Linkage between Food Security and Nutrition Security	January 15, 2018	38
Training on "Pest and Disease Management of Mustard"	January18, 2018	40
Regional Station, Shimla		
Three farmers trainings at Dhanda Farm and at Batseri and Kalpa Panchayat of Kalpa block of Kinnaur district, H.P.	June 8, 2017, November 14 - 15, 2017 & January 17, 2018	183
ZTM&BPD Unit		
Training on "Intellectual Property Rights & Business"	April 10-12, 2017	18
Seed Production Unit		
Dalhani Phaslien Evam Sabjiyon ki Beej Utpadan Takneekein	February 16, 2018	65
Rabi Phaslon ki Beej Utpadan Takneekien	February 19, 2018	40

18.1.1 Training Programmes Organized by the Institute's Centre for Agricultural Technology Assessment and Transfer (CATAT)

In all, 18 on-campus training programmes were organized for agriculture officials and partners from ICAR Institutes, SAUs, VOs and progressive farmers of different states. These programmes were attended by 423 participants from Bihar, J&K, Uttarakhand, Rajasthan, UP, Haryana and NCR, Delhi. One training programme was also organized by IARI for 22 representatives of VOs and SAUs/ICAR partners of collaborative programme on 'Seed Production of Rabi Crops'.

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 22 skill development trainings were organized for farmers and farm women including 7 trainings for field extension functionaries, in which 451 trainees participated. A total number of 59 short duration trainings for farmers, farm women and rural youth were organized, and 1043 beneficiaries participated in these training programmes.

Trainings organized during 2017-18

S. No.	Type of training with target groups	No.	No. of beneficiaries		
			Male	Female	Total
1.	Vocational trainings for rural youth & girls	12	134	128	262
2.	Day long trainings for practicing farmers and farm women i) On - campus ii) Off - campus	 20 39	 358 493	 17 175	 375 668
3.	In-Service trainings for field extension functionaries	7	101	24	125
4.	Trainings under ARYA project	3	31	33	64
	Total	**81**	**1117**	**377**	**1494**

Vocational training course on "Value Addition in Soybean and Pearl-millet

Vocational training course on "Dairy Farming" at KVK, Shikohpur

18.1.3 Other Capacity Building Activities

The Institute's CATAT also conducted several capacity building activities i.e., trainings on application of seed production, bio-fertilizers, soil testing and nutrient management, household nutrition and hygienic practices, nutrition garden, improved agricultural practices for climate change, soil and water mapping, an awareness about stubble burning and agro-advisory campaign at IARI Model Villages and other locations.

19. MISCELLANY

I. Ongoing Projects at IARI as on 31.03.2018

(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	14
b)	Seminars	17
c)	Summer institutes/Winter school	5
d)	Farmers' day (s)	74
e)	Others	76
	Total	**186**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	227
b)	Scientific meetings	155
c)	Workshops	145
d)	Symposia	122
e)	Others	67
	Total	**716**

Abroad

a)	Seminars	8
b)	Scientific meetings	14
c)	Workshops	9
d)	Symposia	6
e)	Others	3
	Total	**40**

IV. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel

Academic Council

- A non - credit compulsory e-course 'PGS 507' to be developed by the discipline of Agricultural Extension from 2018-19 academic session to make students aware about disaster management; and to allocate five seats each for M.Sc. and Ph.D. programme from 2018-19 academic session in addition to the seats finalized for open stream for admission of children/widows of eligible personnel of Security Forces.

Research Advisory Committee

1. School of Crop Improvement

- More emphasis needs to be laid on strategic research of national and international importance including nutritional quality enhancement in addition to the applied research on technological innovations. The material/knowledge generated should be shared with the stake holders.
- Germplasm with unique trait not known earlier should be registered for its wider utilization.

2. School of Horticultural Sciences

- There is need of involvement of geneticists/ molecular biologists with horticulturists to assist in marker assisting breeding in otherwise difficult and time taking breeding of perennial horticultural crops. There should be a strong linkage with basic sciences group for strategic research with IIHR (Bengaluru) and CISH (Lucknow) for mango and IICR, Nagpur & ICAR-RC in NEH regions for promoting scientific cultivation of citrus fruits.
- The Division of Fruits & Horticultural Technology should concentrate on crop improvement research mainly on their strength crops, namely, mango, citrus and grapes. New crops in horticulture may be tested under protected structures for increased water and nutrient use efficiency.
- Emphasis on rootstock breeding in mango (dwarfness, salinity tolerance), citrus (*Phytophthora* rot resistance), grape (salinity and stress tolerance) and guava (wilt tolerance) be made. Wild species in mango and guava should be studied / tried for possible use in breeding programme.
- Tangerine orange varieties showing promise should be promoted for commercial cultivation in north India. Efforts should be made to standardize integrated nutrient and disease management strategies in different fruit crops using bio-fertilizer, bio-pesticides and bio-control agents.
- In Floriculture, CAD laboratory should be established. Landscape part needs to be strengthened. Water conservation is to be looked into among the landscaping activities.
- Sharda melon type of cucurbits should be tested in Kinnaur and other cold desert areas of HP and J & K.
- Developing facilities for large scale multiplication of healthy planting material in different perennial horticultural crops.

3. School of Natural Resource Management

- For reducing cost of cultivation and increasing inputs use efficiency, fertilizer application should be worked out for deficit, sub-optimum and optimum water availability situations.
- In each experiment of NRM, invariably rainwater balance should be indicated along with total water applied through irrigation.
- The efficiency of hydrogel should be tested/tried in rice-fallows and water deficit areas for pulses/ oilseeds production.
- Under the supervision of Joint Director (Research), a working group of Soil Scientist (Soil Physicist), Agricultural Engineer, Agronomist, Crop Improvement, Crop Protection and Extension scientists should be created to address the researchable issues/problems of Conservation Agriculture (especially, the machinery part for crop residue management). This group should work with farmers in a participatory mode.
- Based on the lessons learnt from Long Term Fertilizer Experiments (LTFE) some satellite experiments should be initiated, as per resources availability with the farmer under deficit, sub-optimum and optimum irrigation water supplies as the present experiments are being conducted for irrigated agriculture alone.
- Research on solution oriented innovative approaches in identification of microbes/microbial consortia for rapid and efficient decomposition of sewage sludge/urban/rural bio-waste/garbage and industrial affluent should find top priority for conversion of waste to wealth for enhancing soil health.
- Extensive work on study of root architecture of different crops in the field should be initiated with an objective to increase water and nutrient use efficiency. Water and nutrient use efficient cultivars may be evaluated for different magnitudes of abiotic stresses.
- Presently the Soil Health Card (SHC) being given to the farmers is only a soil fertility status as soil health is an attribute of physical, chemical and biological properties. Organic carbon also represents biological activity as well. For soil physical status one-time determinable values of soil texture, infiltration rate, available water capacity (AWC) and bulk density may be included to make it complete Soil Health Card providing information on water entry in to the soil profile,

water availability, resistance to root growth and proliferation, besides nutrient status. This is essential for increasing input use efficiency. Efforts should be made in this direction to include these parameters in the SHC.

4. School of Crop Protection

- It was suggested to have practical problem solving basis for any such barcode based study of the penicillium isolates or any other study.
- Study on taxonomy of insects based on molecular analysis is not required except the one when we are studying within species variation or biotypes. It was suggested to rely on morphological data for such work.
- The observations on brown plant hopper (BPH) outbreak study should also include insect threshold levels and other parameters besides number of rainy days.
- The molecular diagnostics-PCR and LAMP technology work should be used for making inference on epidemiological studies.
- Presence of khapra beetle, a storage pest, is a trade barrier. The scientists should work out the permissible Phosphine dosage required for control of Khapra beetle.
- For making formulations consisting of pine oil and eucalyptus oil to control whitefly, methodology should be worked out.

5. School of Basic Sciences

- The national phenomics facility should be efficiently utilized for gene tagging/QTL identification related to input use efficiency, abiotic stress(es) management and other requirements of significant importance and also should be made available to other research organizations.
- The donors/genotype(s) identified for possessing novel characteristics should be registered for their utilization by all the stakeholders.

6. School of Social Sciences

- Efforts should be strengthened for imparting trainings for entrepreneurship development and follow up should be documented.
- Case study should be conducted for farmer producer companies employing different market channels with more emphasis on perishable horticultural produce.
- Technology assessment programmes should be conducted in different regions involving regional stations and farmer's feedback should be documented.
- The scientists should develop MNE framework for assessment of technologies.
- To reduce the food loss, holistic value chain research should be conducted.

7. Post Graduate School Activities

- RAC opined that ICAR should be approached for provision for utilizing HRD funds for-

(i) Post Doctoral fellowship and international visits by the scientists;

(ii) Dedicated overseas-associateship programme for faculty upgradation and

(iii) One time seed grant for newly joined scientists.

- The course on International Agriculture should be renamed to International Agriculture Development.
- There is lack of knowledge about agriculture legislation. A course may be started on it.

8. Administrative and Financial Activities

- For deploying/selecting human resource for IARI, Assam, persons should be selected having work experience of those areas.
- Changes made in financial management for its betterment during the last year should be presented. The possibility of application of signing cheques through mobile based app may be worked out.

V. Resource Generation

1) Consultancy & other services

Consultancy services:	nil
Contract research:	₹ 20, 34, 305
Contract service:	₹ 3,40,147
Training:	₹ 1,98,268
Total (A):	₹ 25,72,720

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed: ₹ 14,49, 05, 704

(b) Commercialization: ₹ 42,31,387

(c) Prototype manufacturing: ₹ 4,66,925

Total (B): ₹ 14,96,04,016

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: ₹ 27, 64,761

(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. : ₹ 87,22,600

(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) ₹ 1,07, 793

Total (C) : ₹ 1,15,95,154

Grand Total (A+B+C) : ₹ 25,72,720+ ₹ 14,96,04,016+ ₹ 1,15,95,154 = **₹ 16,37,71,890/-**

VI. Infrastructural Development

- Construction of irrigation channel in 10C and 11 blocks, construction of 500 m^2 polyhouse in 10C block and installation of digestion chamber in Divisional Laboratory of Vegetable Science
- Creation of office cum laboratory building at Amartara Cottage, Shimla and farmers Training Hall at Dhanda Farm of ICAR-IARI Regional Station, Shimla.
- Strengthening of Divisional Laboratory and workshop of Agricultural Engineering with instruments and design centre and farm machinery testing facilities.

VII. All India Coordinated Research Projects in Operation during the Year April 1, 2017 to March 31, 2018

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 April 1, 2017 to March 31, 2018

S.No.	Visitor (s)	Date of Visit
1.	A six- member delegation from Russia	06.06.2017
2.	A visit of Mr. Tshering Wangchen, Sr. Agril/National Oilseeds Coordinator, Research and Development Centre for Organic Agriculture, Bhutan	8.06.2017
3.	An eight- member delegation from Taiwan	3.07.2017
4.	A five- member delegation from UAE	30.08.2017
5.	A delegation from different developing countries of Asia & Africa	28.11.2017
6.	A delegation from Nepal	19.12.2017
7.	A delegation from Vietnam	21.12.2017
8.	A 30 - member delegation of Kansas State University, USA	04.01.2018
9.	A 20- member delegation from 4th ASEAN countries	12.1.2018
10.	A 30- member delegation of South Dakota Agricultural and Rural Leadership (SDARL) from USA	15.02.2018
11.	A ten- member Parliamentary delegation from Iran	27.2.2018
12.	A Polish delegation led by H.E. Mr. Jack Bogucki, Minister of Agriculture and Rural Development.	14.03.2018

A Russian delegation with IARI team

A Polish delegation with IARI team

Appendix 1
Members of Board of Management of IARI
(As on 31.3.2018)

Chairman

Dr. A.K. Singh
Director (Additional charge), IARI

Members

Dr. J.P.Sharma
Joint Director (Research),
(Additional charge), 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

Dr. I.M. Mishra
Head, Division of Agricultural
Engineering

Dr. V.K.Singh
Head, Division of Agronomy

Dr. A.K.Singh
Head, Division of Genetics

Dr. D.K. Yadava
Head, Division of Seed Science
and Technology

Dr. G.K. Mahapatra
Head, IARI Regional Station, Pune

Dr. Premlata Singh
Head (Acting), Division of
Agricultural Extension

Dr. S.K. Singh
Head, Division of Fruits and
Horticultural Technology

Dr. M.Premjit Singh
Vice Chancellor, Central
Agricultural University, Imphal,
Manipur
Agriculture Commissioner
Deptt. of Agril. and Cooperation,
Ministry of Agriculture and
Farmers' Welfare, 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 PO, PS Ruksin,
East Siang, Arunachal Pradesh

Smt. Krishna Yadav
Gurugram, Haryana
AS&FA or his nominee not below
the rank of DD(F)
Development Commissioner of
Delhi Administration

Member - Secretary
Joint Director (Adm.), IARI

Appendix 2

Members of Research Advisory Committee of IARI

(As on 31.3.2018)

Chairman

Dr. P. L. Gautam
Former DDG (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 DDG (Horticulture), ICAR

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

Deputy Director General (Crop Science), ICAR, Krishi Bhawan, New Delhi

Dr. A.K.Singh
Director (Additional charge), IARI

Member – Secretary

Dr. J. P. Sharma
Joint Director (Research)
(Additional Charge)

Appendix 3
Members of Academic Council of IARI
(As on 31.3.2018)

Chairman
Dr. A.K.Singh
Director (Additional charge)

Vice-Chairman
Dr. R.K. Jain
Dean & Joint Director (Edn.)

Members
Dr. N.S. Rathore
Deputy Director General (Edn.), ICAR

Dr. Kuldeep Singh
Director, NBPGR

Dr. N.K.Singh
Director (Acting), NRCPB

Dr. L.M.Bhar
Director (Acting), IASRI

Dr. P.K. Mishra
Director, IISWC, Dehradun

Dr. K.K. Singh
Director, CIAE, Bhopal

Dr. M.R. Dinesh
Director, IIHR, Bengaluru

Dr. J.P. Sharma
Joint Director (Research)
(Additional charge)

Dr. J.P. Sharma
Joint Director (Extension)

Dr. H.S. Gaur
Former VC , SVPUAT, Meerut
27/109/4B/1A, Jawala Nagar, Shahdara
Delhi-110032

Dr. S.K. Datta
Former DDG(CS), ICAR
Flat No. 020302, 1050/1
Sarvey Park
Kolkata - 700075

Dr. P.K. Joshi
Director, South Asia
International Food Policy Research Institute, NASC Complex, New Delhi-110012

Dr. A.K. Singh
Former VC, RVSKVV, Gwalior
Flat No. 71, Ashirvad Apartments
Patparganj New Delhi-110092

Dr. Man Singh, PD (Acting),
Water Technology Centre

Dr. K.M. Manjaiah
Associate Dean, P.G. School

Dr. (Ms.) Shashi Bala Singh
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. M.R. Khan
Professor, Nematology

Dr. (Ms.) Rekha Chaudhury
Professor, Plant Genetic Resources

Dr. V.K. Baranwal
Professor, Plant Pathology

Dr. Madan Pal 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

Dr. Anil Sirohi
Master of Halls of Residences

Mr. Sanchal Bilgrami
Comptroller

Dr. A Nagaraja
Senior Scientist, Fruit Science

Dr. Mahesh C Yadav
Principal Scientist, NBPGR

Ms. Sunita Gupta
Incharge, Prof. M.S. Swaminathan Library

Mr. Satish Naik
President PGSSU

Ms. Priyanka Upreti
Students' Representative to the Academic Council

Member- Secretary
Dr. K.M.Manjaiah
Registar (Acting)

Appendix 4
Members of Extension Council of IARI
(As on 31.3.2018)

Chairperson

Dr.A.K. Singh, DDG (Extension), ICAR & Director (Add. Charge), IARI, New Delhi

Members

Dr. J.P. Sharma, Joint Director (Extension) & Joint Director (Research), (Add. Charge), IARI, New Delhi

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 Science, , 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, Seed Sci. & Tech, IARI, New Delhi

Dr. Indra Mani, Head, Division of Agril. Engg., IARI, New Delhi

Dr. B.S. Dwivedi, , Head, Division of SSAC., IARI, New Delhi

Dr. V.K. Baranwal, Professor, Plant Pathology, IARI, New Delhi

Dr. Sanjay Kumar, Incharge, Seed Production Unit, IARI, New Delhi

Dr. Man Singh, 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-110014

Sh,. A.P. Saini, Joint. Director (Agril.), Delhi Development Deptt,11th floor, MSO Building IP estate, ITO, New Delhi-110002

Ms. Sakshi Mittal, Director (Agril. Mktg) Delhi Dev. Deptt..49, Shamnath Marg. Old. Sectt., Delhi-54

Dr. K.S. Kadian, Head, Dairy Extension Division, NDRI, Karnal-132001

Dr. Shailesh Mishra, Director (FI), Directorate of Extension, Krishi Vistar Sadan, Behind Division of Agromony, 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 31.3.2018)

Chairperson
Director, IARI

Co-chairperson
Joint Director (Research), IARI

Members
Deputy Director General (Crop Sciences), 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 31.3.2018)

Chairman
Dr. A.K.Singh
Director (Additional charge), IARI

Members (Official Side)
Dr. J.P. Sharma
Joint Director (Extension) &
Joint Director (Research) (Add. Charge)

Dr. Alka Singh
Professor, Agricultural Economics
Professor, Nematology

Sh. Sanchal Bilgrami
Comptroller

Secretary (Official Side)
Joint Director (Admn.)

Members of the Staff Side (Elected)
Shri Satyendra Kumar
AAO, Division of Vegetable Science

Shri Yogesh Kumar
Assistant, Division of Plant Pathology

Shri Radhey Krishn Thakur
UDC, Directorate

Shri Raj Kumar
UDC, Directorate

Shri Veer Pal Singh
Technical Officer, CPCT

Shri Ganesh Rai
Technical Assistant, Division of Entomology

Shri Shrawan Kumar
Technical Assistant, AKMU

Shri Shiv Kumar Singh
Technical Assistant, Division of Plant Pathology

Shri Umesh Thakur
Skilled Support Staff, Audit, Directorate

Shri Raj Pal
Skilled Support Staff, Directorate

Shri Shashi Kant Kamat
Skilled Support Staff, Seed Production Unit

Secretary (Staff Side)
Shri Bijender Singh
Skilled Support Staff, CATAT

Appendix 7

Members of Grievance Committee of IARI

(As on 31.3.2018)

Chairman

Dr. R.K.Jain
Dean and Joint Director (Edn.)

Members (Official Side)

Dr. B.S.Tomar
Head, Division of Vegetable Science

Shri Subodh Neeraj
AO, Directorate

Ms. Neha
F&AO, Directorate

Members of the Staff Side (Elected)

Dr. Ambrish Kumar Sharma
Principal Scientist, Division of Genetics

Shri Sunil Kumar
Technician, Division of Agricultural Engineering

Shri Pankaj
LDC, Audit, Directorate

Shri Ranjit Rai
Skilled Support Staff, F&HT

Member-Secretary

Shri Dev Raj
AAO (P-I), Directorate

Appendix 8

Personnel

(As on 31.03.2018)

Directorate

Director (Add. Charge)

Dr. A. K. Singh

Joint Director (Research)

(Add. Charge)

Dr. J.P. Sharma

Dean & Joint Director (Education)

Dr. R.K. Jain

Joint Director (Extension)

Dr. J.P. Sharma

Joint Director (Admn.)&Registrar

(Acting)

Mr. M.K. Jain

Principal Scientist (PME)

Dr. M. Jayanthi

Incharge, Publication Unit

Dr. R.K. Sharma

Comptroller

Mr. Sanchal Bilgrami

Chief Administrative Officers

Mr. M.K. Jain

Mr. Pushpendra Kumar

Agricultural Chemicals

Head

Dr. Anupama

Professor

Dr. Shashi Bala

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

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. M.R. Khan

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. Madan Pal

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. J.P.S. Dabaas

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. Sunita Gupta

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

Dr. G.K.Mahapatro

IARI Regional Station, Pusa

Head (Acting)

Dr. T.R. Das

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. Pankaj

---

*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.