ISSN 0972-6136

ANNUAL REPORT 2022

G20 भारत 2023 INDIA

INTERNATIONAL YEAR OF MILLETS 2023

ICAR-INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI 110012

Annual Report 2022

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

Annual Report 2022

Printed: March, 2023

Supervision and Guidance
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Director

Dr. Viswanathan Chinnusamy
Joint Director (Research)

Compilation Committee and Editorial Team

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Acknowledgements
We acknowledge the help received from the Scientific, Technical, Administrative, Financial and Suppporting staff of the ICAR-Indian Agricultural Research Institute in the compilation of this report.

Correct citation: IARI Annual Report 2022, ICAR-Indian Agricultural Research Institute, New Delhi – 110 012, India.

ISSN 0972-6136

IARI website: www.iari.res.in

Published by the Director, ICAR-Indian Agricultural Research Institute, New Delhi -110 012, India, and printed at M/s M.S. Printers, C-108/1 Back Side, Naraina Industrial Area, Phase I, New Delhi – 110024 (Phone: 011-45104606)

PREFACE

Climate change, deteriorating soil health and dwindling natural resources are the major challenges to the food and nutritional security. The future prosperity of Indian agriculture is, therefore, dependent on our current preparedness for boosting productivity under impending crisis of climate change and diminishing resources. The IARI has embraced this gargantuan challenge and is striving hard to develop high yielding and nutritionally fortified crop varieties with eco-friendly technologies that can maximize profits of the farmers, while conserving the environment.

In the year 2022, IARI released 34 varieties and hybrids with improved yield, quality and stress resilience. These include 16 in field crops, 15 in vegetables and 03 in fruit crops. For tackling the problem of bacterial blight in rice, Pusa 1853, a MAS derived version of the popular rice variety Samba Mahsuri was also notified for release. Direct seeded rice (DSR) is gradually emerging as a preferred technology to save water and the herbicide tolerant Basmati rice varieties *viz*., Pusa Basmati 1979 and Pusa Basmati 1985, developed by the Institute would facilitate DSR through effective weed control in rice fields. The Institute released the first drought tolerant basmati rice variety, Pusa Basmati 1882, with reproductive stage drought tolerance, towards achieving "per drop more crop" in rice. IARI-bred Basmati rice varieties viz., Pusa Basmati 1121, Pusa Basmati 1718, Pusa Basmati 1509 and Pusa Basmati 6 occupied >95% of the Basmati rice area in the country, and contributed ₹ 34,000 crores of foreign exchange during 2022-23. Also, the Institute exhibited impeccable alacrity in responding to the sudden threat of emergence of stunting disease of basmati rice in the North-Western India. It was found that the disease was associated with Southern Rice Black-Streaked Dwarf Virus and appropriate remedies were suggested for the same to minimize the damage.

In wheat, leaf, stem and stripe rust resistant varieties, namely HD 3406 and HD 3407 were developed through MAS, and released. As a step towards achieving nutritional security, this year IARI released two double-biofortified maize hybrids namely, Pusa Biofortified Maize Hybrid-2 and Pusa Biofortified Maize Hybrid-3 which are rich in lysine, tryptophan and provitamin-A. A MAS-derived drought-tolerant variety of chickpea, Pusa JG-16, was also released during this year. A high yielding and low erucic acid (0.79%) variety, Pusa Mustard-34, was also released. While celebrating the 'International Year of Millets', our humble contribution to the nation in 2023 would be the development of biofortified pearl millet varieties by employing the recently identified high iron and zinc genotypes, PPMI 1280, PPMI 1281, PPMI 1283 and PPMI 1284.

The Jalopchar- an eco-friendly waste water treatment technology of the institute was further extended to different parts of the country for safe reuse of waste water in agriculture. The institute is operationally monitoring real-time paddy residue burning across six states of India using satellite images; the data showed that residue burning events were reduced by 31% in 2022 as compared to 2021.

The Post Graduate School of IARI continued to provide national and international leadership in human resource development. The 60^{th} Convocation of the Post Graduate School of IARI was held on February 11, 2022 in hybrid mode, wherein 285 candidates (173 M.Sc., 12 M.Tech. and 100 Ph.D.) including 8 international students (4 M.Sc. and 4 Ph.D.) were awarded degrees. In addition, the degree of Doctorate of Science (*Honoris causa*) was conferred upon Prof. R.B. Singh, Former Director, ICAR-IARI, New Delhi. I am happy to mention that from this year onwards, IARI has added a new chapter to its glorious past by introducing undergraduate program. During academic session 2022-23, the first batch of 330 undergraduate students was admitted at IARI, New Delhi and its outreach centres in four different programs.

Pusa Krishi Vigyan *Mela* 2022, themed "*Takniki Gyan Se Aatmnirbhar Kisan*" was organized from March 9-11, 2022. On this occasion, IARI Fellow Awards were bestowed upon five farmers, while IARI Innovative Farmers' Awards were presented to 36 farmers, including five women farmers, belonging to 22 States/UTs of the country. For the first time, many stakeholders could benefit from the live webcasting of the *mela* in different parts of the country.

The institute worked extensively for the transfer of technologies to various stakeholders including farmers through its vibrant extension and outreach programmes including *Mera Gaon Mera Gaurav* (MGMG), NEH Scheduled Caste Sub Plan (SC-SP), and Tribal Sub Plan (TSP). Under *Mera Gaon Mera Gaurav* (MGMG) Programme, 1922 field interventions were made benefitting 13,668 farmers. The viewership of our channel 'Pusa Samachar' increased to more than 9 lakhs with 29,300 subscribers which has helped to educate the farmers and other stakeholders about the latest technologies and seasonal cultural practices.

During the year 2022, under Lab to Land Initiative, 77 innovative technologies of ICAR-IARI were transferred to 120 industry partners resulting in revenue generation of ₹ 1,70,12,054. Thirty-six agreements were signed with startups for Business, Technical, IP, Physical Space and funding support from IARI. Seventy-six IARI startups showcased their technologies at *PM Kisan Sammelan & Agri- startups Conclave* held at New Delhi.

The scientists of the Institute published 668 research papers in scientific peer-reviewed journals with high international impact factor. I warmly acknowledge and thank the staff of ICAR-IARI for their unswerving commitment and relentless efforts. My thanks are also due to the guidance provided by the members of various expert committees including Research Advisory Committee, Institute Management Committee, Academic Council, etc.

I would like to thank Dr. T.R. Sharma, DDG (Crop Science) and Dr. D.K. Yadava, ADG (Seed), ICAR, for their constant support and guidance. I also thank Dr. Trilochan Mohapatra, Former Secretary, DARE and Ex-Director General, ICAR, and Dr. Himanshu Pathak, Secretary, DARE & Director General, ICAR for being the guiding light for the institute and for providing generous financial support to the institute that enabled us to achieve our objectives.

I acknowledge the funding agencies such as NASF (ICAR), NAHEP (ICAR), DBT, DST and other national & international agencies, who supported 236 externally funded projects for the financial year 2022 that immensely helped in meeting our research, teaching, and service goals.

I express my sincere admiration to the annual report editorial team for bringing out the annual report on time.

I look forward to more productive years ahead.

(Ashok K. Singh)
Director, ICAR-IARI

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.

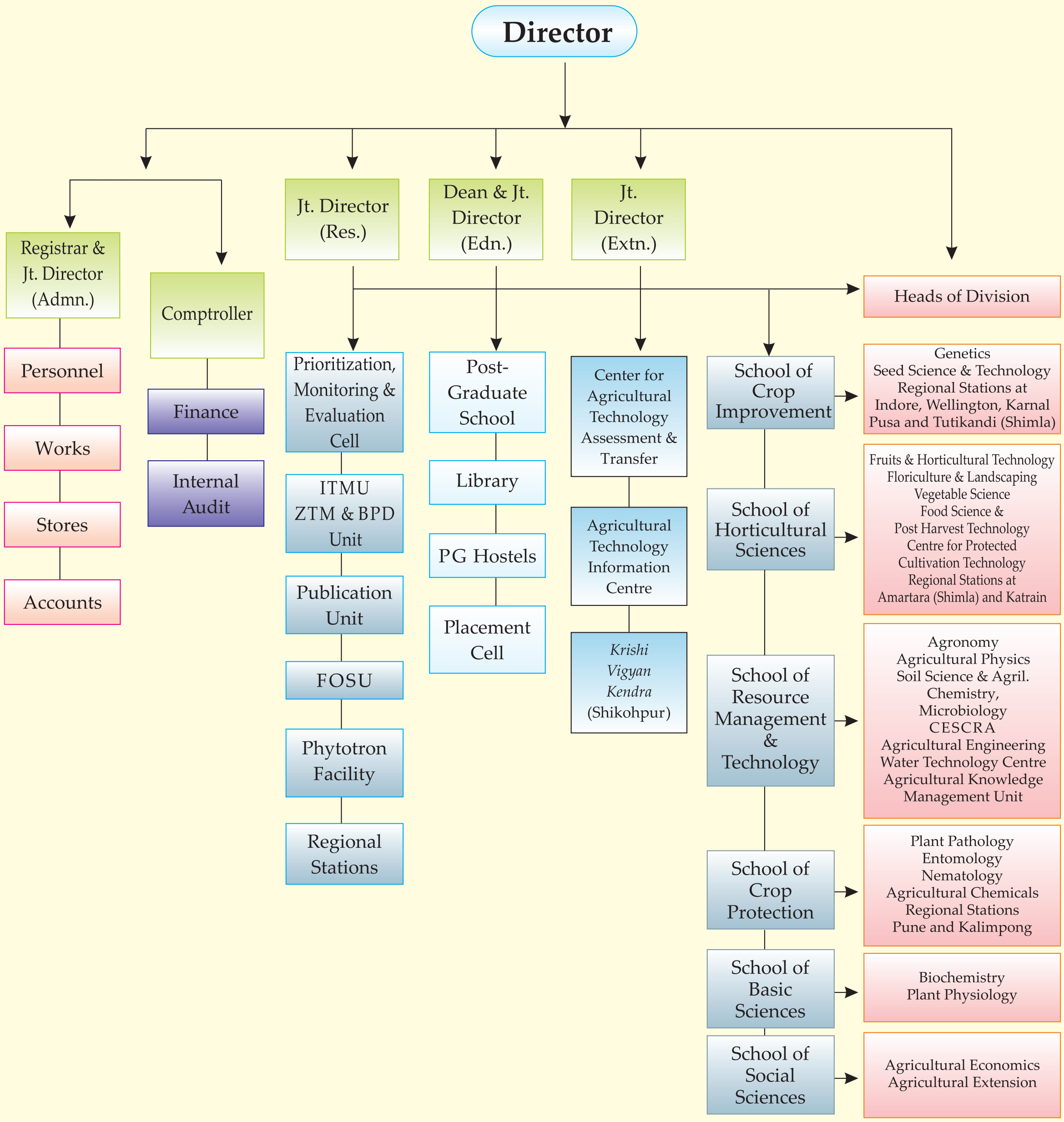
The mandates of the Institute are as follows:

- 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 28.38′23′′ N and 77.09′27′′ E with altitude of 228.6 meter above mean sea level. The climate is sub-tropical and semi-arid with warm and dry summer and cold winters. The daily maximum temperature during the hot period (April 2022-Sepember 2022) ranged from 31.6°C to 42.5°C and the daily minimum temperature ranged from 10.2 °C to 32.5°C. June to September are rainy months during which 1407.2 mm of rainfall was received. Winter sets in from mid-November and is delightful. The daily maximum temperature during winter (November 2021-March 2022) ranged from 11.6°C to 39.0°C and the minimum temperature ranges from 1.5 °C to 20.2°C. During winter 177.9 mm rainfall was received.

The Institute has 20 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 24 national centres functioning under the All India Coordinated Research Projects. It has sanctioned staff strength of 2293 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹66866.00 lakh (Unified Budget) for the year 2022-23.

Indian Agricultural Research Institute



Organizational Structure

EXECUTIVE SUMMARY

ICAR-IARI has played a pivotal role in the livelihood security of the farmers in the country since the green revolution. The institute has released new varieties/hybrids with improved yield, quality and climate resilience in food and horticultural crops, and developed feasible, farmer-friendly technologies for enhancing input use efficiency and profitability. The salient achievements of ICAR-IARI in research, education and extension during 2022 are summarized here.

The School of Crop Improvement has developed several improved crop varieties and hybrids through an integrated approach of conventional and genomics-assisted breeding. During 2022, 16 varieties/hybrids in field crops were developed for the benefit of the farmers. IARI Basmati rice varieties *viz*., Pusa Basmati 1121, Pusa Basmati 1718, Pusa Basmati 1509 and Pusa Basmati 6 which occupy >95% of the Basmati rice area in the country, and have earned INR 34,000 crores foreign exchange during 2022. Direct-seeded rice (DSR) is gradually emerging as a preferred technology to save water. The herbicide-tolerant Basmati rice varieties *viz*., Pusa Basmati 1979 and Pusa Basmati 1985 developed by the Institute, would facilitate DSR through effective weed control in rice fields. In addition, the first drought tolerant basmati rice variety of India, Pusa Basmati 1882 was released this year. It is MAS derived near isogenic line of Pusa Basmati 1 possessing a major QTL, qDTY1.1, governing tolerance to reproductive stage drought stress, with an average yield of 4.69 t/ha under irrigated transplanted condition. A fine grain non-basmati elite rice variety Pusa 1853 - a MAS-derived version of a popular rice variety BPT 5204 (Samba Mahsuri) was notified for release. It possesses *Xa13* and *Xa21* genes governing resistance to bacterial blight, and *Pi54*, *Pi1* and *Pita* genes governing resistance to blast disease.

The IARI-bred wheat varieties *viz*., HD 2967, HD 3086 and HD 3226 etc. are cultivated in >12 m ha, thereby contributing 50 mt of grains of wheat to the nation's granary. In wheat, 10 MAS-derived varieties were released which include HD 3406 and HD 3407, with inbuilt resistance to leaf, stem and stripe- rusts. Another variety, HD 3411, developed through MAS, is adaptable to restricted irrigated conditions. Further, HD 3369, HI 1650 (Pusa Ojaswi), HI 1653 (Pusa Jagrati), HI 1654 (Pusa Aditi), HI 1655 (Pusa Harsha), HI 8826 (Pusa Poshtik) and HI 8830 (Pusa Kirti) have been developed and released for various agro-ecological regions.

In maize, two double-biofortified maize hybrids namely, Pusa Biofortified Maize Hybrid-2 and Pusa Biofortified Maize Hybrid-3 developed through MAS were also notified for release. These nutritionally-rich maize hybrids possess *opaque 2* and *crtRB1* genes and are rich in lysine, tryptophan and provitamin-A. In the case of chickpea, Pusa JG-16 - a NIL of popular variety JG-16, developed through MAS for drought tolerance was released. In mustard, Pusa Mustard-34 - a single zero high yielding variety with low erucic acid (0.79%) has also been released. To promote the 'International Year of Millets', our major focus has been the development of biofortified pearl millet cultivars for providing nutritional security. Four biofortified pearl millet lines *viz*., PPMI 1280, PPMI 1281, PPMI 1283 and PPMI 1284 with iron >60 ppm and zinc >32 ppm were developed for use in the hybrid breeding programme. Besides, improved genotypes with higher productivity, climate resilience and nutritional quality have been developed across crops for their utilization in the breeding program. A total of 7000 q of different classes of seeds of various crops was produced and provided to farmers and different agencies generating revenue of ₹10 crores.

The School of Horticultural Sciences has developed and released vegetable crop varieties Brinjal Pusa Krishna, Pusa Safed Baingan-2, Pusa Hara Baingan-2, Pusa Golden Cherry Tomato-2, Pusa Tomato (Protected)-1, Pusa Cauliflower Hybrid 3, Pusa Cauliflower Hybrid 101, Pusa Snowball Hybrid-2, Pusa Red Cabbage Hybrid-1, Pusa Hybrid-82, Pusa Capsicum-1, Carrot Pusa Prateek, bitter gourd Pusa Hybrid-6, and Pusa Hybrid-5 which were notified by Central Sub Committee on Crop Standard, Notification and Release of Varieties for Horticultural Crops. Similarly, tomato variety Pusa ToLCV Hybrid 6 was identified for Zone-V by AICRP (VC) and eight vegetable varieties namely Pusa Prasanskrit tomato, Pusa Cocktail Tomato, Pusa Peet capsicum, Pusa Parthenocarpic Cucumber Hybrid-1, Pusa Sem-6, Pusa Cauliflower Hybrid 102, Pusa Purple Broccoli-1 and Pusa Lal Bhindi-1 were identified by the Institute Variety Identification Committee.

In Brinjal, DBR-160-2-3-1-3 was identified as highly resistant to *Fusarium* wilt. Brinjal hybrids, BR-40-7-3-2-1, DB-175 and DBR-112-14 were resistant to phomopsis blight, DB-65, DB-31, Swarna Mani showed resistance against virus complex and DBL-21, DBL-08 and DBL-175-5-1 were identified as heat tolerant.

At ICAR- IARI Regional Station, Katrain, low temperature tolerant lines of capsicum KTC- 152 and KTC 144 were identified. Similarly, colored capsicum KTRC-13 (Red), KTOC-4 (Orange), KTYC-5 (Yellow) and KTGC-10 (Green) were found suitable for protected cultivation, and capsicum hybrids KTRC-11 × KTYC-23, KTRC-11 × KTGC-24 and KTOC-2 × KTGC-25 were identified for improved yield contributing traits. A major QTL governing ToLCNDV resistance was mapped on chromosome 2 spanning from a region of 2.1 to 2.8 Mb with a length of 0.7 Mb in cucumber. New sources of resistance to ToLCNV were identified from wild relatives of melon DSM 132 (*C. melo* var. *callosus*) in musk melon. Pusa Okra Hybrid-1, DOH-6 (69 x 92) and DOH-7 (7 x 92) were found to be highly resistant to both YVMV and ELCV. Two elite lines of onion POS20K and POS24K were found to be suitable for *kharif* season.

Three new varieties in fruit crops, *i.e.*, guava hybrids, Pusa Pratiksha and Pusa Arushi and papaya hybrid, Pusa Peet, have been released by the Delhi State Seed Sub- Committee for NCR region. Among mango hybrids, H-1-5, H-1-11, NH-20-2 and NH-18-4 bore fruits weighing more than 250 g/fruit. Similarly, mango hybrids *viz*., NH-17-1, NH-18-4, NH 20-2, NH-3-2, NH-19-2, H-11-2, H-12-5 and H-3-2 had attractive red color on fruit shoulder. Citrus rootstocks SCSH 17-12 and SCSH 9-19 were found highly tolerant to NaCl stress. In papaya, P-9-5 was identified for low temperature tolerance. One unique cluster bearing walnut genotype was identified.

In rose, Pusa Lakshmi and Pusa Bhargava; marigold, Pusa Utsav and Pusa Parv; gladiolus, Pusa Rajat; chrysanthemum, Pusa Lohit and Bougainvillea, Pusa Akansha were released for Delhi-NCT by Delhi State Seed-Sub-committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi.

The plant genetic resources comprising wild relatives of crops, land races, indigenous and exotic collections and introgression lines serve as a rich reservoir of novel genes for higher productivity, biotic and abiotic stress tolerance and nutritional quality for all the crop improvement programs. During 2022, 15 germplasm lines across wheat (6), barley (3), maize (1), lentil (2) and chilli (2) were registered at NBPGR, New Delhi. Also, a large number of germplasm accessions of various crops, possessing unique trait(s), have been granted IC numbers after submission to the gene-bank of NBPGR. The institute has a vibrant program for biosystematics studies of insects, nematodes and other microbes to explore, conserve and enrich the collections. The institute has an active identification service for insects, nematodes and microbes.

The School of Natural Resource Management focuses on the use of non-invasive sensors, remote sensing, machine learning and artificial intelligence approaches to characterize soil and plant health for precision agriculture. Conservation agriculture (CA)-based rice-wheat system with mungbean intervention improved productivity and profitability. CA based maize-mustard cropping system resulted in a 20% increase in maize, 27% in mustard and 65% higher system yield in comparison to conventional till. Cowpea sown on ridge and furrow method with residue retention (3 t/ha) led to highest green pod yield (6.56 t/ha) followed by flat-bed with residue 3 t/ha (6.44 t/ha). Pearl millet-chickpea system gave the highest productivity, water and nutrient use efficiency, net returns, and economic efficiency under rainfed conditions. CA and ICM systems had 10 and 17% higher system productivity, respectively, over conventional system.

Soil and nutrient management research revealed that the C carrying capacity (Cm) of Inceptisol, Mollisol, Vertisol and Alfisol was 49.7, 66.6, 56.8 and 50.7 Mg ha^{-1} at 0–60 cm soil depth, respectively. Humic acid showed a higher stability constant under vertisol than Inceptisol, Alfisol and Entisol. For agri-residue management, Pusa decomposer application registered higher values of decay constants of carbon mineralization than burning and residue incorporation. Sludge application significantly improved the labile and non-labile pools of SOC. Sludge application decreased the moisture sensitivity of C mineralization by 19.1 and 16.9% as compared to control and 100% NPK, respectively. Sugarcane bagasse was most effective in arresting the transfer of arsenic from soil to rice grain. The PSB (*Lactococcus lactis*) was efficient in solubilizing Si and P.

Water management research has led to significant improvement in crop water productivity and profitability. Automatic irrigation system achieved irrigation application efficiency of >85%, distribution uniformity of >0.85 and water requirement efficiency of >95% in wheat crop. Drip fertigation in maize-wheat system improved yield. Jalopchar technology-based waste water treatment reduced heavy metal contents by 83-100% compared to that of untreated waste water.

Research on protected cultivation has come out with promising agro-techniques for highly profitable crop cultivation. IoT and sensor operated Greenhouse Vertical Farming system was developed for lettuce and Pak-Choi. Water saving Tabletop vertical hydroponic systems saved 18% of water. Integrated nematode management techniques were developed for the greenhouse tomato variety.

Agricultural engineering has upscaled many technologies and machinery. A small electric agri-prime mover with an overload protection alarm has been developed to enhance the efficiency of human beings in farm operations. An eco-friendly and cost-effective ohmic-assisted extraction technology was developed for enzymatically hydrolyzed black cumin seed. Solar-powered/battery-operated harvester was developed for leafy vegetables. Battery-assisted weeder with a U-type handle and telescopic arrangement was developed for better efficiency. A potato planter was developed for the disabled farm worker. Sensor-based spraying system was developed and validated for Pusa Decomposer application. A reliable and affordable handheld sensor-based device that can provide quantified information on viral disease severity of tomato and cowpea crops was developed. A sensor-based site-specific sprayer was developed for spraying in cauliflower and brinjal.

Research on food science and post-harvest technology highlighted the anti-diabetic potential of pectin extracted from jack fruit peel. Biocolorants from food waste were developed. The vacuum infusion process was able to increase the iron content of the bean by 38.4% as compared to control. Pasta was made from Kodo, Little and Brown top Millets; crisps were developed from biofortified lentil varieties and high protein breakfast cereal with chickpea was developed.

Research on microbes revealed that rhizobacteria MRD 17 and NSRSSS-1 had beneficial effects on soil biological activities. Five wettable powder formulations were prepared for ready-to-use Pusa Decomposer. *Azospirillum formosense* strains AIM57 and *Bacillus* spp. in co-culture system significantly increased PGP traits (nitrogenase, P-solubilization, siderophore). Co-inoculation (75% FC+75% RDN + *Azospirillum*+ *Bacillus*) showed improved growth of pearl millet over single inoculations. *Mesorhizobium* sp. improved chickpea root nodule morphology and function. Alpha-amylase was produced from apple peel using *Bacillus subtilis*.

Research on environment and climate resilience reported that flatbed system produced more greenhouse gas intensity than ridge and furrow system. Elevated carbon dioxide and ozone was found to affect the microbial communities. Doping with Zn and Mg nano-particles enhanced the soil dehydrogenase and urease enzyme levels. Bioslurry and urea application improved microbial activity. Microplastics in the farm inputs was found to alter the nutrient availability and uptake of nutrients by plants.

The School of Crop Protection focused its research on diagnostics, identification of resistant sources and integrated management of important pests and pathogens of national importance. Report on the emergence of stunting disease of rice across the North-Western Indian rice growing areas was systematically investigated for elucidating its etiology. The disease was found to be associated with Southern Rice Black-Streaked Dwarf Virus (SRBSDV), a double-stranded RNA virus of genus *Fiji* virus. This is the first conclusive evidence of the association of SRBSDV with the stunting disease of rice from India. A full genome of chilli leaf curl virus infecting the bell pepper variety "California Wonder" was characterized. Natural infection of a begomovirus (ChiLCINV) was reported in *S. jamaicensis* from India. Papaya samples collected from Pune, with mild mosaic and mottling symptoms, were first time confirmed for cucumber mosaic virus (CMV) infection. Infection of cucurbit aphid-borne yellow virus in muskmelon was confirmed by sequence comparison and phylogenetic analysis. A reverse transcription-recombinase polymerase amplification (RT-RPA) assay was developed for the diagnosis of citrus yellow vein clearing virus in citrus plants. Different isolates of *Ustilaginoidea virens* collected from eight different states were morphologically characterized and validated at the molecular level. The pathotypes of the causal agent of bakanae disease in rice, *Fusarium fujikuroi*, were characterized. Pathogenic and genetic diversity analysis of 40 isolates of *Bipolaris sorokiniana* was accomplished. Eleven cryptic species of *Fusarium* were identified first time from India under *Fusarium solani* species complex through multi locus sequence analysis. A virulent strain of *Xanthomonas campestris* pv. *Campestris* causing black rot in mustard was characterized.

Genome-edited rice plants (*OsPLD*β*1* gene) in BPT 5204 (Samba Mahsuri) background were developed. *OsPLD*β*1-KO1, OsPLD*β*1-KO2* knock out rice lines showed high level susceptibility to blast disease and bacterial blight disease. Genome-wide association mapping of virulence genes in *Tilletia indica* was accomplished. Small RNA sequenced reads were mapped against *Tilletia indica* and wheat genome. *Tilletia caries*, *Bipolaris maydis*, *Ralstonias olanacearum, Pantoea agglomerans* and *Pantoea deleyi* genomes were sequenced/ re-assembled.

Resistant sources of different insect pests were identified in various crops and the efficacy of different chemicals/biopesticides was tested against various pests in different crops. For bio-intensive management of invasive fall armyworm, *Spodoptera frugiperda* in maize, the egg-larval parasitoid, *Chelonus formosanus sonan* was found to be the most dominant parasitoid (12.55%). The feeding potential and foraging behaviour of *Cheilo menes sexmaculata* (F.) was studied against *Bemesia tabaci*. The foraging behaviour of *C. sexmaculata* at different densities indicated that all the grub and adult stages showed a type-II functional response. The *Allotropaphena cocca* was reported on cotton mealybug (*P. solenopsis*) for the first time in India. Different populations for putative functional genes in *Chilo partellus* were characterized at the molecular level. These studies resulted in the identification of 64 Cytochrome P450 genes, and 36 glutathione S-transferases genes encoding metabolic detoxification which will further help in designing target-specific insecticides to develop appropriate management strategies against *C. partellus.* Studies on a single hot event in the expression of heat-responsive and reproductive genes in *Spodoptera frugiperda* revealed that the up-regulation of heat responsive genes (*Sf-hsp70* and *Sf-SOD*) have a role in heat tolerance, while the down-regulation of *Sf-Vg* and *Sf-USP* has major impact on oocyte development.

The nematicidal potential of plant growth-promoting rhizobacteria against *Meloidogyne incognita* infesting tomato under protected cultivation was studied. PGPR isolates applied as soil drenching significantly reduced nematode incidence in the consortium. Microbial taxa in nematode infected and healthy plants in protected cultivation were compared. The draft genome of the *H. indica* Hms1-i20 was sequenced using three genomic libraries of 300 bp, 600 bp and 5 kb sizes by Illumina HiSeq platform. The size of the draft genome assembly was 91.26 Mb. Comparative analysis of *H. indica* genome in comparison to four other nematode genomes revealed that *H. indica* shared 6,574 orthologous groups with *H. bacteriophora*, 6,635 with *C. elegans*, 6,228 with *S. carpocapsae* and 6,669 with *O. tipulae*. The role of insect gut receptors in TcaB intoxication process was established. Transcription of candidate gut receptors in TcaB-infected larvae was analyzed, and a cadherin-like gene *GmCAD* was cloned from *Galleria mellonella*.

A series of title compounds (40 in number) were synthesized by a reaction of benzaldehydes with 4'-(imidazol-1-yl) acetophenone and chalcones with phenyl hydrazine, respectively. *In vitro* fungicidal bioassay of synthesized compounds against *Rhizoctonia solani* and *Fusarium oxysporum* under laboratory conditions at various concentrations was conducted. Bioactive compounds from *Nigella sativa* seeds for antifungal activity were characterized. Synthesis of amphiphilic polymers using polyethylene glycols of various molecular weights and dimethyl 5-hydroxyisophthalate in the presence of concentrated H_2SO_4 followed by O-alkylation with bromo-hexane and bromo-octadecane was undertaken. A gel formulation of methyl eugenol was prepared to achieve slow release of methyl eugenol. These results revealed that prepared gel formulation was equally effective as 'Pusa trap' till three weeks but showed more whitefly attraction potential in the fourth week.

The method for trace level detection and quantification of 100 pesticides was developed and validated in representative crop matrices (cumin seed and cardamom) under crop group 28 (Spices) and their performance was evaluated on member crops (fenugreek seed and tamarind) with special emphasis on sensitivity, recovery and matrix interferences. An ultrasonic-assisted extraction (UAE) protocol of xanthophylls from African marigold hybrid DAMH-39 was optimized. The effect of pesticide's co-presence on their adsorption in soils was also studied. The presence of imidacloprid decreased fipronil adsorption while imidacloprid adsorption increased in presence of fipronil. Hybrid GO-ZnO nanoparticles were synthesized and characterized using various techniques. For effective weed management in maize, wheat, mustard and vegetables under different tillage systems, efficient control strategies were developed.

The School of Basic Sciences used CRISPR-Cas9 system to create gene-edited mutants of mega rice variety MTU1010 for improving yield and abiotic stress tolerance. Exogenous introduced DNA free SDN1 mutants of *DROUGHT AND SALT TOLERANCE* (*DST*) gene were evaluated in transgenic net house during kharif 2022, and found that genome edited lines produced >20% higher grain yield as compared with MTU1010. For improving drought tolerance of rice by modulating the plant stress hormone Abscisic Acid signalling pathway, genome editing of Clade A Protein Phosphatase 2C family was undertaken. Homozygous mutants of three *OsPP2C* genes in rice cv. MTU1010 was developed. A polycistronic tRNA-gRNA (PTG) mediated sgRNA multiplexing (3X-PTG) approach was also used to construct an expression cassette for multiplex editing of matrix metalloproteinase genes in rice.

Transcriptome analysis of contrasting genotypes of wheat subjected to heat stress led to the identification of 28 full length putative calcium-dependent protein kinases (CDPKs). Phosphoproteome analysis of wheat in response to elevated CO_2 and heat stress under differential nitrogen treatment exhibited significant phosphorylation of various proteins, especially nitrate reductase, that was phosphorylated at two sites. The epigenetic regulation of P-responsive genes by Pup1QTL harboured in near–isogenic line-23 (NIL-23) of Pusa 44 was deciphered under P-starvation stress.

The low inherent glycemic potential of pearl millet was found to be due to the superior crystalline compactness of starch. Besides reducing rancidity, hydrothermal treatment increased the fractions of slowly digestible starch and resistant starch. Rice grains with distinct levels of resistant starch showed a strong correlation between resistant starch, amylose content and granule bound starch synthase (GBSS).

Nutrient retention in processed food is essential for framing the processing methods and customer acceptability. Differentially processed carrot products showed the highest β-carotene levels in citrate buffer-probiotic fermented samples. Development of soymilk syn-biotics indicated that soymilk fermented with 2% raffinose family oligosaccharides (RFOs) + 2% fructo-oligosaccharides (FOS) + 2% sucrose + 1% vanillin had maximum consumer preference. Amongst the different microgreens, maximum nutrient density was provided by pulses (mungbean and lentil) at 7 days after planting.

Phenotyping of recombinant inbred lines (RILs) of wheat for combined heat and drought stress tolerance led to the identification of high stay green RILs (GCP 6 and GCP 33) for improved yield under combined stress. Biochemical endurance of wheat pistil under high night temperature suggested the role of homeostasis of reactive oxygen species and decreased gibberellic acid levels towards stress management. Phenotyping for nutrient use efficiency was done for rice germplasm from North-East India which led to characterization of germplasm to combined nutrient stress (high Fe and low P). The role of miRNA in nitrogen use efficiency in rice elucidated significant upregulation of miR5384, miR9776 and miR159 by N deficiency in panicle and leaf. For upgrading the physiological studies on gas exchange in wheat ear, a prototype of a chamber for measuring wheat ear photosynthesis was developed.

In vegetables, QTL sequence analysis was conducted to study the resistance to diseases like Alternaria leaf spot (ALS), black rot and downy mildew in cauliflower and cucumber. SSR markers were developed for assessing the diversity in okra, onion, garlic and introgression of traits like parthenocarpy in cucumber.

In wheat, GWAS was performed on 400 diverse genotypes to identify QTLs for seedling-stage leaf rust resistance. Pyramiding and marker-assisted transfer of genes for seedling and adult plant rust resistance (APR) was also performed. Three APR genes (*Lr34/Yr18+Lr46/Yr29+ Lr67/Yr46* and *Lr34/Yr18+Lr46/Yr29+Lr68*) showed near immunity to both leaf and stripe rusts at adult plant stages.

The loci and candidate genes for micronutrients (Zn and Fe) and quality (grain protein content and thousand grain weight) traits were identified through GWAS of bread wheat genotypes. Rice grain quality, in terms of γ-oryzanol, revealed a maximum accumulation of cycloartenyl caffeate in the non-seed tissues, which was significantly reduced after milling.

In maize, *C1-I* gene-specific markers, MGU-CI-InDel8 and MGU-C1-SNP1, were developed for anthocyanin-based identification of haploid seeds. The drought stress-regulatory network in maize revealed that *LEAFY*, ZmMADS1, Silky1/ZmMADS11, *Ids1* and *Sid1* played a major role in the transition from the vegetative to the reproductive stage.

Transcriptomic analysis of contrasting genotypes of chickpea and lentil led to the identification of metabolic pathways and genes differentially regulated under salinity and alkalinity stress, respectively. GWAS for root nodulation traits in chickpea led to the identification of 7 SNPs associated with nodulation. Transcriptomic analysis for seed size in lentil revealed the involvement of cell division and growth-related microRNAs, miR3457 and miR1440. A unique lentil genotype, L4717-NM, was identified as a natural mutant of variety L4717, which had high antioxidant capacity, total phenolic and ascorbic acid content. RNA-seq analysis in lentils following inoculation with *R. bataticola* revealed the differential expression of disease-responsive proteins *viz*., LRR family proteins, LRR-RLKs, protein kinases, etc., in the host-pathogen interaction. Mapping for inheritance of seed size led to the identification of five major QTLs in soybean.

The machine learning approach for the prediction of soil mean weight diameter (MWD) showed SVM model had higher flexibility for satisfactory prediction of MWD compared to other models which could be improvised by inclusion of bulk density. The surface soil moisture (SSM) maps for the IARI farm were successfully validated with the field irrigation zone map. Non-invasive nano-sensors were developed for on-site detection of soil nitrate content. Studies on the efficacy of nanoparticles showed that a combination of nanoparticles of zinc and iron (ZnO-NPs, Fe_2O_3–NPs) resulted in significant improvement in grain yield plant^{-1} in soybean.

Crop residue burning has become a serious environmental pollution issue that threatens human health. Thermal satellite remote sensing was used to monitor the burning of crop residue in North-West India on a daily basis. Also, Sentinel-2 satellite data was used to develop a robust methodology for distinguishing Happy seeder and Super seeder (HS-SS) sown wheat from the conventional tillage (CT).

Machine learning was employed to develop image-based software named "PusaInfo Seed" for assessing seed morphometry and phenotyping. Spectro-radiometric and UAV acquired hyperspectral data was evaluated using machine learning models to predict leaf nitrogen content to manage nitrogen application in wheat. Remote sensing through the surface energy balance approach was employed for spatial estimation of evapotranspiration in wheat.

The School of Social Sciences undertook studies on the assessment of government schemes and technologies, climate change adaptation, agri-preneurship and nutritional security. A study on e-NAM, an innovative approach to agricultural marketing, showed that only 15% of the APMC markets were linked with this platform and farmers' participation rate was around 13%. A detailed analysis of the market choice of paddy farmers showed that 46% of farmers preferred selling to local traders. Contrastingly, the price realized in the local market was less than the MSP. The small and marginal farmers and farmers belonging to the disadvantaged section of the society like SC/ST farmers preferred local traders over APMCs.

Export of fresh and processed food has registered a growth rate of 9 and 5%, respectively, for the period 2009-10 to 2020-21. India has higher relative rejection rate (RRR) of fruits in Australia compared to China, while China has a higher RRR of fruits in EU and USA as compared to India. A partial budgeting analysis showed that the adopters of happy seeder gained additional average net revenues amounting to ₹ 12,210/- which could be attributed to yield gains and expenditure reduction. The average technical efficiency score of adopters (0.987) was higher than that of non-adopters. A structural break analysis study on the 'Kerala Conservation of Paddy Land and Wetland Act' revealed that the Act could significantly arrest reduction in paddy land area in Kerala to an extent of 11, 253 ha annually.

An analysis of the determinants of malnutrition revealed that improved food grains productivity along with diversity in food consumption basket as measured by increased pulses in the diet showed a reduction in the incidence of malnutrition (stunting and wasting) in the children. Linkages between Dietary Diversity and Nutritional Outcomes were empirically studied by employing a panel regression analysis random effect model. A negative relationship between the degree of variety in food consumption and undernutrition was observed. A negative and significant relationship was observed between under-nutrition incidence, women's literacy and health insurance. Four training programmes for skill building in Nutrition Sensitive Agriculture (NSA) for the empowerment of rural women were organized through Nutrition Sensitive Agriculture Centres (NSACs) established in Harsanakala and Jagdishpur villages of Sonipat district of Haryana and Sunehra and Bassi villages of Baghpat District of U.P.

A video based extension initiative, 'Pusa Samachar', launched on August 15, 2020 to disseminate and educate the farmers and other stakeholders about the latest technologies and seasonal cultural practices secured a subscription of 29,300 for the IARI YouTube Channel. The total viewership is more than 9 lakhs. A total of 274 topics were covered in 17 different disciplines/areas including farmer's success stories.

Convergence based extension approach helped to construct one additional check bund in the adopted village-Dohari in Gaya (Bihar) with people's collective contribution of 10% cost of the bund in terms of labour. It led to the availability of one irrigation in 15 acres of additional land. Pusa Kisan Vikas Samiti has been formed with 35 farmers to manage the interventions. The social learning approach helped the farmers adopt climate-resilient technologies like direct seeded rice, zero-till wheat, summer moong, and IPM in cotton. Twenty seven demonstrations of climate resilient technologies (direct seeded rice, zero-till wheat, summer moong) were laid out at village Sangel in Mewat, Haryana.

Socio-economic assessment of 'Farm Pond on Demand" scheme, launched in February 2016 by the State Agriculture Department in Maharashtra, was carried out in Vidharbha and Marathawada regions of Maharashtra. It revealed the cultivated land utilization index of major crops increased after the adoption of farm ponds from 0.22 to 0.67.

Personal entrepreneurial competencies (PECs) of individuals and entrepreneurial climate to establish and attain the entrepreneurial success were analyzed. Two Farmer Producer Companies (FPCs) were established with 100 members each and four women SHGs were formed in project villages in collaboration with NABARD.

Pusa Krishi Vigyan *Mela*-2022 was organized at the IARI *mela* ground from March 9-11, 2022 with the theme on "*Takniki Gyan Se Aatmnirbhar Kisan*". IARI Fellow and IARI Innovative Farmers' Awards were bestowed upon 05 and 36 farmers, respectively. Farm technologies developed by the Institute for sustainable agricultural development were displayed in the thematic pandal. More than 70,000 visitors from different parts of the country, including farmers, farm women, extension workers, entrepreneurs, students and others visited the *mela*. Also, for the first time, many stakeholders could benefit from the live webcasting of the *mela* in different parts of the country.

ATIC provided products, technologies and information services to the different stakeholders through a 'Single Window Delivery System'. Farm advisory services were provided to 14,665 farmers and other stakeholders during the year. Pusa seeds of worth ₹ 26,84,388/- and farm publications worth ₹ 24,030/- were sold to the farmers.

IARI's KVK situated at Gurugram, Haryana organized events to commemorate various days *viz*., World Soil Day, National Girl Child Day, World Pulse Day, International Women's Day, World Environment Day, National Kisan Diwas, etc. National campaign on "Poshan Abhiyan and Tree Plantation" were organized at KVK campus on September 17, 2022, in which 152 beneficiaries participated.

Under SC-SP, 5724 SC farmers benefitted and 10412 demonstrations of improved varieties of field and horticultural crops were organized. A total of 31 demonstrations of nine new wheat varieties were organized in the district Dhar, M.P. under the Tribal Sub-Plan. *Mera Gaon Mera Gaurav* programme is being implemented by IARI in 121 clusters comprising 621 villages by 503 scientists of the Institute along with IASRI and NBPGR.

The Post Graduate School of IARI continued to provide national and international leadership in human resource development. So far, 4617 M.Sc., 84 M. Tech. and 5179 Ph. D. students have been awarded degrees including 495 international students. The institute also received accreditation from the National Agricultural Education Accreditation Board of ICAR (2020-2025 with an 'A' Grade). The 60th Convocation of the Post Graduate School of the IARI was held on February 11, 2022, in hybrid mode. Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt. of India, Shri Narendra Singh Tomar was the Chief Guest and Shri Kailash Choudhary, Hon'ble Union Minister of State for Agriculture and Farmers Welfare, Govt.

of India, was the Guest of Honour on the occasion. During this Convocation, 285 candidates (173 M.Sc., 12 M. Tech. and 100 Ph.D.) including 8 international students (4 M.Sc. and 4 Ph.D.) were awarded degrees. In addition, the degree of Doctorate of Science (*Honoris causa*) was conferred upon Prof. R.B. Singh, Former Director, IARI, New Delhi.

IARI is playing a key role in establishing the Afghan National University of Agricultural Sciences and Technology (ANASTU), Kandhar, Afghanistan, and Advanced Centre for Agricultural Research and Education (ACARE) at Yezin Agricultural University (YAU), Myanmar in collaboration with the Ministry of External Affairs (MEA), GoI. Under ANASTU programme, the teaching and research guidance of 4th batch has been completed in online mode. To facilitate online teaching, a tele-education facility has been established at the ICAR-IARI, New Delhi. Under the ACARE programme, short term (2 weeks) training programmes for the benefit of stakeholders of Myanmar Agriculture were conducted by IARI in collaboration with YAU, Myanmar.

The scientists of the institute published 668 research papers in scientific peer-reviewed journals with international impact factor. In addition, several other publications in the form of symposia papers, books/book chapters, popular articles, technical bulletins, regular and *ad-hoc* publications, both in English and Hindi, were brought out for the timely dissemination of the technical know-how and other important information to the respective stakeholders. Several national and international training courses and other capacity building programmes were conducted for the benefit of farmers, academicians, researchers, extension workers and other professionals. New linkages and collaborations with several national and international institutions/organizations were fostered. Many scientists, students and faculty of the institute received several prestigious awards and recognitions and brought laurels to the institute.

1. CROP IMPROVEMENT

The crop improvement programme of the institute is primarily aimed at enhancement of the productivity and nutritional quality of various field crops. Marker-assisted selection (MAS) is increasingly used to complement the conventional methods of crop improvement. Improved varieties with higher productivity, enhanced nutritional quality and tolerance to biotic and abiotic stresses suited to different agro-ecological conditions have been developed and released during the reporting period. Besides, a large number of promising genotypes in several crops are under various stages of evaluation in ICAR-All India Coordinated trials. The crop improvement programme was complemented by quality seed production and progress in other relevant areas of seed science.

1.1 CEREALS

1.1.1 Wheat:

1.1.1.1 Varieties released

HD 3406 (Unnat HD 2967) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: HD 3406 is a near isogenic line (NIL) of popular wheat variety, HD 2967. It is released under timely sown irrigated conditions of the North Western Plain Zone (NWPZ). It possesses an average yield of 54.7 q/ha and a potential yield of 70.4 q/ha. HD 3406 has *LrTrk/Yr* gene which provides resistance to both leaf and stripe rust.

Field view of HD 3406

HD 3407 (Unnat HD 2932) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a NIL of popular wheat variety, HD 2932. It is released under the late-sown irrigated conditions of the Central Zone (CZ). It has an average yield of 46.8 q/ha and a potential yield of 69.6 q/ha. HD 3407 possesses *Lr19/Sr25* and *Lr24/Sr24* genes for both leaf and stem rust resistance, and *Yr10* gene for stripe rust resistance.

Field view of HD 3407

HD 3411 [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released under timely sown irrigated conditions of the North Eastern Plain Zone (NEPZ). It's average yield is 46.8 q/ha with a potential yield of 65.8 q/ha. It has resistance to yellow and brown rusts, and moderate resistance against leaf

Field view of HD 3411

blight, powdery mildew, Karnal bunt and flag smut. It has a *Glu-1* score of 10/10.

HD 3369 [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released under restricted irrigation conditions of NWPZ. It's average yield is 50.6 q/ha with a potential yield of 71.4 q/ha. It is resistant to yellow and brown rust and moderately resistant to leaf blight, powdery mildew, Karnal bunt and flag smut. It has a *Glu-1* score of 8/10.

Field view of HD 3369

HI 1650 (Pusa Ojaswi) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released for timely sown irrigated conditions of the CZ. It's average yield is 57.2 q/ha with a potential yield of 73.8 q/ha. It is highly resistant to stem and leaf rust. It has high zinc (42.7 ppm) and iron (39.5 ppm).

Field view of HI 1650

HI 1653 (Pusa Jagrati) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released for timely sown restricted irrigated conditions of NWPZ. It's average yield is 51.1 q/ha with a potential yield of 69.3 q/ha. It is immuned to blast disease and show high levels of resistance to stripe and leaf rust.

Field view of HI 1653

HI 1654 (Pusa Aditi) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released for timely sown, restricted irrigated conditions of NWPZ. It's average yield is 51.8 q/ha with a potential yield of 78.2 q/ha. It has high levels of resistance to blast, stripe, and leaf rust. It has an excellent chapatti quality (7.5) with a Glu score of 10/10.

Field view of HI 1654

HI 1655 (Pusa Harsha) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a bread wheat variety released for timely sown restricted irrigated conditions

Field view of HI 1655

of CZ. It's average yield is 38.8 q/ha with a potential yield of 59.8 q/ha. It showed high levels of field resistance to leaf and stem rust.

HI 8826 (Pusa Poshtik) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a durum wheat variety released for timely sown irrigated conditions of the Peninsular Zone (PZ). It's average yield is 48.8 q/ha with a potential yield of 73.7 q/ha. It has high levels of field resistance to stem and leaf rust. It has good levels of yellow pigment content (7.0 ppm).

Field view of HI 8826

HI 8830 (Pusa Kirti) [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a durum wheat variety released for timely sown restricted irrigated conditions of CZ. It's average yield is 40.4 q/ha with a potential yield of 65.3 q/ha. It has high levels of field resistance to stem and leaf rust. It has higher yellow pigment (7.4 ppm).

Field view of HI 8830

1.1.1.2 Genotypes contributed to AICRP trials

Sixty six genotypes were contributed to AICRP trials as per details given below:

AVT	HS 691, HS 692, HD 3386*,HD 3470^{M}, HD 3471^{M}, HI 1668, HD 3428, HD 3388*, HI 1669, HI 1670, HI 1673, HI 1674, HI 1675, HD 3469, HI 8841(D), HI 1672, HI 1665*, HI 8840 (D)* *Final year entry, ^{M}: MABB entry
NIVT	**NIVT 1A:** HD 3472, HD 3444, HD 3445, HD 3446, HD 3447, **NIVT 1B:** HD 3448, HD 3449, HP 1979, HP 1978, HD 3467, **NIVT 2:**HD 3450, HD 3451, HI 1683, HI 1684, **NIVT 3A:** HD 3452, HD 3453, HD 3454, HD 3455, HP 1980, **NIVT 3B:** HD 3456, HI 1685, HI 1686, HI 1687, **NIVT 4:** HI 8848 (D), HI 8849 (D), HI 8850 (D), **NIVT 5A:** HD 3457, HD 3458, HD 3459, HD 3460, HD 3468, **NIVT 5B:** HI 1688, HI 1689, HI 1693, HI 8851 (D), HI 8852 (D), **IVT-NHZ:** HS695, HS 696, HS 697, HS 698, HS 699, HD 3466, **NIVT 6A:** HD 3461, HD 3462, HD 3463, HD 3464, **NIVT 6B:** HI 1690, HI 1691

1.1.1.3 Promising genotypes under IARI Common Varietal Trials

A total of 170 promising genotypes superior for grain yield and disease resistance across Delhi, Indore, Pusa, Shimla and Wellington were evaluated in different IARI common multi-location varietal trials.

1.1.1.4 Evaluation of advanced breeding lines and handling of segregating materials

Among 1242 segregating breeding lines evaluated at rust hot spot, Dhaulakuan, 601 were selected on the basis of rust resistance. Besides, 660 F_2 segregants derived from 24 diverse crosses of wheat were also selected and advanced to F_3.

1.1.2 Barley

1.1.2.1 Barley entries in coordinated trials

Among 34 barley entries, five genotypes *viz.*, BHS 493, BHS 494, BHS 495, BHS 496 and BHS 497 entered for testing in AVT-TS-RF-Dual/Grain purpose of NHZ.

1.1.2.2 Barley segregating materials generated

A set of 53 advanced F_{10} barley lines were evaluated, and based on eperformance, 34 entered the station trials. Besides, 667 segregating lines in different generations were evaluated and 620 were advanced to next generation. One hundred and eighty two F_2 plant progenies were advanced to F_3.

1.1.2.3 Development of non-lodging hulless barley

Lodging has become one of the main factors affecting the production and yield of hulless barley. Hulless barley is more promising as its grain contains chemical compounds of higher value than those in hulled barley. However, the major limiting factors of hulless barley cultivation are low yield and poor lodging resistance. In order to develop non lodging hulless barley, we have crossed elite hulled barley lines with hulless barley. In 2022, BC_2F_1s and F_2s were sown and raised. The plants that were hulless and non-lodging type were selected and further backcrossed.

1.1.3 Rice

1.1.3.1 Variety released

Pusa Basmati 1882 [Gazette notification No. S.O. 4065 (E), dated 31.08.2022]: Pusa Basmati 1882 is a MAS-derived NIL of Pusa Basmati 1 possessing a major QTL, *qDTY1.1* governing tolerance to reproductive stage drought stress, with seed-to-seed maturity of 134 days and an average yield of 4.69 t/ha under irrigated transplanted conditions. It has been released and notified for the Basmati growing regions of Western Uttar Pradesh, the National Capital Region of Delhi, Uttarakhand, Haryana, Punjab, and Jammu and Kashmir. This is the first drought-tolerant Basmati rice variety released in India.

Field view of Pusa Basmati 1882

Pusa Samba 1853 [Gazette notification No. S.O. 4065 (E), dated 31.08.2022]: Pusa Samba 1853 is a MAS-derived NIL of a popular rice variety, BPT 5204 (Samba Mahsuri), possessing two genes governing resistance to bacterial blight viz. *xa13* and *Xa21*, and three genes governing resistance to blast disease viz. *Pi54*, *Pi1* and *Pita*, with seed-to-seed maturity of 140-145 days and an average yield of 3.98 t/ ha. It has medium slender grains and acceptable quality parameters. It has been released and notified for commercial cultivation in the states of Andhra Pradesh and Telangana.

Field view of Pusa Samba 1853

1.1.3.2 Elite Lines in All India Coordinated Rice Improvement Programme

A total of 28 genotypes were nominated in different stages of testing in the AICRIP trials during *kharif* 2022. This includes seven entries promoted from respective trials conducted in *kharif* 2021 and 21 new entries. The details are as follows: AVT2-IME (1), AVT1-ETP (1), AVT1-IM (1), AVT1-LPT (2), AVT2-NILs (Drt) (2), AVT1-NILs (Basmati) (2), IVT-BT (3), IVT-ETP (1), IVT-IME (2), IVT-IM (3), IVT-L (2), IVT-MS (2), IHRT-MS (1), IVT-ASG (3) and AVT1-NILs (BB+Blast) (2).

1.1.4 Maize

1.1.4.1 Hybrids released

Pusa Biofortified Maize Hybrid-2 [Gazette notification No. S.O. 4065 (E), dated: 31-08-2022]: It is a provitamin-A rich QPM hybrid developed through

MAS for *crtRB1* gene. It is released for NWPZ, NEPZ and CWZ. It has 5.90 ppm of provitamin-A compared to 1-2 ppm in traditional hybrids. It also possesses high lysine (3.47%) and tryptophan (0.92%) in protein. It has an average grain yield of 75.4 q/ha (NWPZ), 53.7 q/ha (NEPZ) and 51.1 q/ha (CWZ). It matures in an average of 91.2 days (NWPZ), 87.7 days (NEPZ) and 89.3 days (CWZ).

Grain characteristics of Pusa Biofortified Maize Hybrid-2

Pusa Biofortified Maize Hybrid-3 [Gazette Notification S.O. 4065 (E), dated 31-08-2022]: It is a provitamin-A rich QPM hybrid developed through MAS for *crtRB1* gene. It has been released for NWPZ, PZ and CWZ. It has 5.70 ppm of provitamin-A compared to 1-2 ppm in traditional hybrids. It also possesses high lysine (3.52%) and tryptophan (0.87%) in protein. It has an average grain yield of 82.2 q/ha (NWPZ), 71.6 q/ha (PZ) and 58.5 q/ha (CWZ). It matures in an average of 92.0 days (NWPZ), 94.3 days (PZ) and 77.9 days (CWZ).

Cob characteristics of Pusa Biofortified Maize Hybrid-3

1.1.4.2 Commercialization of biofortified and specialty hybrids

Eleven MoUs have been signed with six companies *viz.*, (i) M/s Mansoon Seeds Private Limited (Maharashtra), (ii) M/s Subeejam Farmer Producer Company Ltd. (Madhya Pradesh), (iii) M/s Nilanchal Agriscience LLP (Assam), (iv) M/s Delta Agrigenetics Private Limited (Andhra Pradesh), (v) M/s Trimurti Plant Sciences Private Limited (Telangana) and (vi) M/s Indo-US Biotech Limited (Gujarat), thereby, generating INR 30.68 lakhs as revenue.

1.1.4.3 Entries in AICRP trials

Biofortified hybrids *viz.*, APTQH-5 (QPM+proA+vitE) and APH-4 (QPM+proA), baby corn hybrids (ABHS4-2 and AH7188), popcorn hybrids (APCH-2 and APCH-3) and forage hybrid (AFH7) were tested in AVT-II. Besides, APQH4 (QPM+proA), APTQH1 (QPM+proA+vitE), ALPQH1 (QPM+proA+low phytate), ALQH9 (QPM+low phytate), AQWH4 (QPM+waxy), APSKH1 (QPM+proA rich sweet corn) were tested in AVT-I. Two QPM+proA maize hybrids viz. APH5 and APH6; and one popcorn hybrid (APCH4) were tested under NIVT. In the case of field corn, AH8727 (early maturing) in AVT-II, and AH 8323 and AH 8178 (early maturing) were tested in AVT-I. Besides, two-grain maize composites (ADC 2 and ADC 3) and one maize composite (ADFM 2) were also tested in AVT-I. Further, five in early (AHD 2008, AHD 2053 AH-4670, AH-4679 and AH-4167), eight medium (AHD 2037, AHD 8452, AH-4669, AH-4671, AH-4683, AH-4668, AH-4158 and AH-4271) and four late maturity (AHD 2081, AHD 2108, AH4684 and AH-4685) field corn hybrids; four maize composites (ADC 4, ADC 5, AC-5 and AC-6), two fodder maize composite (ADFM 4 and ADFM 5) and one drought tolerant (AH3002) maize hybrid were tested in NIVT during *kharif* 2022. Besides, three hybrids (AHD 8452, AH 8089 and AH 2077) were sent to NDDB for silage trials.

1.1.4.4 Accelerating the breeding cycle

Improved haploid inducer (HI) lines: HI lines *mtl* and *dmp* genes and higher anthocyanin in seeds and plant parts were developed. These HI lines possess higher anthocyanin in seeds and plant parts over the earlier developed HI lines. These improved HI lines possess 8-10% haploid induction rate (HIR).

1.1.4.5 Breeding for nutritional quality

Genetic variation for methionine: In a set of 48 diverse inbreds evaluated at three locations, methionine in grain varied from 0.03-0.31% with an average of 0.15%. Nine inbreds with >0.25% methionine were selected for further analysis. Of these, three inbreds were also high in lysine and tryptophan.

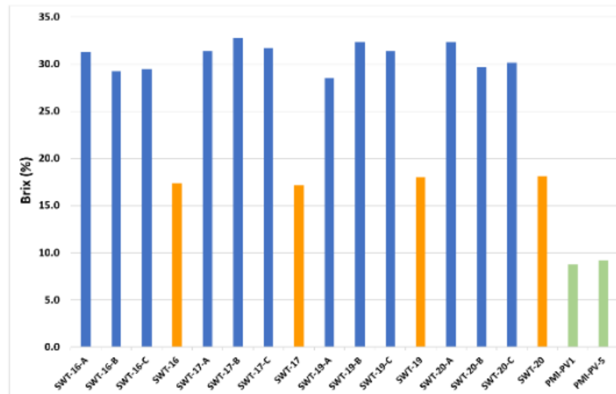
Temporal expression analysis of *vte4* and *crtRB1* in sweet corn inbreds: Six biofortified sweet corn inbreds (*vte4* and *crtRB1*) and three traditional sweet corn inbreds (*vte4*+ and *crtRB1*+) were analyzed at 20-, 24- and 28-days after pollination (DAP). Vitamin-E attained the peak at 24-DAP, while provitamin-A peaked at 20-DAP. Transcripts of *vte4* and *crtRB1* had the highest peak at 24-DAP. Biofortified inbreds recorded higher transcript levels of *vte4* (10-folds) and lower levels of *crtRB1* (8-folds) over *vte4*+ and *crtRB1*+, respectively.

Expression dynamics of *lpa1* gene during different stages of kernel development: The expression pattern of a wild (*LPA1*) and mutant (*lpa1-1*) allele was analyzed during 15-, 30-, and 45-DAP. The *lpa1-1* gene reached its highest peak at 15-DAP. The correlation of transcript levels of *lpa1-1* with phytic acid/total phosphorus was positive (r= 0.98).

1.1.4.6 Breeding for specialty corn

Development of maize with low glycaemic index (GI): Maize grains possesses 25-30% amylose and a high glycaemic index (GI: 80-90). The experimental hybrids possessed significantly higher amylose (38.1%) and resistant starch (RS: 20.9%) over checks (amylose: 29.1%, RS: 2.3%). PUSA-AML-H12 (amylose: 49.1%, RS: 23.9%), PUSA-AML-H18 (amylose: 45.6%, RS: 23.8%) and PUSA-AML-H16 (amylose: 45.4%, RS: 23.5%) were the most promising hybrids.

Development of *sugary1* and *shrunken2* -based sweet corn hybrids: PSSC-1 and PSSC-2 are the released *sh2*-based sweet corn hybrids. Recessive *sugary1* (*su1*) was introgressed using MAS. Hybrids with *su1su1/sh2sh2* possessed higher brix (~24-25%) over the original hybrids (~17-18%).



Comparison of brix among *su1su1/sh2sh2* (blue bars) based hybrids over *sh2*-based original (orange bars) and field corn hybrids (green bars)

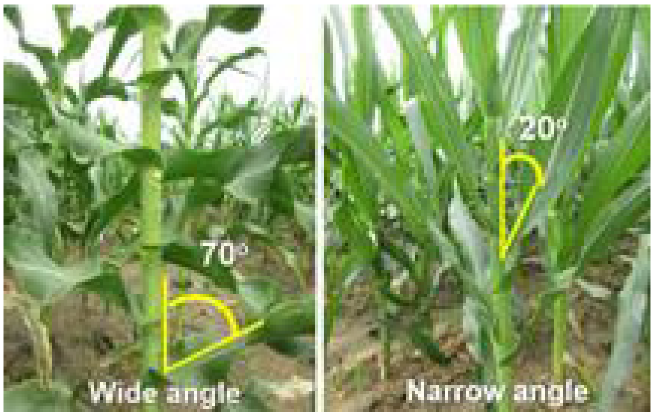
Genetic dissection of embryo-related traits for enhancement of kernel oil: Embryo is the key determinant of kernel oil in maize. The analysis revealed the significance of additive and dominance main effects, and additive × additive and dominance × dominance interaction effects with a predominance of dominance and dominance × dominance effects for most of the embryo-traits. Duplicate epistasis was observed across the crosses and locations.

Introgression of *waxy1* allele in pro vitamin-A-rich QPM hybrids: The recessive *waxy1* allele that causes high amylopectin compared to normal maize (*Waxy1*) was introgressed into provitamin-A rich QPM inbreds *viz.*, PMI-PV5 and PMI-PV9 through MAS. The reconstituted hybrids possessed >97% amylopectin, >3.30% lysine, >0.80% tryptophan and provitamin-A (>8.00 ppm).

Introgression of *shrunken2* (*sh2*) allele: The recessive *sh2*-gene was introgressed into the parents of HM4. The MAS-derived inbreds viz., HKI1105-sh2 and HKI323-sh2 possessed 17.8% and 18.4% brix over the recurrent parents (7-8% brix).

1.1.4.7 Breeding for plant architecture

Genetic variation of leaf angle for high-density planting: A set of 48 inbreds were evaluated for plant architectures at multilocations. Leaf angles between stem and leaf blade varied from 18-85°. Five inbreds with narrow leaf angles and semi-erect leaves were identified.



Inbreds with contrasting leaf angles

Development of hybrid suitable for high-density planting: The recessive *lg1* gene was introgressed into the parental inbreds of the HM4 using MAS. The introgressed progenies possessed extremely narrow leaf angle (~10°) compared to 30-35° among the recurrent parents.

1.1.4.8 Breeding for fodder quality traits

Evaluation of biofortified maize hybrids for forage and silage quality traits: A set of 13 maize cultivars including released biofortified hybrids were evaluated for forage and silage quality traits in collaboration with IGFRI, Jhansi. Based on the analysis, biofortified hybrids *viz*. Pusa Vivek QPM9 Improved and Pusa HM9 Improved, and sweet corn hybrids *viz*. PSSC-1 and PSSC-2 hybrids were found to be promising for crude protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), and *in-vitro* dry matter digestibility (IVDMD) traits.

1.1.4.9 Selection for high grain yield

Promising hybrid for Madhya Pradesh: AH-4271 recorded 26% superiority over PJHM-1 in Madhya Pradesh. It also had 18% and 12% grain yield superiority over Bio-9544 and PJHM-1, respectively in Delhi.

Evaluation of experimental hybrids: A total of 30 medium maturing experimental hybrids were evaluated at six locations. Seven hybrids were found promising and stable over national check, Bio 9544. Another set of 25 experimental hybrids was evaluated at Delhi and Mandasaur for their *rabi*/*spring* adaptability.

Identification of high-yielding white maize inbred lines: Four white inbreds (AI 401, AI 402, AI 403, and AI 404) having yielding ability >3.5 t/ha were identified.

Grain and ear characteristics of white maize inbreds

Identification of general and specific combiner for late maturity: A total of 10 late maturing inbred lines were crossed in a diallel mating design, and AI 512, AI 518, and AI 542 were identified as promising general combiners for yield and yield component traits.

1.1.4.10 Resistance to biotic stress

Development of hybrids with disease resistance: AH-8323, AH-8178, AH-8181, AH-8127, AH-8721, AH-2053, AH-2077, H-2138, H-2015 and H-2009 were found to have grain yield of >10 t/ha and resistant to TLB with a disease score of less than 2.0 (0-9 scale).

Development of inbred lines with disease resistance: A set of 10 newly developed inbreds were identified to be resistant to TLB with productivity of >3.5 t/ha.

Advancement of generation for new inbred development with resistance to TLB. About 25 F_2s, 30 F_3s, 50 F_4s and 50 F_5s were advanced to next generations. The lines tolerant to TLB were advanced. Further, crosses between potential hybrids were undertaken to develop a new maize pool for use in deriving improved inbred lines.

Evaluation of maize inbreds for tolerance to Fall Army Worm (FAW): Five new biofortified inbreds, MGU-FAW-161, MGU-FAW-172, MGU-FAW-181, MGU-FAW-195 and MGU-FAW-203 were found promising with tolerance to FAW. In field corn, CDM-1330, DDM-2309, DIM-204, PDM-24, PDIM 639, C 79, AI 501, AI 525, AI 540, PML 55, PML 42 and AI 542 were found to be tolerant to FAW.

FAW infestation in resistant and susceptible inbreds

1.1.4.11 Tolerance to abiotic stress

Promising hybrid under drought stress: AH3002, a medium maturity hybrid was found promising with moderate tolerance to drought conditions. The hybrid was superior to Bio 9544 at Delhi and Hyderabad. AH3002 was nominated to AICRP during *kharif* 2022.

Screening maize genotypes under excess soil moisture (ESM): Two hybrids (HQPM7 and AWH-1) and three parental lines (PV2, AW1 and AW2) and 33 germplasm accessions were identified as tolerant to ESM conditions.

1.2 MILLETS

1.2.1 Pearl millet

1.2.1.1 Evaluation of early maturing hybrids

Initial Station Hybrid Trial: Thirty-eight hybrids of the early maturity group were tested at Delhi during *kharif* 2022. One hybrid, H-5132 (411A × 10216) was found promising based on yield and related traits.

Intermediate Station Hybrid Trial: Seventy-five hybrids of the early maturity group were tested at Delhi during *kharif* 2022. Five hybrids *viz*. H-4843 (411A × 10180), H-4844 (411A × 10183), H-4929 (411A × 10197), H-4944 (411A × 10258) and H-4995 (411A × 10271) were found promising based on yield and related traits.

1.2.1.2 Evaluation of medium maturing hybrids

Initial Station Hybrid Trial: Ninety-eight hybrids of the medium maturity group were tested at Delhi during *kharif* 2022. Three hybrids viz. H-5143 (ICMA 11222 × CB 263), H-5144 (ICMA 14222 × CB 127) and H-5573 (ICMA 14222 × 1144) were found promising based on yield and related traits.

Intermediate Station Hybrid Trial: Fifty hybrids of medium maturity group were tested at Delhi during *kharif* 2022. Three hybrids *viz*. H-5009 (ICMA 11222 × CB 295), H-5053 (ICMA 11222 × CB 11) and H-5086 (ICMA 13222 × 2024) were found promising based on yield and related traits.

Nominations in AICRIP trials: A total of 24 entries were nominated to various trials conducted during *kharif* 2022. Two hybrids (Pusa 2201 and Pusa 2202) were nominated to Initial Hybrid Trial (Early), while two hybrids (Pusa 2203 and Pusa 2204) were nominated to Initial Hybrid Trial (Medium). Three populations *viz*. Pusa Composite 729, Pusa Composite 730 and Pusa Composite 731 were nominated to the Initial Population Trial. Five biofortified restorer lines *viz*. PPMI 1302, PPMI 1303, PPMI 1304, PPMI 1305 and PPMI 1306 were nominated to Elite Joint Biofortification Nursery (EJBFN). Six biofortified restorer lines viz. PPMI 1286, PPMI 1287, PPMI 1288, PPMI 1289, PPMI 1290 and PPMI 1291 were nominated to CRP Biofortification Parental line trial (CRB-PLT). Three restorer lines *viz*., PPMI 1295, PPMI 1296 and PPMI 1297 were nominated for PMPHY 2a trial. Three entries *viz*. PPMI 1292, PPMI 1293 and PPMI 1294 were nominated to PMPHY-7 for screening genotypes for heat stress tolerance at the seedling stage.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Release of variety

Pusa JG 16 [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a MAS-derived version of JG 16. It is a drought tolerant variety, and also resistant to *Fusarium* wilt. It possesses medium sized grain (24-25 g/100 seeds) with 21-22% protein. It provides 1.35 t/ha of average yield with a potential yield of 2.12 t/ha. It matures in 111 days. Pusa JG 16 has been released for cultivation in Madhya Pradesh, Maharashtra, Gujarat, Chhattisgarh, Southern Rajasthan and Bundelkhand region of Uttar Pradesh.

Grain characteristics of Pusa JG 16

1.3.1.2 Promising chickpea entries in AICRP trials

Out of the 14 entries tested in different coordinated trials during *rabi* 2021-22, four have been promoted to AVT-I. BG 4031 ranked first and promoted to AVT-I (late sown) in NWPZ and NEPZ; BG 4036 to AVT-I (mechanical harvesting) in SZ; BG 4037 to AVT-I (mechanical harvesting) in NWPZ and NEPZ; and BG 4035 to AVT-I (extra-large seeded kabuli) in WCZ. In addition, eight desi entries (BG 4038, BG 4039, BG 4040, BG 4041, BG 4042, BG 4045, BG 4046 and BGD20103) and two large seeded kabuli types (BG 4043 and BG 4044) were nominated in five different NIVTs during 2022-23.

1.3.1.3 Characterization of recombinant inbred line populations and selection for earliness, lodging resistance, stem determinacy and seed yield

A recombinant inbred line (RIL) population of Pusa 362 (late) × BGD 132 (early) comprising 267 lines was evaluated for the time of flowering and seed yield. BGD 9976 (2.87 t/ha), BG 4032 (2.91 t/ha), BGD119 (2.78 t/ha), BG 3078-1 (2.44 t/ha) and BGD 9722 (2.88 t/ha) are the early flowerings, podding and maturing (<125 days duration) breeding lines having high seed yield potential. BGD 9976 was also found to be cold tolerant with the ability to form podding at a lower temperature (<15^{0}C). Another RIL population of Pusa72 (indeterminate, *Dt1*) × BG3078-1 (semi-determinate, *Dt2*) comprising 156 lines was characterized for earliness and seed yield. Some of the indeterminate and early flowering RILs produced greater yield up to 557 g/plot compared to the highest yielding semi-determinate inbred (488.4 g), indeterminate late parent BGD 72 (493.1 g) and semi-determinate early parent BG3078-1 (348.7 g). Thirty four indeterminate and semi-determinate breeding lines derived from indeterminate x semi-determinate crosses with seed yield potential of >2.5 to 3.75 t/ha were selected. Besides, evaluation of selected RILs and breeding lines derived from Pusa 362 (lodging, *sb1sb2*) × FLIP 07-183C (non-lodging, *Sb1Sb2*) under a restricted irrigation environment (one irrigation at the pre-flowering stage) showed that the highest yielding lodging resistant chickpea line produced 4.0 t/ha compared to parents, Pusa 362 (2.83 t/ha) and FLIP07-183C (2.6 t/ha).

1.3.1.4 Screening of pre-breeding lines against rust disease

One hundred seventy three pre-breeding lines were screened against rust disease under artificial epiphytotic condition for two years. A *Cicer pinnatifidum* accession (ILWC0) showed resistance reaction against the disease.

1.3.1.5 Yield evaluation of dry root rot (DRR) tolerant lines and phenotyping of mapping population for DRR

Fifteen DRR tolerant lines were evaluated for yield under replicated trial for three years. Three entries (SSD 718-231, SSD718-50 and SSD718-18) recorded higher grain yield with less than 10% disease incidence.

1.3.1.6 Screening of germplasm against wilt disease

Five hundred germplasm lines were screened against *Fusarium* wilt in sick pots. One hundred forty two lines were highly resistant to wilt disease, while 116 lines were moderately resistant.

1.3.1.7 Yield evaluation of elite lines under rainfed condition

Twenty four breeding lines were tested under rainfed conditions at RRC Dharwad. Three entries (BGD 20103, CVTRF 21-04 and BGD 20137) recorded significantly higher grain yield than the check entry, BGD 111-1.

1.3.2 Pigeonpea

1.3.2.1 Evaluation of newly developed short duration determinate semi-erect compact plant type with semi-dwarf stature

Fifty advanced generation lines with determinate semi-erect compact plant type and semi-dwarf stature with bold seed size were evaluated with check variety; Pusa Arhar 16 and 10 high yielding lines were selected. Yield ranged from 15.68 to 22.31 q/ha. PDTM 20-18, PDTM 20-55, PDTM 20-36 and PDTM 20-37 were identified as promising, and suitable for higher plant population density and mechanized cultivation.

Plant architecture of PDTM 20-18

1.3.2.2 Evaluation of advanced generation lines with determinate dwarf plant type suitable for mechanized cultivation

Six advanced generation lines with determinate dwarf semi-erect compact plant type with a large number of primary branches were evaluated. Grain yield ranged from 19.73 to 24.42 q/ha.

1.3.3 Lentil & Mungbean

1.3.3.1 Lentil hybridization

Fifty five crosses were made to combine earliness, high grain Fe and Zn concentration, bold (for CZ) and small seed (for NEPZ) size and wilt and rust resistance. Six interspecific crosses were made to transfer desired traits from unadapted to adapted background.

1.3.3.2 Breeding materials in lentil

Sixty eight crosses made last year were raised, six F_2 populations were also raised. Ten crosses (177 SPS) in F_3, 51 crosses (924 SPS) in F_4, 63 crosses (1194 SPS) in F_5 and 36 crosses (371 SPS) in F_6 were evaluated.

1.3.3.3 Mungbean hybridization

Forty-five crosses were made to combine MYMV resistance, earliness and bold seed size.

1.3.3.4 Breeding materials in mungbean

Twenty eight crosses made last year were raised, and 10 F_2 populations were also raised. Twenty nine crosses (159 SPS) in F_3, 20 crosses (184 SPS) in F_4, 26 crosses (824 SPS) in F_5 and 44 crosses (1418 SPS) in F_6 were evaluated.

1.4 OILSEED CROPS

1.4.1 Mustard

1.4.1.1 Variety released

Pusa Mustard 34 [Gazette Notification S.O. 1056 (E), dated 06.03.2023]: It is a single zero (<2% erucic acid) Indian mustard variety released for cultivation in Rajasthan (Northern and Western parts), Punjab, Haryana, Delhi, Western Uttar Pradesh, plains of Jammu & Kashmir and Himachal Pradesh. It possesses low erucic acid (0.79%) in its oil (36.0%). It is tolerant to water stress conditions. It has a long main shoot (73 cm) with high siliqua density.

Pusa Mustard 34

1.4.1.2 Elite lines tested in AICRP trials

A total of 19 Indian mustard genotypes were evaluated in different AICRP Rapeseed-Mustard Trials

Year of testing	Entries
AVT II (1)	LES 60 (low erucic acid strain promoted to AVT-II trial in Zone II)
AVT I (2)	PDZ-14 and PDZ-15 (promoted to AVT-I Q Trial in Zone-II & III)
IVT (14)	IVT-Early Sown (NPJ-248, NPJ-249), IVT-Late Sown (NPJ 250 & NPJ 251); IVT-TS Irrigated (NPJ 252 & NPJ 253), IVT-TS-RF (NPJ 254 & NPJ 255), IVT-Salinity (NPJ 256, NPJ 231) and IVT-Quality [PDZ-16 (00), PDZ-17 (00), LES 64 (0), LES 65 (0)]
IHT (2)	Pusa Mustard Hybrid 64 and Pusa Mustard Hybrid 65

Trials conducted for evaluation of promising genotypes: A total of 21 trials including nine AICRP RM trials (IVT-Early Sown, AVT-Early Sown, IVT-Late sown, IVT-Timely Sown, IVT-White Rust Resistance, IHT, AVT-I+II-Timely Sown Irrigated, AVT-NILs and IVT Quality Mustard), eight mustard station trials (MST Early Sown, MST Timely Sown Irrigated, MST Timely Sown Rainfed, MST Quality Mustard, MST Timely Sown Hybrids-1, MST Short Duration Hybrids-2, MST Timely Sown Hybrids-3 and MST Late Sown), and four trials under CRP-Hybrid Technology (CRPMLT-1, CRPMLT-2, CRPMLT-3 and CRPMLT-4) were conducted successfully.

Promising genotypes/hybrids evaluated in Station Trials: A total of 88 promising genotypes identified based on superiority for seed yield and oil content were evaluated in five trials viz., MST Early Sown (15 entries), MST Timely Sown Irrigated (23 entries), MST Timely Sown Rainfed (19 entries), MST Quality Mustard (18 entries) and MST Late Sown (13 entries) along with the checks.

Hybrids evaluated in Station Trials: A total of 105 hybrids generated by ICAR-IARI New Delhi were evaluated *viz.*, MSTH-1 Early Sown (8 hybrids), MSTH-TS -2 (22 hybrids), MSTH-TS -3 (39 hybrids) trials and three trials *viz*. MLT 1 (5 hybrids), CRP MLT 2 (15 hybrids) and CRP MLT 2 (16 hybrids) under CRP-Hybrid Technology Project.

Demonstration of Indian mustard in Karnataka: A small scale feasibility trial of four Indian mustard varieties (PM 25, PM 28, PM 30 and PM 31) at two places (IIHR-Heserghatta, Bengaluru and ZARS- Kalaburagi) were conducted.

1.4.1.3 Evaluation and advancement of breeding material for varietal development

Short duration breeding materials generated: A total of 27 progenies (F_6 :11 and F_7: 16) were bulked and 145 single plants were selected (F_6: 1; F_5: 15; F_4: 46, F_3: 24 and F_2: 59) under early sown conditions. Whereas, from late sown breeding material, 39 progenies (F_7: 6 & F_6: 33) were bulked and a total of 264 single plants (F_6: 5, F_5: 40, F_4:49, F_3:50 and F_2:120) were selected for further evaluation and advancement.

Breeding materials generated for timely sown conditions: Out of a total of 557 progenies/populations raised under timely sown conditions (F_1: 79; F_2: 47;

MCF_1: 22, F_3: 95; MCF_2: 38; F_4: 37;MCF_4: 133; F_5: 58; F_6: 9, MCF_6: 17; and F_7: 22) a total of 514 (F_1: 49; MCF_1: 66; F_2: 213; MCF_2: 49; F_3: 79; F_4: 29; MCF_4: 28, F_5: 42; F_6: 3; MCF_6: 4 and F_7: 1), single plants/progenies were selected and 30 entries were bulked for testing in station trials. Thirteen progenies were bulked based on oil content, seed size and yield performance.

Breeding material with 0/00 quality generated: Segregating generations were advanced and single plants were selected for 0/00 trait in F_2 (121), BC_1F_2 (186), F_3 (257), F_4 (90) and F_5 (129) generations. A total of 10 and 13 entries were bulked from F_6 and F_7 generations, respectively, for the low erucic acid (0). Similarly, seven entries were bulked each from F_6 and F_7 generations, respectively, for low erucic acid and low total glucos inolates (00).

Hybridization: A total of 44 crosses to develop short-duration genotypes suitable for early or late sown conditions, 79 single crosses and 22 multiple/ three-way crosses to develop varieties suitable for timely sown conditions and 26 crosses (4 single and 22 multiple) were attempted to enhance oil and meal quality along with seed yield. *Brassica carinata* derived *B. juncea* introgression lines were used as male and/ or female parent(s) in generating 280 fresh crosses for the development of mustard varieties suitable for rainfed situations.

1.4.1.4 Hybrid Breeding

Cytoplasm diversification and CMS line development: A total of 57 CMS lines (26 *mori*, 14 *eru*, 13 *ber* and 4 *ogu* cytoplasms) were maintained by attempting three paired crosses each with the pollen-tested plants. Further, to transfer 10 nuclear backgrounds to *Ogu* cytoplasm, $F_1/BC_2/BC_4$ crosses were attempted.

Restorer development and maintenance: Fertility restorers in BC_5F_3 and BC_6F_3 generations were tested through microscopic examination for fertility restoration and maintained through selfing. One hundred and seven fertility restorers were also maintained by raising 394 progenies. Further, 292 single plants were selected and selfed for their maintenance.

To develop fertility restorers with improved agro-morphological traits, a total of 49 segregating progenies were raised, and 213 fertile single plants were selected and selfed.

Shuttle breeding for white rust and/or powdery mildew resistance: Six F_2 populations involving powdery mildew and white rust disease resistant accession (PMW 18) were raised at Wellington. Based on white rust reaction, 86 single plants and 35 plants in F_3 generation were selected. Fifteen bi-parental crosses among the selected individual plants in F_2 were also attempted. Two crosses were advanced from $BC_2F_4$to BC_2F_5 (54 SPS) and BC_2F_6 (12 SPS); four crosses from BC_3F_4 to BC_3F_5 (52 SPS) and BC_3F_6 (14 SPS), and eight crosses from BC_1F_4 to BC_1F_5 (120 SPS) and BC_1F_6 (42 SPS) for transferring powdery mildew resistance from PMW 18 to Indian mustard cultivars. Eight F_2 populations generated by involving PMW 18 were also advanced to F_3 (61 SPS) and F_4 (19 SPS). Besides, 111 lines of RBJ (*Resynthesized brassica juncea*) entries of rapeseed-mustard were evaluated for white rust at Pusa Bihar. Promising entries were selected for utilization in breeding programme.

1.4.2 Soybean

1.4.2.1 Entries in AICRP trials

Five genotypes *viz*. DS1510, DS1529, DS1547-E, DS1550 E and DS1701 were evaluated during *kharif*-2022.

1.4.2.2 Development of herbicide-tolerant soybean

Seven Indian soybean varieties *viz*., JS9560, JS335, JS20234, JS2069, JS2098, JS2029 and DS9712 were crossed with herbicide tolerant American variety S14-9017GT. F_1s and the BC_1F_1 plants of the entire cross combinations were checked for introgression of the target gene and the status of recurrent parent genome recovery. Selected plants were backcrossed to respective recurrent parent. The cross combination involving JS9560 has reached BC_2F_2 generation.

1.4.2.3 Identification of genotypes with higher pods/plant

About 300 inter-specific RILs were field evaluated for the different seed characters and yield parameters. RIL Nos. 7-23-3, 7-34-1, 9-12-3, 7-2-4, and 19-33-3 that contained more than 150 pods/plants were identified. RIL No. 19-33-3 was highly resistant to YMV.

Field view of RIL No. 19-33-3 contain >150 pods/plant

1.4.2.4 Identification of genotypes with low oil content

Usually, soybean contains about 20% oil. However, RILs with a lower level of oil *viz*., 4-32-1 (6.13%), 9-11-3 (6.51%), 6-1-1 (7.46%), 25-44-2 (7.87%), 9-2-2 (8.42%), 9-2-5 (8.45%) and 25-58-2 (8.62%) were identified. To understand the relationship of oil content with seed storability, seeds of 20 RILs with low oil content, were stored for three consecutive years (2019-21) in ambient conditions, and evaluated for seed germination percentage. It was found that the low-oil-containing RILs had relatively better seed storability than with higher oil content.

1.4.2.5 Evaluation of lipoxygenase and Kunitz trypsin inhibitor-free lines

Thirty-three MAS-derived lines, which are free from off-flavour producing lipoxygenase allele (*Lox2*) and Kunitz Trypsin Inhibitor producing *KTI* allele, were field evaluated for various morphological traits including yield and yield contributing characters. Lines with desirable traits and yield have been identified, and they will be tested subsequently in national-level trials for release as essentially derived varieties (EDVs) of soybean. Two already developed KTI free lines DS-9421 and DS-9422 were grown and evaluated for different yield-related characters.

1.4.2.6 Development of off-flavour free vegetable soybean

To eliminate the off-flavour from the vegetable soybean, the null allele of *Lox2* gene was transferred from a donor genotype into the vegetable soybean genotype Swarna Vasundhara through MAS. The plants with the target allele in the background of Swarna Vasundhara are in the BC_2F_1 generation.

1.4.2.7 Waterlogging tolerance

A total of 500 germplasm accessions were screened under flooded pots at V3-V4 conditions. Seventeen genotypes were identified with tolerance exhibiting survival to the next stage.

1.4.2.8 Indirect somatic embryogenesis protocol in soybean anther and microspore

Anthers and microspores isolated from five selected soybean accessions used as explants were evaluated for their ability to form a callus, somatic embryos and subsequent regeneration into plants. The highest percentage of morphogenetic calli was obtained with 3.0-3.5 mm long flower buds of SKAF148 on BNN medium supplemented with 2,4-D (2.0 mg l^{-1}), and BAP (1.0 mgl^{-1}). A visible callus was observed about 14 days after inoculation of the anther in callus induction. Meanwhile, the appearance of microcalli from microspore as explant took 45 days in the induction medium. MS media along with BAP (1.0 mg l^{-1}) resulted in the highest shoot induction in calli obtained from anthers. Both embryogenic friable and non-embryogenic compact calli were noted.

1.4.2.9 Screening germplasm against pod borer

Pink pod borer (*Cydia ptychora*) is an emerging pest of soybean in the Southern zone. A total of 714 soybean genotypes were screened for tolerance to pod borer under late sown conditions during *kharif* 2022. Twenty eight highly tolerant lines (EC 1037672, EC 1037729, EC 1037874, IC 993238, BC 965, BC1150, BC1271, GP508, GP519, GP566, GP609, GP625, GP682, GP697, GP710, GP749, GP755, GP760, GP781, GP796, GP811, GP 36, PK 1169, SL 46, V3, V23, 1050 and SL 955) with <1% infected pods were identified. Seven germplasm lines (GP 11, GP 14, GP 15, GP 16, GP 17, GP 36 and GP 38) recorded <10% pod damage during both seasons (*kharif* 2021 and 2022) and hence these lines were confirmed as tolerant to pink pod borer.

Pink Pod borer tolerant germplasm line GP 14

1.4.2.10 Identification of extra-early soybean genotypes

A total of 714 soybean genotypes were evaluated under late sown conditions during *kharif* 2022. Among these, twelve lines (EC 1037672, EC 1037711, EC 1037703, EC 993229, EC 1037536, EC 1037831, EC 1037882, EC 1037564, EC 1037568, EC 1037743, EC 1037842 and EC 1037900) were identified as extra-early lines which matured within 70 days after sowing.

1.4.2.11 Yield evaluation of elite breeding lines

Twenty-one elite breeding lines along with DSb 34 (check) were tested during *kharif* 2022 at RRC, Dharwad. V-6 recorded significantly higher grain yield than DSb 34, while V-9, V-14 and V-21 were on par with the check. In another trial, 24 elite breeding lines were also evaluated for yield. V-14 recorded a higher yield than the check variety DSb 34, while the entries V-1 and V-9 were on par with the check.

1.4.2.12 Yield evaluation of popular cultivars under the natural epiphytic condition

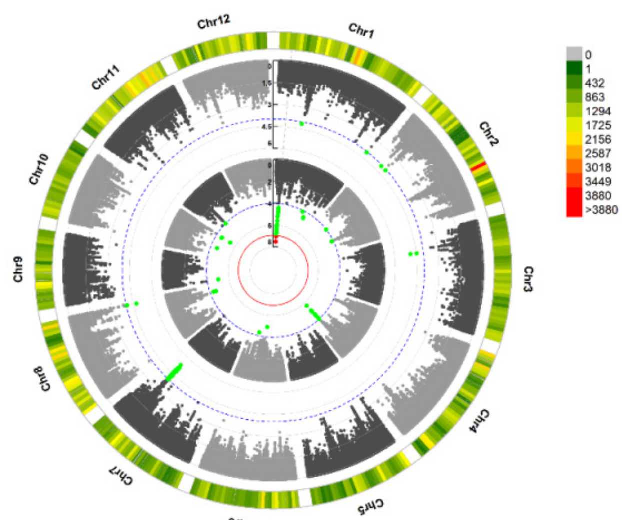
Nine soybean elite cultivars were evaluated for yield under natural epiphytic conditions of rust incidence during *kharif* 2022 at RRC, Dharwad. DSb 23, DSb 21 and DSb 34 recorded higher grain yield compared to rust susceptible varieties.

1.5 SEED SCIENCE & TECHNOLOGY

1.5.1 Studies on seed quality traits

1.5.1.1 Seed dormancy studies in rice

A set of 218 genotypes from 3K panel of rice genome project were grown, and the seeds was harvested after 30-40 DAP. The intensity of dormancy (IOD) ranged from 0-100% with a mean of 66.5%, and the 50% germination (DSDS50) ranged between 0-124 days with a mean of 23 days. The genome-wide



Circular Manhattan plot showing the significant SNPs associated with dormancy in rice

association studies (GWAS) revealed highly significant SNP (rs3647495) on chromosome 1. Besides, six more significant SNPs were identified based on the linkage disequilibrium.

1.5.1.2 Identification of QTLs/genes associated with early seedling vigour characters in rice

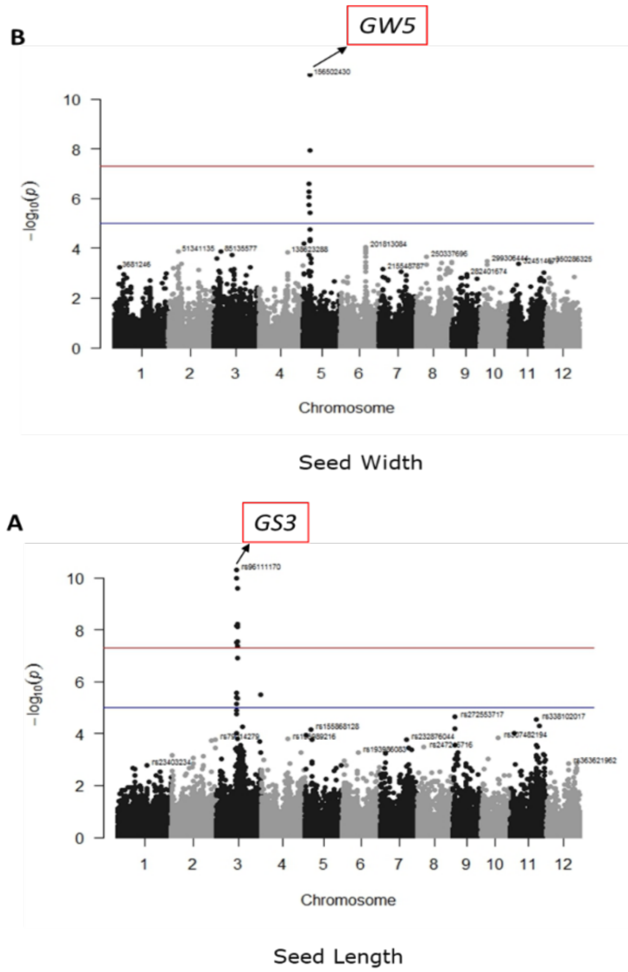
GWAS analysis was undertaken using two rice populations comprising of 192 genotypes that were genotyped using 60K rice SNP array and 236 genotypes from 3KRG. Significant variation was observed for 50% lemma rupture (LR) in both the rice populations. Five QTNs *viz*. qLR3.1, qLR6.2, qLR7.1, qLR3.2 and qLR6.1 with significant phenotypic variation ranging from 5.91 to 22.11% were identified.

1.5.1.3 Early seed vigour traits in maize

A total of 197 maize lines were studied for seed germination and vigour parameters *viz*. speed of germination, mean germination time (MGT), germination index, coefficient of velocity of germination and vigour indices under sub-optimum temperature conditions (15° and 20°C). The principal component analysis of maize lines showed that germination index, MGT, speed of germination, coefficient of velocity of germination had high correlation with early seed vigour of maize lines, while correlation with these parameters were higher under 15°C than 20°C indicating that lines with early vigour traits have better performance under low temperature regimes.

1.5.1.4 Multi-spectral image analysis of diverse rice germplasm lines

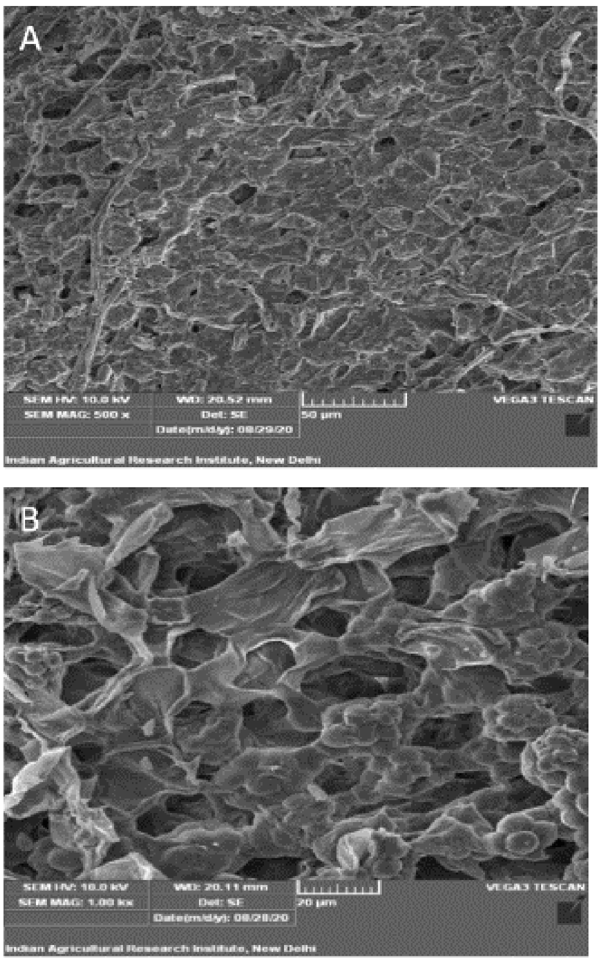
Digital images of around 1100 diverse rice germplasm across 19 different spectral bands were captured. The phenotypic values for seed morphological traits indicated large genotypic variation in the rice germplasm. GWAS resulted in identification of a most significant and prominent genomic region across the genome for seed length and seed width on chromosome 3 and 5, respectively.



Genome-wide association analysis for seed morphological traits obtained using multi-spectral imaging. GWAS results for seed length (A) and seed width (B). Manhattan plots indicate SNPs from each chromosome along x-axis and the -$\log_{10}(p)$ values for the association along the y-axis

1.5.1.5 Basis of hardseededness in mungbean

A significant difference for physico-chemical parameters like lignin content, cellulose, xylose and arabinose content, total phenol and calcium content was observed between hard and non-hard seeded genotypes, and also between *kharif* and summer season produced seeds. The rise in structural carbohydrates, phenols and calcium may be the reason behind the higher occurrence of hardseeds in *kharif* season compared to that in summer season. Scanning electron microscopy showed clear difference between hard and non-hard seeds in relation to growing seasons and seed storage. The hard-seeded genotype was characterized by closely packed hilum cells, closed strophiole, absence of cracks in hilum, lowered depth of the midge below the hilum region, plane topography of hilum surrounding cells and vertical side of the seeds of hard-seeded genotype. On the contrary, the non-hard seeded genotype can be characterized by loosely packed hilum cells, opened strophiole, presence of cracks in the hilum, higher depth of midge of lower hilum portion and emulated topography of hilum surrounding cells and ventral side of the seeds.



Arrangement of hilum cells in A: compact (TM 96/25), B: loose (Pant M5)

1.5.1.6 Seed dormancy behaviour in cucumber

Variability for extent of dormancy in cucumber genotypes ranged from 1-4 months. The dormancy behaviour was controlled by seed coat, GA-ABA content and physiological maturity of seed. Seasonal variations were observed for seed dormancy behaviour. Seed dormancy could be mitigated by dry heat treatment (70°C for 3 days), GA_3@ 1000ppm for 24 h and KNO_3@ 1% treatment.

1.5.2 Studies on seed priming

1.5.2.1 Improving the seed quality and yield attributes of chickpea using nanoparticles

Seeds treated with dry nano ZnO @ 250 ppm improved all the seed quality parameters *viz.* germination percentage (92%), average shoot length (14.31cm), average root length (21.19 cm), average normal seedling length (35.5cm), seedling dry weight (0.513g), seedling vigour index-I (3265), seedling vigour index-II (47.16), dehydrogenase enzyme activity (OD value 1.126) in comparison to untreated control. Further, lowest pathogen infection percentage (13.33%) was also recorded in seeds treated with dry nano ZnO @ 250 ppm, dry nano ZnO @ 500 ppm and dry nanoTiO_2 @ 100 ppm compared to both the controls. The study on seed yield attributes revealed that significantly higher field emergence (90.67%), days to 50% flowering (125.3 days), plant height (53.07 cm), number of branches per plant (8.27), number of pods per plant (63.67), seed yield per plant (12.83 g), harvest index (39.95) and test weight (24.53 g) were recorded in seed treated with dry nano ZnO @ 250 ppm compared to the control.

1.5.2.2 Seed quality enhancement in chilli

Sub-optimum temperature during off-season seed production in chilli hinders seed germination and stand establishment. High (Kashi Anmol) and low vigour (Arka Lohit) seed lots of chilli were subjected to seed enhancement treatments to ensure high germination, vigour and good field stand. Results showed that solid matrix priming (Vermiculite for 24 h) improved field emergence by 16.00% and 11.53%, hydropriming (24 h) by 7.69% and 7.50% and magneto-priming (50 mT for 30 min) by 4.6% and 3.8 % in high and low seed vigour lots, respectively, as compared to non-primed seeds under sub-optimum temperature conditions. The number of seeds per pod, fruit yield per plant, seed yield per plant and 1000-seed weight significantly differed among treatments wherein solid matrix primed seeds performed best followed by magneto-primed seeds.

1.5.3 Seed production technology

1.5.3.1 Pollen viability in tomato

Pollen viability studies revealed that the fresh pollen had significantly higher viability as compared to the pollen stored at ambient temperature and at 4°C in all hybrids under both, *kharif* and *rabi* seasons as well as in open, net-house and polyhouse conditions.

1.5.3.2 Stigma receptivity in tomato

Stigma receptivity studies in all hybrids under both the seasons as well as under all the growing conditions revealed that the pollination on the 2nd day after emasculation resulted in significantly higher fruit setting and seeds with higher germination, seedling length, seedling dry weight, SV-I, SV-II and lesser EC in all hybrids during both the seasons.

1.5.3.3 Effect of sowing dates and planting seasons on the seed yield and quality attributes with special reference to *Mungbean yellow mosaic India virus* (MYMIV)

Two mungbean varieties, *viz*., Pusa 1371 (resistant to MYMIV) and Pusa 9531 (Susceptible to MYMIV) were evaluated under field conditions with three sowing dates at 10 days interval in *kharif* (20th July, 30th July and 10th August) and Spring-Summer season (20th March, 30th March and 10th April). The minimum disease incidence along with good growth and high yield parameters like number of pods and seed yield per plant was recorded in Pusa 1371 during second and third sowing as compared to first sowing. In *spring-summer*, minimum disease incidence along with good growth and yield parameters was observed with first and second sowings in both the varieties. Interestingly, highest seed quality parameters were observed in 2nd and 3rd sowing of *kharif* season with no significant difference in spring-summer season. Based on the observations of two seasons, it is recommended to take the sowing of mungbean during spring-summer season as there is no influence of MYMIV on seed quality even though disease incidence occurs during the third sowing.

1.5.4 Effect of abiotic stress on seed yield and quality

1.5.4.1 Thermotolerance studies in rice

The seed germination and early seedling stages are highly susceptible to heat stress. A screening protocol was developed for basal and acquired thermos-tolerance of imbibed seeds in rice using a heat susceptible genotype (IR64). The basal thermo-tolerance (BT) was identified as 57°C for 30 minutes, where a 70% decline in germination was observed. The BT was validated in heat tolerant and susceptible genotypes, where tolerant genotypes showed almost double germination percentage of the identified BT.

1.5.4.2 Effect of high temperature stress at seedling stage in lentil

A total of 162 RILs of lentil were germinated under ambient temperature (20°C) and high temperature (35°C). The mean germination of 94% was recorded at optimum temperature (20°C), while it was 88% at 35°C. The temperature significantly affected the other seed quality parameters like mean germination time, coefficient of velocity of germination and biochemical parameters like superoxide dismutase, catalyse and MDA content.

1.5.4.3 Effect of high temperature stress at seedling stage in Indian mustard

Conventional, single zero and double zero genotypes were germinated under four different temperature regimes *viz*. 20°C, 30°C, 40°C and variable temperature range from 25-40°C in the growth chamber of National Phytotron Facility, ICAR-IARI, New Delhi with a sequence of specific temperatures along with the durations similar to that experienced in actual field conditions during the seedling establishment of Indian mustard. Significant differences were observed in germination percentage and biochemical parameters *viz.* chlorophyll content, proline content, antioxidant enzymatic activities like superoxide dismutase, catalase and peroxidase among the genotypes and temperature regimes and their interactions. Physiological mechanisms of Indian mustard at early seedling growth stage is dependent on accumulation of osmolyte *viz.* proline and complementation with enhanced antioxidant enzymes.

1.5.5 Seed health

1.5.5.1 Effect of soybean yellow mottle mosaic virus on seed yield and quality parameters of various soybean cultivars

Soybean yellow mottle mosaic virus (SYMMV) is an important virus pathogen in leguminous crops including soybean with symptoms of mosaic, mottle and veinal mild mottling. However, there is no information regarding availability of resistant sources and its effect on soybean production. Agro-inoculation of French bean cv. Arka Sharat with full length SYMMV genome present in a binary vector produced successful systemic symptoms of mosaic and chlorotic blotches. Mechanical sap inoculation of 18 soybean varieties with French bean leaves infected with SYMMV produced varying systemic symptoms like chlorotic spots, chlorotic blotches, mosaic, mottle, mild mottling and veinal mild mottling by 16-20 days of post inoculation. The percent disease incidence on a scale of 0-5 showed out of 18 varieties, SL979 was found to be moderately resistant. Detection of SYMMV using polyclonal antibodies in DAC-ELISA showed the highest titre values in SL-744, SL-958, SL-979 and SL-1028. RT-PCR analysis of the eighteen soybean varieties with coat protein specific primers gave amplification of 1065bp fragment.

2. HORTICULTURAL SCIENCES

Horticulture sector has become one of the major drivers of growth as it is more remunerative. In recent past it has experienced phenomenal increase in area as well as production. This sector provides employment possibilities across primary, secondary and tertiary sectors. Fruits are more resilient to change in weather conditions and the vegetables augment the income of small and marginal farmers. It has become a key driver for economic development in many states in the country. The School of Horticulture Sciences was created in 2013. Presently, focused attention is being made on genetic improvement, cost effective production technologies, efficient input management, postharvest management and value addition of horticultural crops. Several improved varieties have been identified in different horticultural crops and notified at the State and Central level for different agroclimatic regions. In addition, several valuable genetic materials have been generated having resistance/ tolerance against abiotic and biotic stresses. Efforts have been made to amalgamate the conventional strategies with the modern technologies in achieving the higher productivity of horticultural crops.

2.1 VEGETABLE CROPS

Varieties notified by Central Sub Committee on Crop Standard, Notification and Release of Varieties for Horticultural Crops

Brinjal: Pusa Krishna (DBR-03): This variety was notified for commercial cultivation in Zone VII (Madhya Pradesh and Maharashtra). Fruits are oval round with dark green calyx.

Pusa Safed Baingan-2 and Pusa Hara Baingan-2 was released by Delhi State Seed Sub-Committee and notified by Central Sub Committee on Crop Standard, Notification and Release of Varieties for Horticultural Crops for NCT Delhi.

Tomato: Two varieties, Pusa Golden Cherry Tomato-2 and Pusa Tomato (Protected)-1, promising for cultivation under protected environments were notified by CVRC for cultivation in Delhi & NCT.

Cauliflower: Pusa Cauliflower Hybrid 3 (DCH 976): The first CMS based hybrid in mid-late group of Indian cauliflower from public sector. Suitable for sowing in July to August and harvesting in October to December months under mid-hill regions. Average marketable curd weight is 1,150-1,250 g and marketable curd yield is 370-390 q/ha.

DCH 976

Cauliflower: Pusa Cauliflower Hybrid 101 (DCH 1467): It is a high yielding SI based hybrid in early group of Indian cauliflower. It has been notified for Zone IV- Sub-humid Sutlej-Ganga Alluvial Plains (Punjab, UP, Bihar, Jharkhand). Suitable for sowing in June-July months and harvesting in mid-October to mid-November. Average marketable curd weight is 600-650 g and marketable curd yield is 180-190 q/ha.

DCH 1467

Cauliflower: Pusa Snowball Hybrid-2: At ICAR- IARI Regional Station, Katrain, the first doubled haploid-based Snowball cauliflower has been developed. The average curd yield under NCR is 60.19 t/ha, average curd weight is 1.41 kg with 5-12% more yield compared to Pusa Snowball Hybrid-1. Curds are attractive snow white in colour which retained is even after few days of sunlight exposure. It has been released by the Delhi State Seed Sub Committee and notified by the CVRC during 2022.

Field view Curd view
Pusa Snowball Hybrid-2

Cabbage: Pusa Red Cabbage Hybrid-1: This is the first hybrid of red cabbage from public sector developed by using cytoplasmic male sterility (CMS) system. The average head weight and yield under multi-location evaluation trials is 1.10 kg and 43.63 t/ha, respectively. The anthocyanin content in the edible portion is 7.94 mg/100 g (7.5 times higher than in white cabbage, 1.05 mg). It has been released by the Delhi State Seed Sub Committee and notified by the CVRC during 2022 (S.O. 3254(E) dated 20.07.2022).

Pusa Red Cabbage Hybrid-1

Cabbage: Pusa Hybrid-82 (KTCBH-822): This is a CMS system based dark green coloured hybrid having flat head shape, very compact and covered with outer leaf. It matures in 65-75 days after transplanting. It has a very good field staying capacity (25-30 days) after head formation. Average yield is 40.3 t/ha in multi-location trials which is 19% higher than the commercial check. It has been released and notified by the CVRC during 2022.

Pusa Hybrid-82

Capsicum: Pusa Capsicum-1: From ICAR- IARI regional station, Katrain, an early capsicum variety having bell shaped attractive green coloured fruits has been released and notified by the CVRC during 2022. Fruits are 6.0 to 7.0 cm long with soft skin, crispy, tender flesh and average fruit weight 67.0 g. Fruits become ready for first harvest in 70-75 days. Average fruit yield is 21.3 t/ha, which is 27.9% higher than national check Nishat-1.

Pusa Capsicum-1

Carrot: Pusa Prateek: It has been notified for Zone VI (Rajasthan, Gujarat, Haryana and Delhi) and Zone VIII (Karnataka, Tamil Nadu, Kerala and Pondicherry). The average root weight is 100-120 g having root length of 20-22 cm. It is ready for root harvest in 85-90 days after sowing. The average root yield is 30 t/ha.

Bitter gourd: Pusa Hybrid-6: This hybrid was notified for cultivation in Zone I (Humid Western Himalayan Region, i.e., Jammu & Kashmir, Himachal Pradesh, and Uttarakhand). It is suitable for spring-summer season under open field conditions with higher female to male flower ratio. First fruit harvesting starts within 45-50 days after sowing with average fruit weight of 75 g. Average fruit yield is 25.5 t/h.

Pusa Hybrid-6

Bitter Gourd: Pusa Hybrid-5: This variety is suitable for spring-summer season under open field conditions with higher female to male flower ratio (2:1). First fruit harvesting starts within 44-48 days after sowing with average fruit weight of 70 g. Average fruit yield is 24.5 t/h.

Varieties identified by AICRP (VC)

Tomato: Pusa ToLCV Hyb-6: This tomato F_1 hybrid was identified for release and notified in AICRP (VC) Group Meeting 2022 for Zone-V.

Varieties Identified by IARI Variety Identification Committee (IVIC)

Tomato: Pusa Prasanskrit: It was identified by IVIC and recommended for cultivation in Delhi NCT. It is a processing type variety having *Ty-3* gene for ToLCV resistance and suitable for protected cultivation as well as open field conditions.

Pusa Prasanskrit

Tomato: Pusa Cocktail Tomato: It was identified by IVIC for cultivation in Delhi and National Capital Territory. It has *Ty-3* gene for ToLCV resistance. It is suitable for table purpose owing to high nutritive value and long keeping quality (>15 days). This variety is suitable for low-cost nethouse/ protected cultivation.

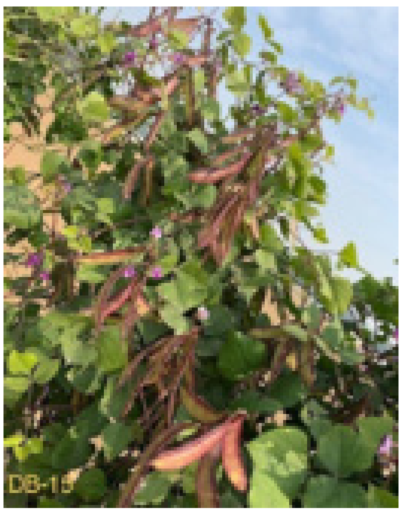
Pusa Cocktail Tomato

Capsicum: Pusa Preet: It was identified by IVIC for cultivation in Delhi and National Capital Territory. Fruits are red in colour with average fruit weight of 85.0 g and suitable for cultivation under low cost protected structures.

Cucumber: Pusa Parthenocarpic Cucumber Hybrid-1: First F_1 hybrid of parthenocarpic gynoecious cucumber suitable for cultivation under protected conditions. The fruits ready for first harvesting in 40-45 days after sowing both under polyhouse and insect proof net house conditions. Average fruit length is 18.32 cm and width 3.14 cm with fruit weight of 115.0 g. Average fruit yield is 143.6 t/ha.

Pusa Parthenocarpic Cucumber Hybrid-1

Dolichos Bean: Pusa Sem-6 (DB 15): It is pole type early maturing variety and pods become ready for first harvest within 110-120 days of sowing. Pods are very attractive greenish pink to purplish in colour with dark purple suture. Pods are smooth, flat, non-fibrous, slightly curved towards dorsal suture. The pod length is 9-10 cm, pod width 1.8-2.0 cm and 10 pods weight 60-65 g and seed weight 32 g. Pod facing sun change colour from green to pink-purplish in cold winter. Average pod yield is 181.2 q/ha.



Pusa Sem-6

Cauliflower: Pusa Cauliflower Hybrid 102 (DCH 9867): It is the first CMS (*Ogura*) based hybrid in early maturity group of Indian Cauliflower from public sector. Suitable for sowing in June–July and transplanting in July-August. Average marketable curd weight is 600-650 g and marketable curd yield is 24.0 t/ha. It has moderate resistance field reaction to downy mildew and black rot under field conditions.

DCH 9867

Broccoli: Pusa Purple Broccoli-1 (DPB-1): DPB-1 is the first anthocyanin rich short duration purple heading type broccoli. It is suitable for cultivation in *Rabi* season under Delhi conditions. It attains marketable head in 75-85 days after transplanting and rich in anthocyanin (30.31 ± 0.68 mg/100 g FW) content. Its average head weight is 570 g with potential marketable yield of 21.8 t/ha.

DPB-1

Okra: Pusa Lal Bhindi-1: It is a red coloured okra variety yielding 150 q/ha. It is rich in anthocyanin 130 µg/g with high antioxidant content (357 µg/g GAE) and dietary fibre (3.63%).

Pusa Lal Bhindi-1

2.1.1 Solanaceous crops

2.1.1.1 Tomato

Entries in AICRP- VC trials: Two promising entries were promoted to AICRP (VC) ToLCV resistance (2021/TOLCV/Hyb/AVT-1) trial. One entry for ToLCD resistance was nominated to AICRP (VC) ToLCV resistance 2022/ TOLCV/ Determinate/ Varietal-2022/ IET trial. A total of 105 genotypes including 60 F_1s and 55 MABB lines were evaluated for reaction to ToLCD, yield, quality, and processing attributes. Among promising hybrids H-507 was found suitable for processing.

Breeding for protected environment: Thirty tomato genotypes (11 parents and 24 hybrids) were evaluated under protected conditions along with four commercial checks (GS-600, NS-4266, Himsohna and US-2853). Maximum yield was recorded in Pusa Rakshit (17.0 q) followed by NS-4266 (16.5 q), NS-2853 (15.0 q) and Himsohna (14.5 q) in 100 sq. m area. New hybrid combinations DTPH-760 and DTPH-860 also recorded significantly higher yield (16.0 and 16.3 q) in 100 sq. m. area. Hybrid Plum Sel-1 had fruit weight of 35 g. High TSS (9.0° Brix) was recorded in Cherry Selection-1 followed by orange cherry Selection 530 (8.0° Brix). Genotype having better firmness were Pusa Rakshit, GS-600, NS-4266 (greater than 5.5 N and 5.8 N in peel and pulp, respectively), while cherry type had low firmness (lower than 3.0 N and 2.5 N in peel and pulp, respectively).

2.1.1.2 Brinjal

Screening for *Fusarium* wilt and virus resistance: The germplasm line DBR-160-2-3-1-3 was found highly resistant for *Fusarium* wilt and the interspecific hybrids, namely, Pusa Shyamla × *S. macrocarpum*, Pusa Bindu × *S. macrocarpum* were resistant to *Fusarium* wilt under field and artificial conditions. BR-40-7-3-2-1, DB-175 and DBR-112-14 were found resistant to *Phomopsis* blight. The lines DB-65, DB-31, Swarna Mani were found to be resistant against virus complex whereas Pusa Safed Baingan 1, DBR-131 were susceptible. The lines DBL-21, DBL-08 and DBL-175-5-1 were found to be heat tolerant.

Hybrids and varietal evaluation: Out of 45 hybrids, 35 were long fruited and 10 were round fruited. The round fruited hybrids, namely, DBHL-407, DBHL-1407 and DBHL-13 showed superior performance in terms of yield with an average yield of 38.07, 37.98 and 37.57 t/ha, respectively. Among the long fruited hybrids, DBHR-25 (41.76 t/ha) and DBHR-4070 (40.66 t/ha) were found promising for yield.

2.1.1.3 Chilli

Development of mapping population for leaf curl resistance and heat tolerance: Development of RIL mapping population (121 individuals) using DLS-Sel-10 as resistant parent and Phule Mukta as susceptible is in F_6 generation. This population is being developed for fine mapping of genes controlling resistance to leaf curl disease in chilli. F_2 and backcross mapping populations using A-161-1 as heat tolerant parent have also been generated and phenotyped for different morphological, physiological and biochemical traits.

Evaluation of chilli genotypes for capsaicin and capsanthin retention capacity: Forty chilli genotypes including varietal lines and stabilized breeding lines were evaluated for capsaicin and capsanthin retention capacity (C & CRC) after storage for six months. Most of the genotypes showed significant reduction in C & CRC after four months of storage. However, Byadgi Dabbii and KTPL-19 had highest ability to retain capsanthin even after six months of storage. Chilli Japani Long, LCA-424, Pusa Sadabahar and KTPL-19 manifested highest ability to retain capsaicin even after six months of storage. Two chilli genotypes DCHV-92 under AVT-I chilli varietal trials and DChV-274 under IET chilli varietal trials are being tested in AICRP (VC) at 27 locations across India during *Kharif* season 2022.

2.1.1.4 Capsicum

Identification of low temperature tolerant lines: KTC- 152 and KTC 144 that flower and set fruit at low temperature (5.2° C) under net house condition during December–January were identified.

Identification of promising lines for fruit set and quality: KTC-152 gave yield of 1.19 kg/plant and KTC-144 gave 1.02 kg/plant. Four selections have been made for the development of coloured capsicum (OP). Lines KTC-130 and KTC-145-1 were found promising for production of coloured capsicum of orange and red colour having good horticultural traits. F_1 hybrids like KTC-130 × Y W, KTC-142 × Y W (790 g/plant) and KTC-152 X KTC-131 (810 g/plant) was found promising for colour hybrids.

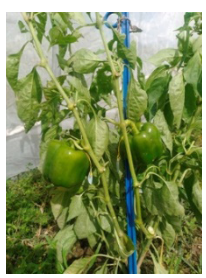
Evaluation of coloured capsicum germplasm under protected conditions: At ICAR- IARI regional station, Katrain, six genotypes of capsicum along with two check cultivars were evaluated for yield and its contributing traits. KTRC-13 (Red) (30.52 t/ha) followed by KTOC-4 (Orange) (30.36 t/ha), KTYC-5 (Yellow) (30.07 t/ha) and KTGC-10 (Green) (29.68 t/ha) performed better over the check cultivars *viz*., Pusa Capsicum-1 (Green) (22.57 t/ha) and California Wonder (Green) (19.70 t/ha).


KTRC-13


KTOC-4


KTYC-5


Pusa Capsicum-1


California Wonder

Hybrids evaluation: At ICAR- IARI regional station, Katrain, 35 hybrids of capsicum including one standard check cultivar (Asha) were evaluated for yield and its attributing traits. Among them, KTRC-11 × KTYC-23 (36.30 t/ha), KTRC-11 × KTGC-24 (36.26 t/ha) and KTOC-2 × KTGC-25 (35.63 t/ha) performed better over the check cultivar *viz*., Asha (27.82 t/ha).

Entries contributed in AICRP (VC) trials: From ICAR-IARI regional station, Katrain, two open pollinated genotypes (KTRC-13 and KTRC-14) were contributed to IET, while two entries (KTOC-1 and KTYC-17) were advanced to AVT-1 trials.

2.1.2 Cole crops

2.1.2.1 Cauliflower

New promising hybrids: CMS based F_1 hybrids (226) of early group cauliflower were evaluated during September–November maturity period. The promising new F_1 hybrids were DCEH-4108, DCEH-9808, DCEH-2307 for September maturity (>15 t/ha), DCEH-52415, DCEH-9830, DCEH-2315 and DCEH-2308 for October maturity (>20 t/ha) and DCEH-6730, DCEH-2310, DCEH-6709 and DCEH-2371 for November maturity (>25 t/ha). In mid-early group, the promising hybrids (>30 t/ha) were DCMEH-911, DCMEH 8461, DCMEH-8405, DCMEH 902, and DCMEH 911 for mid-November to mid-December. In mid-late group, DCMLH-2276, DCML were found promising.

H-8476, DCMLH-8414 and DCMLH-8411 for mid-December to mid-January harvesting have been identified. F_1 hybrids e.g. DCEH 31503, DCEH 7523 of early group; DCMH-8404, DCMH-8476 of mid group were advanced to AVT-I in AICRP (VC). Among orange cauliflower, DoCEH-1204, DoCEH-15419 and DoCEH 529819 in early group (>15 t/ha) and DoCMH-8423 and DoCMH-8419 (>20 t/ha) were promising and produced orange and acceptable curds.


DCEH 31503


DCEH 9830

DoCEH-1204

DoCEH-8419

Purple cauliflower: Out of 101 $F_{2:3}$ progenies from two crosses Pusa Ashwini × PPCF-1 and Pusa Kartiki × PPCF-1, 12 progenies were found to be promising for early maturity (October-November), attractive curd size (500-750 g) and flowering in December–January months including DC-6704-35 and DC-2304-61. Anthocyanin content in progenies ranged from 125.02 to 143.77 mg/100g FW. Homozygous purple F_2 plants were crossed with orange genotype (Or-4) for combining both *Pr* (anthocyanin) and *Or* genes in Indian cauliflower and purple colour of curd was observed as dominant phenotype.

Orange cauliflower: Selected $F_{2:3}$(256) and $F_{2:5}$(8) progenies raised and observed for curd phenotype and bolting behaviour. Of these, Or-4, Or-5, Or 325, Or-84-18-19 and Or-1-1 produced medium size curds (150-200 g) in October–November months. These genotypes produce proper flowers and pollens for use in hybrid breeding. Two DNA markers namely OrIC-123 (≈525 bp for *Or* locus) and OrIC-346 (≈275 bp for *Or* locus) were developed as co-dominant markers for *Or* gene.

2.1.2.2 Snowball cauliflower

Evaluation of CMS and inbred parental lines-based hybrids of snowball cauliflower: At ICAR- IARI Regional Station, Katrain, 90 F_1 hybrids were evaluated during 2021-22. Out of which 10 hybrids performed better than check cultivars *viz.*, Pusa Snowball Hybrid-1 (PSBH-1) and Himdev with a heterosis range of 1.67-41.58 and 6.60-48.45%, respectively. They were found suitable for harvesting during 1st week of February to 3rd week of March.

Screening and evaluation of cauliflower germplasm for off-season cultivation: Forty genotypes (lines/ hybrids) of cauliflower were screened for their curd formation ability during summer season. Only one hybrid *viz.*, KTCF-53A4 × KTCF-4B formed good quality curds with marketable curd weight up to 1.0 kg. This hybrid may be tested in multi-location trials before its release for off-season cultivation in hilly regions of the country.

Introgression of β-carotene (*Or*) and anthocyanin (*Pr*) rich genes in snowball cauliflower: BC_4 population of the introgressed β-carotene (Or gene) and anthocyanin (Pr gene) rich genes into different genotypes of snowball cauliflower (Pusa Snowball K-1 and Pusa Snowball K-25) was evaluated during winter season of 2021-22. The plants carrying β-carotene rich 'Or' and anthocyanin rich 'Pr' genes will be advanced to next generation based on their biochemical profiles.

Orange cauliflower (BC_4)

Purple cauliflower (BC_4)

KTCF-59A2×KTCF-70B

KTCF-74A1×KTCF-36B

KTCF-60A3×KTCF-33B

PSBH-1 (Check-1)

Himdev (Check-2)

Promising CMS and inbred parental lines-based hybrids of snowball cauliflower

Evaluation of promising snowball cauliflower hybrids in multi-location yield trials: Promising F_1 hybrids (14) were evaluated along with check cultivars at three different locations *viz*., Katrain, New Delhi and Solan. Among all, 13 hybrids were found superior over both the check cultivars *viz*., Pusa Snowball Hybrid-1 (PSBH-1) and Pusa Hybrid-301 (PH-301) with a heterosis range of 0.96-31.80 and 4.24-36.09 per cent, respectively and were found suitable for harvesting during 1st week of February to 1st week of March.

2021/KTCFH-6270

2020/KTCFH-7

2020/KTCFH-17

PSBH-1 (Check-1)

PH-301 (Check-2)

Utilization of yellow gypsum in cauliflower under variable environment: Effects of yellow gypsum application on yield and its contributing traits of snowball cauliflower var. Pusa Snowball K-1 during winter season of 2021-22 was studied at the farmer's field. In the first experiment, treatment comprising of 100% NPK (recommended dose of crop) + 20 t/ha FYM + 30 kg/ha sulphur through yellow gypsum was found best. Whereas, in the second experiment, farmers' practice on nutrient management (FP) followed by application of yellow gypsum @ 30 kg/ha was best for yield and its contributing traits.

Entries contributed in AICRP (VC) trials: During the year 2022, two open pollinated genotypes (KTCF-9B and KTCF-10B) and two CMS based hybrids (KTCFH-5975 and KTCFH-6037) of mid-season cauliflower along with two open pollinated genotypes (KTCF-38 and KTCF-40) of late-season cauliflower were contributed to AICRP (VC) IET. Two open pollinated genotypes (KTCF-36 and KTCF-37) and two CMS based hybrids (KTCFH-534 and KTCFH-6270) of late-season cauliflower along with two CMS based hybrids (KTCFH-514 and KTCFH-8470) of mid-season cauliflower were advanced to AVT-I. Besides, two open pollinated genotypes (KTCF-14 and KTCF-25) and two CMS based hybrids of mid-season cauliflower (KTCF-11 and KTCF-22) were advanced to AVT-II trials.

2.1.2.3 Broccoli

Evaluation of CMS based F_1 hybrids of broccoli: During the year 2021-22, 50 hybrids of broccoli were evaluated for yield and horticultural traits against a private sector hybrid Saki. Hybrid KTSA × EC-791397 recorded significantly higher head yield (28.58 t/ha) followed by KTSA × V-Pl-4-1 (24.42 t/ha) compared to best check *viz*., Saki F_1 (14.08 t/ha).

KTSA × EC-791397

KTSA × V-Pl-4-1

Development of high yielding DH lines of broccoli: During winter season of 2021-22, biochemical analysis of 13 genotypes (donors) and 1150 DH_1 lines was attempted and based on the different quality parameters, 38 promising DH_1 lines were identified.

Entries contributed in AICRP (VC) trials: Four hybrids (KTHB-303, KTHB-304, KTHB-3111 & KTHB-3411) of broccoli were advanced to AVT-I.

Tropical broccoli: In tropicalization process of broccoli, eight promising progenies (F:4) were evaluated and three of them namely DC-Brocco-33, DC-Brocco-51, and DC-Brocco-13-7 were found promising for early maturity (November 1st fortnight). These genotypes had medium size heads (25-350 g), medium buds and proper flowering and seed setting under Delhi conditions. A new tropicalized genotype DC-Brocco-13 (18.5 t/ha) out performed the check varieties Palam Samridhi (15.4 t/ha) and Pusa KTS-1 (13.5 t/ha).

2.1.2.4 Cabbage

Evaluation of CMS based F_1 hybrids of white cabbage: At ICAR- IARI regional station, Katrain, 35 hybrids of white cabbage developed by utilizing 5 CMS lines and 7 testers were evaluated for different horticultural and biochemical traits. Based on estimation of heterosis for yield, top hybrids showed 33.84 to 67.54 per cent increase over best standard check. On the basis of nutritional quality, hybrid 5A × EC-686713 recorded the highest CUPRAC value, total carotenoids, β carotene and ascorbic acid content (6.78 µ mol trolox/g, 2.31 mg/100g, 2.97 µg/100g and 26.55 mg/100g, respectively).


2A × EC-686715 **5A × EC-686708**


6A × CH-6 **2A × CH-6**

Evaluation of F_1 hybrids of red cabbage: Twenty-one CMS based red cabbage F_1 hybrids were evaluated against Pusa Red Cabbage Hybrid-1 as check. Hybrid KRGA × RC-1 recorded significantly higher marketable yield of 46.80 t/ha over the standard check (29.51 t/ha).


KGRA × RC-1 **PMA × KRG**

Entries contributed in AICRP (VC) trials: During the year, four hybrids of cabbage (KTCBH-213, KTCBH-513, KTCBH-230 and KTCBH-630) were contributed to IET. In addition, two open pollinated varieties (KTCB-24 and KTCB-30) and three CMS based hybrids (KTCBH-225, KTCBH-625 and KTCBH-619) were advanced to AVT-I trials.

2.1.3 Cucurbitaceous crops

2.1.3.1 Cucumber

Development and evaluation of gynoecious based F_1 hybrids: Out of 71 F_1 hybrids evaluated, gynoecious hybrids DCH-143 and DCH-148 yielded 25.8 and 26.1 t/ha, respectively, as compared to national check Pant Sankar Kharif (18.1 t/ha). Another 67 F_1 hybrids were developed using 5 gynoecious lines of cucumber of which two F_1 hybrids, DCH-143 and DCH-148, have been proposed for testing under AICRP (VC) and are under IET stage and two F_1 hybrids, IMPUCH-143 and IMPUCH-148, are under AVT-1 stage of AICRP (VC).

Inheritance and molecular mapping of ToLCNDV resistance in cucumber: All the F_1 hybrid plants of DC-773 x DC-70 were susceptible in nature. Inheritance pattern of ToLCNDV in the F_2 population and back cross population of DC-773 X DC-70 followed Mendelian mono-hybrid ratio of 3:1 for susceptible to resistance. Incase of back cross 1:1 where F_1 was crossed with resistant parent (DC-70) and when crossed with susceptible parent (DC-773), 1:0 susceptible to resistant ratio suggested the role of single recessive gene. Based on the ΔSNP-index, one QTL was identified on the chromosome 2. The SNPs in the QTL region were ToLCNDVCs_Sy30-2, ToLCNDVCs_VT30-2, ToLCNDVCs_Re-2 and SNPCS2_3 with LOD peaks between 3.07 and 3.93. A major QTL on chromosome 2 spanning from a region of 2.1 to 2.8 Mb with a length of 0.7 Mb has been identified.

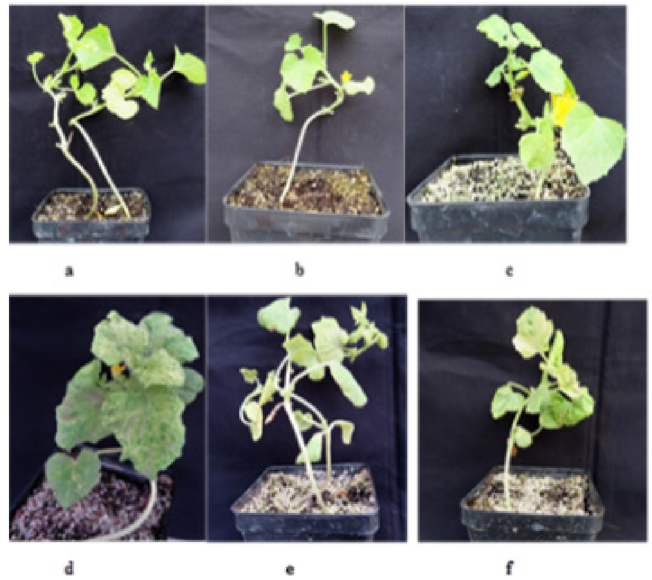
2.1.3.2 Muskmelon

Promising hybrids: Among 36 hybrids evaluated in open field, two hybrids DMH-18 (24.6 t/ha, TSS 11.9 °brix) and DMH-23 (23.8 t/ha, TSS 11.8 °brix) were found to be most promising in station trial.

Specialty melon hybrids DMH- 112 was found to be most promising with yield of 5.6 t/1000 m^2 followed by DMH-119 (5.4 t/1000 m^2) and DMH 139 (5.4 t/1000 m^2) under net house cultivation during off season. Novel monoecious line (DMM-31) with round fruit and excellent fruit quality was developed for easy and economical hybrid development and seed production with yield potential of 5.9 t/1000 m^2 in net house. In a station trial with 18 lines, DMM-207, DMM 216, DMM 208, DMM 230 and DMM 364 were found very promising for cultivation under net house. Specialty melon (*C. melo* var. *inodorous)* genotypes DHM-162 (5.2 t/1000 m^2 with green flesh and TSS 13.1 ^{o}brix), DHM 226(5.1 t/ 1000 m^2) and DHM-159 (5.0 t/1000 m^2) were found promising for protected cultivation with shelf-life 15 days more than muskmelon genotypes from *Cantalupensis* group.

Source of resistance for *ToLCNDV:* New sources of resistance to ToLCNV were identified from wild relatives of melon DSM 132 (*C. melo* var. *callosus*) with the minimum disease severity index (DSI) of 0.00 followed by DSM 19 (DSI 3.50, 4.50) and DSM-11-7 (DSI 7.00, 6.11) from *C. melo* var. *momordica* under natural epiphytotic screening. Resistance in these genotypes was further confirmed through challenge inoculation with the viruliferous whitefly carrying ToLCNDV in the greenhouse conditions, which showed a minimum vulnerability index in DSM 132 (VI, 2.0), DSM 19 (VI, 6.67) and DSM-11-7 (VI, 11.34).

Genetics of ToLCNDV resistance in new melon germplasm DSM 132 (*C. melo* var. *callosus*): Highly susceptible DOM 115 (*Cucumis melo* var. *conomon*) was crossed with the resistant source DSM-132 (*C. melo* var. *callosus*) to generate F_1, F_2, BC_1P_1 and BC_1P_2 populations for screening under natural epiphytotic conditions and validation through challenge inoculation with viruliferous whiteflies. It was concluded that complementary gene interaction between two independent genes was responsible for ToLCNDV resistance as F_2 segregated in 9:7 (resistant: susceptible) ratio**.** Similarly, highly susceptible Pusa Sarda (*Cucumis melo* var. *inodorous*) with desirable fruit characters was crossed with the resistant DSM-19 (*C. melo* var. *momordica*) to produce F_1, F_2, BC_1P_1 and BC_1P_2 populations for screening under natural epiphytotic conditions and validated through challenge inoculation with viruliferous whiteflies. Inheritance in DSM 19 was identified as monogenic recessive in both the screening methods.



Resistant genotypes, (a) DSM 132, (b) DSM 19, (c) DSM-11-7; Susceptible genotypes, (d) Pusa Sarda (e) DOM 115 (f) Pusa Sunehari

2.1.3.3 Bitter gourd

Promising hybrids: Hybrids DBGH-4 and DBGH-2163 have been promoted to AVT-I and DBGH 5201 and DBGH 4863 to AVT II trials of AICRP (VC). Twenty-eight hybrids were evaluated for yield and related traits and three best performing hybrids were G-21 × DBGS-2 (30.44 t/ha), G-48 × G-12 (28.96 t/ha) and G-21 × S-54 (27.66 t/ha). Two best hybrid combinations entered in IET trials of AICRP (VC).

Screening for virus resistance in bitter gourd and development of mapping population: Resistant line DBGS-2 and susceptible lines Pusa Purvi, Pusa Rasdar and Pusa Vishesh were confirmed for their true resistance/susceptibility with pure culture of ToLCNDV. The long fruited genotype, Sel-2 (DBGS-2) was found to be resistant to virus complex including ToLCNDV when grown under open field conditions with the vulnerability index of 16.33% under *Kharif* season with promising yield (25.23 t/ha). The susceptible/

resistant lines were confirmed for ToLCNDV using tomato leaf curl New Delhi virus primers. The cross combinations (DBGS-2 × Pusa Purvi, DBGS-2 × Pusa Rasdar and DBGS-2 × Pusa Vishesh) were developed and advanced to B_1, B_2 and F_2 population for genetic study of ToLCNDV in bitter gourd.

Promising selections for protected cultivation: DBGS-32 and DBGS-57 were found promising under polyhouse and net house conditions. Yield of 4.17 and 3.76 q/100 m^2 under polyhouse was recorded with fruit weight of 95 and 120 g, respectively. DBGS-32 yielded 4.68 q/100m^2 with average fruit weight of 131 g whereas DBGS-57 produced 4.11q/100m^2 with average fruit weight of 138 g under insect proof net houses and exceled in yield compared to private hybrids Nandita (VNR seeds), KSP1198 (Kalash Seeds) and Prachi (East West Seeds).

2.1.3.4 Bottle gourd

Screening for powdery mildew under artificial epiphytotic condition: Thirty-five genotypes including indigenous collections, exotic collections and cultivated varieties were screened at cotyledonary leaf stage for resistance to powdery mildew. IC0319838, IC337078, IC296733, EC800995 and EC750696 were found resistant with disease reaction ranging between 0-10%.

EC800995 (Resistant)

Pusa Naveen (Susceptible)

2.1.3.5 Sponge gourd

Promising hybrids: Out of 51 sponge gourd F_1 hybrids evaluated, DSGH-38 (17.2 t/ha) and DSGH-95 (16.3 t/ha) were found promising as compared to national check Kalyanpur Hari Chikni (11.8 t/ha). DSGH-38 entered in AVT-2, DSGH-95 was advanced to AVT-II and two new entries (DSGH-132 and DSGH-134) entered in AVT-1 of AICRP (VC) trials.

2.1.4 Malvaceae crop

2.1.4.1 Okra

Seventy-six hybrid combinations along with 26 private sector leading hybrids were evaluated for yield and resistance to Bhindi Yellow Vein Mosaic Virus (YVMV) and Enation leaf curl virus (ELCV). Three hybrids, namely, Pusa Okra Hybrid-1, DOH-6 (69x92) and DOH-7(7x92) were found to be highly resistant to both YVMV and ELCV. Fruit yield and quality of above hybrids were on par to the best private hybrids. Hybrid-9 (66x69) and Pusa Okra Hybrid-1 recorded fruiting at shorter internodes (4 cm). Hybrids DOH-3, Pusa Okra Hybrid-1 and DOH-6 were found to be moderately tolerant to leaf hopper.

Based on the natural epiphytotic screening *A. moschatus* (IC-141055), *A. tetraphyllus* (IC-90476-1) and *A. caillei* (SKM) showed less incidence of YVMV, and no incidence of ELCV. Lowest fruit setting and seed setting efficiency was recorded in *A. moschautus* derived population (5 and 27%, respectively), while seed setting efficiency was maximum in A. *caillei* (45%). The BC_1F_1 population of *A. moschatus* showed lowest value for number of seeds per pod (0.72) and low crossability of *A. moschatus* with cultivated okra.

2.1.5 Root crops

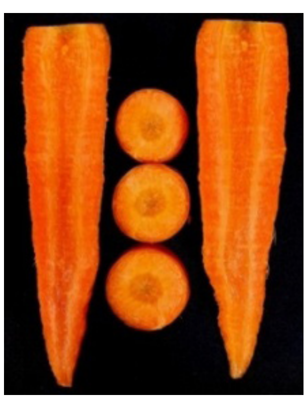
2.1.5.1 Carrot

Evaluation of breeding lines for yield and quality: In August end sowing, 48 genotypes/ inbred lines were assessed and based on the quality for root shape, surface, colour and appearance; the genotypes DCat-4, DCat-13 and DCat-91 were found promising. Sixty-five genotypes/ breeding lines were assessed for quantitative and quality traits during normal season and based on root shape, surface, colour and appearance, the promising high yielding genotypes identified were DCat-13, DCat-20 P, DCat-36, DCat-53, DCat-98, DCat-105 and DCat-112.

Evaluation of hybrids for yield and quality: In normal season, 112 CMS based F_1 hybrids of tropical carrot were assessed for quantitative and qualitative traits. Based on the quality for root shape, surface, external and internal colour, self-core and external appearance, the promising high yielding F_1 hybrids with red colour were DCatH-533, DCatH-532, DCatH-113, DCatH-775, DCatH-537, DCatH-73 and DCatH-988. Whereas in orange root colour group, DCatH-711 was found promising. Among 48 CMS based F_1 hybrids assessed for total carotenoids, lycopene, β-carotene and total antioxidant activity, promising hybrids were DCatH-9837 for total carotenoids (79.04 µg/g fw), lycopene (42.07 µg/g fw) and β-carotene (33.84 µg/g fw) contents, and DCatH-736 for total antioxidant activity (16.33 mg GAE/100 g fw).

Entries in AICRP (VC) trials: Two hybrid entries (DCatH-73 and DCatH-13) entered in tropical carrot hybrid IET trial for evaluation under different zones and two hybrid (DCatH-7 and DCatH-19) advanced to AVT-I of AICRP (VC) trials.

Evaluation of temperate carrot germplasm: At ICAR- IARI regional station, Katrain, six genotypes of temperate carrot along with Nantese as check cultivar were evaluated for different quantitative traits. Among all genotypes, KT-17-1 (Yellow) (29.38 t/ha) followed by KT-35 (Orange) (27.94 t/ha) and KS-60 (Orange) (26.70 t/ha) performed better over the check cultivar Nantese (25.708 t/ha).

KT-17-1 **KT-35**


KT-60 **Nantese**

Evaluation of CMS based F_1 hybrids of carrot: One hundred F_1 hybrids of temperate carrot were evaluated for yield and its contributing traits against Pusa Nayanjyoti as check. A total of 5 hybrids *viz.*, KT-62 A × KS-73 (33.55 t/ha), KT-10 A × KS-17-1 (33.26 t/ha), KT-10 A × KS-22 (28.64 t/ha), KT-28 A × New Kuroda (28.13 t/ha) and KT-7A × KS-17-1 (27.47 t/ha) were found superior than the check cultivar (25.71 t/ha).



KT-62 A × KS-73 **KT-10 A × KS-17-1** **KT-10 A × KS-22**


KT-28 A× New Kuroda **KT-7A × KS-17-1**

Entries contributed in AICRP (VC) trials: Four open pollinated varieties *viz.*, KTTC-17, KTTC-21, KTTC-22 and KTTC-73 of temperate carrot were contributed to IET and four CMS based hybrids (KTTCH-804, KTTCH-954, KTTCH-2859 and KTTCH-9659) of temperate carrot were advanced to AVT-I trials.

2.1.5.2 Radish

Promising genotype Selection-14: The colour of petiole and root skin of Selection-14 is pink. It attains marketable maturity in 50-53 days after sowing during *rabi* season. The roots are 7-8 cm long, 3.5 cm in diameter with average root weight of 75 g. The average root yield is 18-20 t/ha.

Selection-14

2.1.6 Bulbous crops

2.1.6.1 Onion

Breeding for superior varieties/hybrids during *kharif* season: Two elite lines POS20K (2020ENTO) and POS24K (2020HORT) were evaluated along with the recommended onion varieties suitable for *kharif* season. POS20K yielded higher (18-100%) compared to recommended varieties *viz*., Bhima Dark Red (BDR), Bhima Super, Phule Samarth and Phursungi Local.

POS24K

POS20K

POS24K (white breeding line) yielded higher (47%) than Bhima Shubra and around 90% higher than PWR.

Breeding for bolting tolerance during *late kharif* season: Fifty-three polycross breeding lines were evaluated for bolting resistance during late *kharif* season and all accessions had more than 80% bolting.

Breeding for *rabi* season onion: Forty-five onion accessions were evaluated for biochemical parameters, mineral composition and yield. A wide variation for dry matter (6.9-14.7 g/100g), TFC (16.2 – 64.5 mg QE/100g FW), TPC (10.0-31.2 mg GAE/100g FW), pyruvic acid (4.9-18.4 µmol/g FW), TSS (7.0-14.4 °B), Vit. C, CUPRAC, FRAP and DPPH was observed. Wide range of variation for various mineral contents (Ca, Cu, Fe, Na, K, Mg, Mn, Zn and S) was also observed. Pusa Madhavi (46.6 t/ha) was the highest yielder followed by B780 (45.2 t/ha).

Evaluation of long day red onion germplasm: At ICAR- IARI regional station, Katrain, 5 inbred lines with red colour were evaluated along with check cultivar *viz*., Brown Spanish for different horticultural traits. Among these, KTON-8 (44.24 t/ha), KTON-66 (43.59 t/ha), KTON-51 (42.93 t/ha) and KTON-21 (40.89 t/ha) were found superior than the check cultivar (32.80 t/ha).

KTON-8

KTON-66

KTON-51 KTON-21

All India Network Research Project on Onion and Garlic: Under AINRPOG, onion entries in *rabi* (58) and in garlic (27) were tested for yield and other traits. In addition, two open pollinated genotypes of long day onion *viz*., KTON-51 and KTON-66 were contributed for testing under AINRPOG.

2.1.7 Leguminous crops

2.1.7.1 Garden pea

New genetic material developed for high yield and disease resistance: Evaluated 25 new bulks derived from F_6 generations breeding materials against 3 checks (Pusa Shree, VRP 6 and Arkel). Among these, 10 lines were grouped as early and 8 medium maturity. The promising genotypes in early group were GP 1501 (10.83 t/ha), GP 1502 (11.25 t/ha), GP 1504 (12.70 t/ha), GP 1802 (12.08 t/ha), GP 1803. In medium maturity group, genotypes having high degree of powdery mildew resistance were GP 1503, GP 1505 and GP 1804.

Validation of *Fw* gene (*Fusarium* wilt resistance) linked CAPS marker in cultivated and wild garden pea: *Pisum* accessions (130) including alien species *viz*., *Pisum fulvum, Pisum elatius, Pisum sativum* var. *elatius, Pisum sativum* and commercial susceptible garden pea varieties (Kashi Nandini, Kashi Uday, MA-7, Pusa Pragati, Arkel and PB-89) were grown in the artificial sick pots. Among the 70 genotypes of *P. sativum* var. *Hortense*, 12 genotypes (GP2230, GP2239, GP2208, GP2215, M1, M6, M7, M8, M9, M11, M12, M13) and two genotypes (N-3, N-13) of *P. fulvum*, one genotype (M2) of *P. elatius*, four genotypes (N-6, N-8, N-11 and N-14) of *P. sativum* ssp. *elatius* were found to have strong resistance against *Fusarium* wilt (fop-1). These cultivated and wild genotypes were validated genotypically by using functional CAPS marker (THO) linked with *Fw* gene.

Screening of garden pea lines for heat tolerance: A set of 85 garden pea genotypes were assessed for heat tolerance under both controlled and field conditions. At seedling stage, there were 19 tolerant and 14 moderately tolerant genotypes and at reproductive stage there were 5 tolerant and 2 moderately tolerant. The genotypes with tolerance under field condition were GP-61, GP-1104, GP-912-II, GP-915-II, GP-902, GP-48, EC-598646, EC-598654, EC-598638 and EC-598649 at the seedling stage screening.

Development of RILS for *Fusarium* wilt resistance using inter-specific hybridization: The RILs population at the stage of F_4 *viz*., PSM-3 × *Pisum sativum* ssp. *elatius* 'N-8', Pusa Pragati × *P. sativum* ssp. *elatius* 'N-14', VRP-6 × *P. sativum* ssp. *elatius* 'N-8', PB-89 × *P. sativum* ssp. *elatius* 'N-14', MA-7 × M-1, PB-89 × *P. sativum* ssp. *elatius* 'N-8' were developed using single seed descent method. This would be useful mapping population to map *Fw* gene in *P. sativum* ssp. *elatius.*

Entries in AICRP (VC) trial: Two entries GP1101 (Early) and GP 1505 (powdery mildew resistance) were advanced from AVT-I to AVT-II. Two entries GP1504 and GP1802 were advanced from IET to AVT-I garden pea trials.

2.2 FRUIT CROPS

2.2.1 Mango

Evaluation of hybrids: Mango hybrids (63 Nos.) were evaluated for 15 physico-chemical traits, of which the maximum fruit weight was observed in H-1-5 (352.66 g) followed by H-1-11 (327.58 g), NH-20-2 (326.65 g) and NH-18-4 (279.10 g). Pulp content in hybrids varied from 45.01 (H-7-4) to 73.80 (NH-16-2) per cent and TSS ranged from 14.5 to 26.2 °Brix. Mango hybrids *viz*., NH-17-1, NH-18-4, NH 20-2, NH-19-2, H-11-2, H-12-5 and H-3-2 had attractive red coloration on fruit shoulder and Pusa Manohari (H-8-11) showed field tolerance to floral malformation.

DUS characterization of mango hybrids: Mango hybrids (24 Nos.) bred at the Institute were characterized. Significant differences were observed for leaf, inflorescence, flowering and fruit parameters.

Most of the hybrids (91.6%) showed presence of twisting leaf blade, except H-3-2 and H-4-8. Inflorescence length was maximum in H-7-1 (46.58 cm). Pusa Manohari had strongest anthocyanin coloration on rachis and Pusa Pratibha showed early flowering. The fruits of Pusa Lalima matured early. Based on morphological parameters, a barcode has been generated for all 24 mango hybrids.

Molecular characterization of mango hybrids: Molecular characterization of 24 mango hybrids was attempted using 89 polymorphic HMSSRs. The PIC value varied from 0.04 (HMSSR1382) to 0.72 (HMSSR1289) with an average of 0.39. Model based population structure analysis broadly grouped mango hybrids into two major classes. The generated allelic profile of polymorphic markers has been translated into DNA barcodes of 24 mango hybrids. Total 11 hybrid specific alleles have been identified of which seven hybrid-specific alleles could be validated. The present set of HMSSRs was found to be highly informative and will serve as a useful resource for future molecular research in mango.

Molecular understanding of scion-rootstock interaction: The interactive effect of rootstock on quality attributes of scion genotypes was studied using five mango varieties grafted on three rootstocks *viz*., Kurukkan, Olour and K-5. A total of 25 physico-chemical parameters were studied and most of these parameters were found to be influenced by the rootstock genotypes upon grafting. The Olour rootstock proved best to improve the fruit quality and shelf-life of scion varieties. Physico-chemical parameters-based clustering did not group scion varieties precisely according to their grafted rootstock. A total of 24 shelf-life-specific polymorphic SSRs were screened and cluster analysis clearly showed that scion grafted on Kurukkan and Olour rootstock have more similarity while scion varieties grafted on K-5 rootstock grouped together.

2.2.2 Citrus

Development of acid citrus scion hybrids: The hybrid, ACSH-7-14/18 yielded bigger fruits (89.40 x 65.40 mm width) with higher juice content (76.40 ml/ fruit). Number of seeds per fruit was least in Pusa Abhinav (14.56) with highest titratable acid (6.65%) in juice. Hybrids ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18 and Konkan SL yielded the fruits with thin peel (1.03-1.57 mm). Among the 10 hybrids, the highest number of fruits was recorded in ACSH-7-14/18 (40 fruits/ plant). Hybrids ACSH-3-2/18 and ACSH-3-15-18 along with Konkan SL and Pusa Abhinav fruited twice. Two hybrids (ACSH-3-4/18 and ACSH-3-14-18) were tolerant, eight were immune (ACSH-3-2/18, ACSH-3-15/18, ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18, ACSH-7-14/18, ACSH-7-15/18, ACSH-9-1/18 and Konkan SL) and only one (Pusa Abhinav) was susceptible to citrus canker.

Development of sweet citrus for enhanced nutritional properties: The mineral nutrients P, K, Ca, Mg, Fe, Zn, Mn, Cu, Na and Cl content in the fruit juice exhibited significant differences. The highest P content was registered in SCSH-9-2/12 (114.69 ppm) while, hybrid SCSH-9-10/12 outperformed for K content (1195.47 ppm). The Ca content was significantly higher in SCSH-13-17/12 (662.40 ppm). SCSH-5-10/12 proved the richest source of Mg (101.76 ppm). SCSH -9-6/12 proved superior for Fe content (6.53 ppm) while SCSH -9-17/12 hybrids excelled for Zn (2.97 ppm) and Mn (1.24 ppm) contents. Two hybrids, namely, SCSH-7-2/12 and SCSH -9-6/12 proved equally good to have the highest Cu content (0.84 ppm in each). The hybrids SCSH-9-6/12 and SCSH-9-10/12 outperformed for Na content (42.40-44.00 ppm).

Assessment of Redblush grapefruit mutants: Three mutants of Redblush grapefruit were evaluated for yield and fruit quality. RB-2 and RB-3 proved statistically similar for high TSS content (10.10°-10.46°B). RB-1 and RB-2 were found to have thinner peel (3.25-3.52 mm). The highest juice content was recorded in RB-2 (54.97%).

Evaluation of Darjeeling Mandarin: Twenty accessions of Darjeeling mandarin have been assessed for yield and fruit quality parameters. OL-22 was found promising with respect to high fruit weight (153.80 g),

Promising lines of Darjeeling Mandarin

fruit volume (148.90 ml), pulp weight (112.20), no. of segments (9.70), seed weight (3.12 g) and juice content (68.90 ml). While, BTL-22 recorded highest TSS of 11.20° Brix, ascorbic acid (32.56 mg/100ml of juice) and total sugar (9.04%). Highest fruits/plant was recorded in CSP-22. Based on yield and other horticultural traits, OL-22, BTL-22 and CSP-22 were found promising.

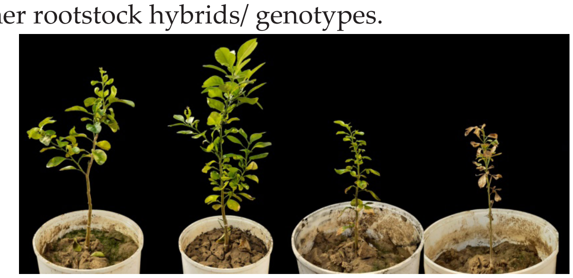
Collection and characterization of pummelo clones: The fruit size in the accessions 628798, 628799 and 628800 was found ideal (medium-sized). The accession 628798 bore thin-skinned (1.15 cm) and the accessions 628799 and 628800 bore dark red-fleshed fruits with solid core.

Thin Rind Fruit

Dark Red Fleshed Fruit

Collection of Citrus Germplasm: *Citrus jyambiri* (Kali Jyambir), *Citrus maxima* (Bhogate), *Citrus limonia* (Rangpur lime), *Citrus reshni* (Cleopatra Mandarin), *Citrus medica* (Bimbira Large), *Citrus medica* (Bimbira Small) have been collected from different parts of West Bengal.

Rootstock breeding for *Phytophthora* and salt tolerance: Four polyembryonic rootstock hybrids namely, SCSH 17-12 and SCSH 9-19 (Pummelo × Sweet orange) and CRH 21-9 and CRH 21-13 (Pummelo × Tryer citrange) were evaluated against the NaCl (50 mM) induced salinity. Of these hybrids, SCSH 17-12 and SCSH 9-19 were found highly tolerant (in respect of defoliation) showing lesser effects of salinity over other rootstock hybrids/ genotypes.



SCSH 17-12 SCSH 9-19 CRH 21-13 CRH 21-9

Cleopatra X639 Jatti Khatti

Citrus rootstocks under 50 mM NaCl salinity stress

***In vitro* mutagenesis in Kinnow mandarin:** Since the nodal explant gave poor response with respect to *in vitro* regeneration, modified *in-ovulo* nucellus culture technique was attempted. Comprehensive examination of different developmental stages confirmed the optimum explant development in 21-25 mm (Stage III) fruits during last week of May to first week of June. Identified ovule stage induced direct somatic embryos from micropylar end on induction medium containing DKW + kinetin 5.0 mg L^{-1} + malt extract 1000 mg L^{-1}. Anatomical and molecular studies confirmed the single cell origin of somatic embryos and genetically stable emblings.

***In vitro* mutagenesis in sweet orange:** Protocol for indirect embryogenesis in sweet orange was standardized. Callusing was observed to be significantly higher in the treatment combination of MS + 2,4-D (1.5 mg L^{-1}) + BAP (1.0 mg L^{-1}) + ME (500 mg L^{-1}) with epicotyl proved best for callusing. Embryogenesis (59.09%) and germination (33.61%) were achieved best in MS + BAP (2 mg L^{-1}) + NAA (0.1 mg L^{-1}) + ME (500 mg L^{-1}). Among different carbon sources, 5% glycerol supplemented with the same treatment combination proved best in inducing the highest number of SE/ callus mass (73.26), SE (65.27%) and plantlet formation (68.77%).

2.2.3 Grape

Augmentation of germplasm: The dormant cuttings of different wild *Vitis* species *viz*., *V. himalayana*, *Parthenocissus* (EC452215), *V. ficifolia* (EC452206) and *V. riparia* (EC 452207) received from NBPGR RS Phagli (H.P.) were planted in the pots. Identified one unique grape genotype having extra early maturity (15 May 2021) and loose bunches having a difference in the date of natural bud break at least 20 days between the extra early genotype and the late genotype Pusa Seedless.

Evaluation of hybrids: Twenty-two grape hybrids developed in the background of Pusa Navrang were evaluated for juice purpose. Hybrids 16/2A-R4-P9, 16/2A-R2-P7, 16/2A-R4-P7 and 16/2A-R3-P3 have been identified for juice purpose. The improved hybrids have the better berry weight and yield potential than the Pusa Navrang. The maximum juice recovery was recorded in hybrid Hyb.16/2A-R4P9 followed by Hyb. 16/2A-R4P7' as compared to the Pusa Navrang. In addition, it was also found superior in terms of bunch weight and yield per vine basis. The berries are seeded and ten turier in nature, which matures by the 2nd week of June.

16/2A-R4-P9 16/2A-R4-P7

2.2.4 Guava

Guava hybrids released for Delhi NCT

Guava: Pusa Pratiksha (GH-2015-7A): It is a cross between Hisar Safeda × Purple Guava. It has white pulp, soft seeds, excellent flavour and better fruit quality. Average fruit weight (172.5 g), ascorbic acid content (190.46 mg/100 g of pulp), total soluble solids (12.7^{o} Brix), total phenolic content (165.72 mg/100 g GAE of FW) and titratable acidity (0.45-0.51%) with average yield of 35-40 t/ha.

Pusa Pratiksha

Guava: Pusa Aarushi (GH-2016-2F): It is a smooth surface pink pulped hybrid between Pant Prabhat × Arka Kiran having excellent nutritional quality and yield potential. Average fruit weight (190-210 g), antioxidant activity (3.7-4.5 mg/100 g of FW), total flavonoids (55.45-81.45 μM TE/g FW), ascorbic acid (158.97-175.6 mg /100 g of pulp), total soluble solids (11.56 °Brix), phenolic content (125.73- 140.00 mg/100 g GAE of FW) and titratable acidity (0.41-0.45%) having yield potential of 40-45 t/ha.

Pusa Aarushi

Germplasm augmentation: A total of 35 guava genotypes seeds were introduced from the USDA, Hilo through NBPGR, New Delhi. Out of which, 23 genotypes seedlings were planted in the field gene bank of the guava. Besides, 20 new guava genotypes were collected from the various ICAR institute, State Agricultural University and planted in the field gene bank.

Hybrid evaluation: The pink pulp guava $F_{1,}$ HSU× SH-16-8-2 and white pulp $F_{1,}$ HSU× SH-16-8-18 were found promising. The $F_{1,}$ HSU× SH-16-8-2 contained 5.806 mg/100g lycopene, 4.611 mg/100 g total anthocyanins, 0.879 mg/100 g total carotenoids with TSS 17.2 °Brix while $F1_{,}$ HSU× SH-16-8-18 has more pulp thickness (14.75 mm) with TSS 16.4 °Brix.

HSU x SH-16-8-2

HSU x SH-16-8-18

2.2.5 Papaya

Hybrids evaluation: A total of 36 papaya genotypes including six inbred lines and 30 hybrids were evaluated for different traits. Parent genotypes, PN (63.0 cm) followed by P-9-12 (78.67 cm) had shortest plant height (at flower initiation) while P-7-9 (95.67 cm) and PS 3 (83.67 cm) had tallest plants. The fruit weight was found maximum in the hybrid, P-7-2 × P-9-12 (1075 g) followed by P-9-12 × P-7-2 (1074 g) and PN × P-7-2 (1063 g). In parent genotypes, maximum yield per plant was recorded in PS3 (53.49 kg) followed by P-9-5 (46.07 kg), while lowest in PN (24.20 kg). In hybrids, P-9-5 × P-7-2 (56.98 kg) had highest yield followed by P-9-12 × P-7-2 (55.08 kg) while lowest was in hybrid, P-7-2 × PN (27.74 kg).

Evaluation of papaya genotypes for low temperature tolerance: Pusa Nanha, Red Lady, P-9-5, P-7-9, and wild species, *Vasconcellea cundinamarcensis* were evaluated under low temperature in controlled conditions. *V. cundinamarcensis* showed greater tolerance to low-temperature stress followed by P-9-5 and P-7-9 having the highest RWC, MSI, chlorophyll content, total soluble proteins, and proline contents. In LTS-treated papaya genotypes *viz*., P-9-5 and *V. cundinamarcensis*, a sum of 106 proteins (72 upregulated and 34 down regulated SAAPs) and 116 proteins (76 upregulated and 40 downregulated) were differentially expressed.

2.2.6 Temperate fruit crops

One unique walnut of four years of age having cluster bearing habit of seven fruits in a bunch was identified. Walnut genotypes (15) were evaluated for phenotypic diversity and to select superior trees. Among the accessions, dry nut weight ranged from 9.9 to 12.2 g. Nut size index was found in between 33.5 to 40.5 mm and 41.5–51.5% of kernel recovery was observed.

Bunch bearing Walnut

Performance of pomegranate genotypes (Ichakdana, Mohammad Ali, Jellore Seedless, P-26, Nabha, Ganesh, Kandhari Hansi, Kandhari Kabuli, Jodhpur Red, P-23, G-38) were assessed for yield as well as physico-chemical characters. Fruit weight varied from 105.9-399.9 g in different genotypes and TSS ranged from 11.9-15.5 °Brix.

Performance of plum cultivars was studied on Behmi rootstock for yield, quality and shelf life. The maximum average fruit weight was recorded in Black Amber (69.65 g). Vitamin-C content in different cultivars varied from 7.81-10.74 mg/100 g. However, total sugar content was maximum in Santa Rosa (11.59%). Maximum shelf-life was recorded in Black Amber (28 days) with lowest in Satsuma (4 days) at room temperature.

Studies on pruning severity and time in kiwi was conducted. Pruning of 50% of previous season growth during 18-25 January gave better yield and quality. Apricot collections were evaluated and fruit weight varied from 34.1-92.8 g, TSS ranges from 16.9-23.5 ^{0}brix.

Germplasm of temperate fruit crops maintained in field gene bank: Apple (96), pear (17), peaches and nectarine (15), prune and plum (09), apricot (28), strawberry (105), kiwi (08), walnut (19), almond (09), persimmom (05) and cherry (16).

2.2.7 Production technologies of fruit crops

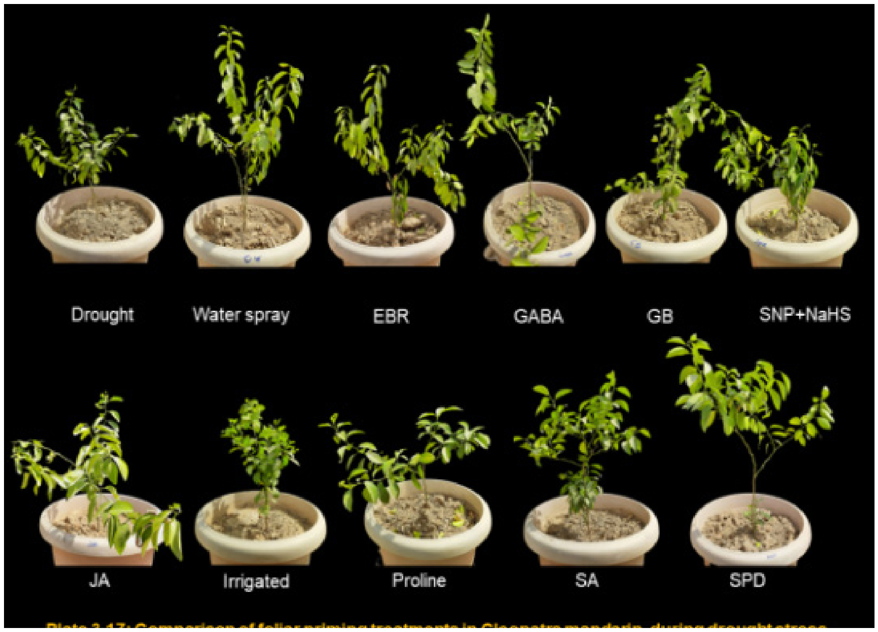
2.2.7.1 Mango

Manipulation of canopy vigour in mango scion cultivars using rootstocks: The performance of mango varieties, grafted on five polyembryonic rootstocks has evaluated. Pusa Arunima had higher canopy volume (261.48 m^3) and K-2 rootstock imparted the dwarfness to all the mango varieties. The highest yield efficiency (0.65 kg/m^3) and yield/m canopy diameter (12.72 kg) was recorded in Amrapali, while grown on K-2 rootstock. K-3 and K-2 rootstocks excelled for fruit weight (197.41 g) and acid content (0.31%), respectively. Amrapali proved superior for high TSS (23.28-24.90° B) on Olour and K-3 rootstocks, while highest content of titratable acid (0.42%) was recorded in the fruits of Pusa Surya, when grown on K-2 rootstock.

2.2.7.2 Citrus

Evaluation of Darjeeling mandarin on different rootstocks: Darjeeling mandarin budded on rough lemon gave a greater number of fruits/tree (76.32/ tree). Fruit weight (109.25 g) was maximum on rough lemon. The juice recovery percentage was maximum on rough lemon (51.24%). The trees on rough lemon accumulated more N and Ca (2.75% and 2.61%, respectively).

Alleviation of abiotic stress effect in citrus: Among nine citrus rootstocks screened against three weeks of drought stress, X639 was found tolerant, while Cleopatra mandarin proved highly susceptible to drought. X639 exhibited highest relative shoot increment (RSI) of 8% under drought conditions followed by RLC 1. At the end of drought stress and rewatering, all rootstock genotypes were observed for negative leaf change (-12% to -62%), except X639 and RLC-1. Based on potential stomatal conductance index (3.03), leaf gas exchange parameters, relative water content, membrane stability index, higher photosynthetic pigments and chlorophyll stability index under drought stress, X639 rootstock was found to be most tolerant to drought stress.



Comparative influence of new generation chemicals on Cleopatra rootstock under drought stress

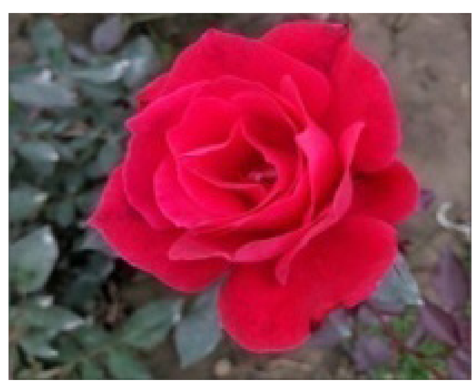
Drought mitigation through new generation chemicals in citrus: Drought mitigating plant bioregulators (PBRs) *viz*., 24 epibrassinolide, γ-aminobutyric acid, glycine betaine, jasmonic acid, proline (PRO), salicylic acid (SA), SNP + NaHS and spermidine (SPD) were used on contrasting rootstocks namely Cleopatra mandarin (drought susceptible) and X639 (drought tolerant). Priming treatments with PRO, SPD, SA significantly reduced the leaf wilting and leaf drop (ranging from 17 to 51%) in Cleopatra mandarin at the end of drought stress. It significantly increased the percentage of fully open stomata (87, 76 and 57%, respectively) compared to drought stress in both genotypes. During drought stress, significantly higher RWC (>72%) and MSI was recorded in Cleopatra mandarin with foliar priming of PRO, SA and SPD.

Evaluation of sweet orange on potential rootstocks for tree vigour, yield and fruit quality: The tree vigour, fruit yield and quality of two newly released cultivars of sweet orange (Pusa Sharad and Pusa Round) were significantly influenced, while budded on different rootstocks. Overall, C 35 and Yama Mikan rootstocks proved dwarf for Pusa Sharad. RLC-6 and C 35 rootstocks proved high yielding for Pusa Sharad (17.34 kg/ tree) and Pusa Round (20.70 kg/ tree), respectively. The highest juice content in the fruits of Pusa Sharad (54.74%) was recorded while grown on C 35. The rootstocks C 35, X639 and Yama Mikan proved equally good to impart higher TSS in the fruit juice of Pusa Sharad (8.10°-8.22° B) and Pusa Round (8.00°-8.30° B).

2.3 ORNAMENTAL CROPS

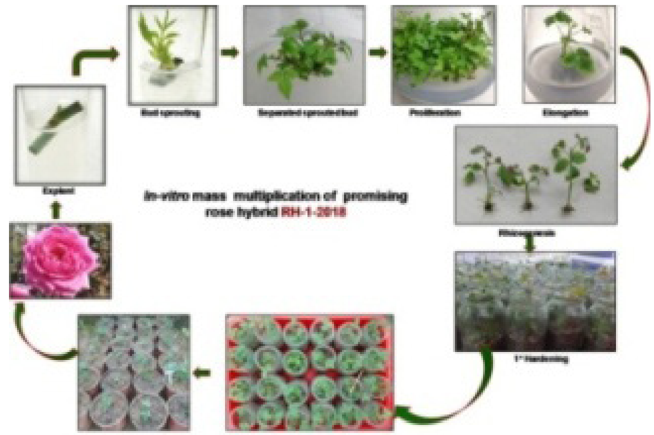
2.3.1 Rose

Rose: Pusa Lakshmi: This variety belongs to Floribunda group and has mild fragrance. It is propagated by semi hard wood cuttings and budding. The variety is highly floriferous and has recurrent flowering. The variety is ideal for garden display purpose. This variety was released for Delhi NCT by Delhi State Seed-Sub-



Pusa Lakshmi

RH-3-2018



In-vitro protocol for multiplication

committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

Pusa Bhargava: This variety belongs to Hybrid Tea group of rose. The flowers are double, compact, red-purple in colour. The variety is highly floriferous and has recurrent flowering. It is propagated by budding. The variety is ideal for garden display purpose and flower arrangements. This variety was released for Delhi NCT by Delhi State Seed-Sub-committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

Promising hybrids of rose

RH-3-2018 (BRRS-3): It belongs to a Floribunda group. It produces pink coloured medium sized blooms. It has fragrant flowers, less petal shedding, compact and more flower anchorage. The *in vitro* protocol for multiplication of RH-3-18 has been standardized.

RH-1-2019: It belongs to a Hybrid Tea group. It produces creamish white coloured medium sized blooms. The plants are short and narrow bushy. The *in-vitro* protocol has been standardized for mass multiplication of the promising hybrids and RH-1-2019.

Marker-trait association studies to identify genomic regions governing flower-related traits in rose: In rose, a total of 29 SSR loci were found to be associated with different flower related traits. One SSR loci RhAB-38 was found to be associated with the number of petals per flower, SSR loci MK-2171, MK-122501 were associated with flower diameter, SSR loci 476,CL-388 1,CTG-356, MK-2171, Rh-60 were associated with petal

In-vitro protocol for multiplication of the promising hybrid (RH-1-2019) length, SSR loci CTG-356 was associated with petal width, SSR loci Rh-48, 466, MK-124082, MK-122502 were associated with flower weight. SSR loci, C-139, CTG-356 were associated with anthocyanin content, SSR loci 490, CTG-356, Rpu-14 were associated with number of flowers per plant.

2.3.2 Marigold

Pusa Utsav: It produces compact and medium sized flowers of orange colour. The variety is very floriferous and gives high flower yield (18-20 t/ha). In northern plains, it flowers during October-November (festive season). It is suitable for loose flower production and bedding/ landscape purposes. This variety was released for Delhi NCT by Delhi State Seed-Sub-committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

Pusa Parv: It produces compact and medium sized flowers of dark red colour. The variety is very floriferous and gives high flower yield (18-20 t/ha). In Northern plains, it flowers during October-November (festive season). It is suitable for loose flower production as well as for bedding/landscape purpose. This variety was released for Delhi NCT by Delhi State Seed-Sub-Committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

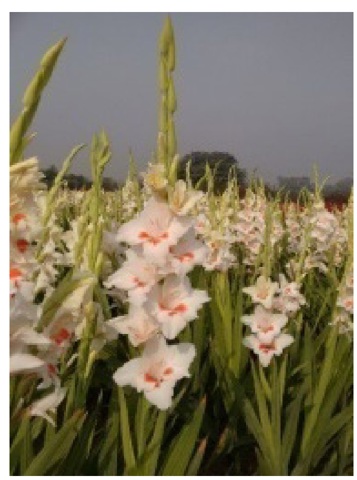
Pusa Utsav

Pusa Parv

Development of protocol for production of doubled haploids in African marigold: In order to improve the gynogenesis efficiency, induced parthenogenesis approach using irradiated pollen technique was attempted in marigold. Flower buds (before anther dehiscence) of French marigold genotype 'Pusa Deep' were irradiated with different doses of gamma radiations *viz*., 0, 100, 200, 300, 400 and 500 Gy. The irradiated pollen were used to pollinate the flower buds of DAMH-24 and DAMH-55 and the pseudo-fertilized ovaries, 25-30 days after pollination, were excised and cultured under *in vitro* conditions to rescue the embryo induced through parthenogenesis. The irradiated pollen technique was found effective in enhancing the parthenocarpic embryo development in marigold. The pseudo-fertilized ovaries cultured under *in vitro* conditions showed better direct germination response than the unfertilized ovaries.

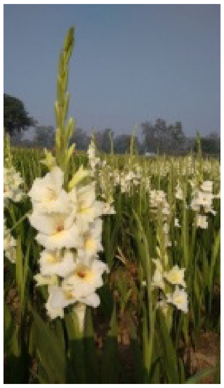
2.3.3 Gladiolus

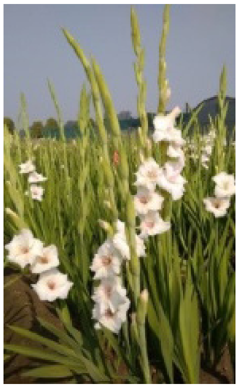
Pusa Rajat: It produces 19-21 white coloured florets with red spot on tepals. It is a very good multiplier and each plant produces on an average 3.33 corms and number of cormels are also more ranging from 65-70 per plants. It is a multicolour variety and florets are highly attractive and can be used at any occasion for various purposes. This variety was released for Delhi NCT by Delhi State Seed-Sub-Committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

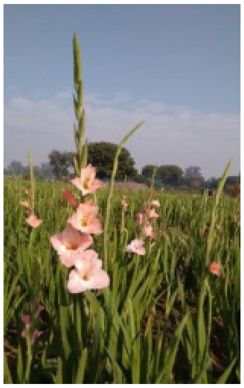


Pusa Rajat


Green Pasture x Regency


Chandni x Snow Princess


High Hopes x Open Seedling


Melody Open Seedling

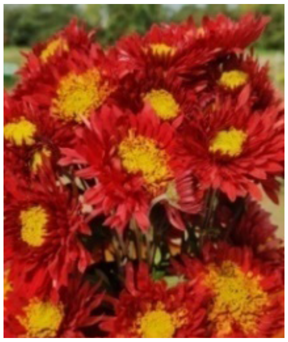

P-16-1x Eurovision

Evaluation of promising gladiolus hybrids for commercial traits: Twenty-nine promising hybrids including check variety White Prosperity were evaluated for different traits. The results indicated that early flowering in Chandni x Snow Princess, P-16-1 x Eurovision, Melody Open Seedlings and High Hopes Open Seedlings ranging from 76.0 – 88.3 days after planting. Hybrids AVE x Mayur, Vidushi Mutant, Mayur x Howard, PB x LS, Mayur x GW and Green Lilac Open Seedlings exhibited more than 19 florets per spike.

Pollen viability and pollen size studies in gladiolus: Pollen viability and size of 21 genotypes of gladiolus were examined. Pollen viability ranged from 92-100% and Pusa Srijana and Pusa Red Valentine recorded cent percent viability followed by the Berlew (open), *Gladiolus callianthus,* Howard, Pusa Mohini, Sancerre, Shweta, Smoky Lady, Oscar and Sunayana which recorded pollen viability of 99%. The polar axis length of pollen ranged from 141.15 to 283.36 µm, where genotype *Gladiolus callianthus* (283.36 µm) recorded the maximum polar axis length followed by Chandini (211.66 µm) and Jyotsna (201.8 µm).

2.3.4 Chrysanthemum

Pusa Lohit: It bears medium size flowers (6.44 cm) with red ray florets. Plants attain height of 60 cm with a good spread of 70 cm. It bears medium size (6.44 cm) red flowers. This selection is suitable for garden display under abiotic conditions. This variety was released for Delhi NCT by Delhi State Seed-Sub-committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.


Pusa Lohit

Screening for osmotic stress tolerance of chrysanthemum (*Chrysanthemum morifolium* Ramat.): Forty-five spray cultivars of chrysanthemum were evaluated in hydroponics for osmotic stress tolerance. To induce osmotic stress, seedlings were placed in Hoagland solution enriched with 10% polyethylene glycol, with regular Hoagland solution serving as control. On the basis of stress susceptibility index, multi-trait genotypic idiotypic distance index and Smith-Hazel index, cultivar 'Mini Jessie' was found highly tolerant to osmotic stress followed by Salmon, Bidhan Sabita and Paper White. However, Berbo and Yellow cultivars were highly susceptible to osmotic stress.

2.3.5 Bougainvillea

Pusa Akansha: Leaves are variegated with yellowish cream margin and light green colour centre. Bracts are in purple group (NN 78) as light reddish purple. The bracts and variegated leaves of this variety makes it very attractive for garden purposes. It is propagated by hard wood cutting and layering. This variety was released for Delhi NCT by Delhi State Seed-Sub-Committee for Agricultural & Horticultural Crops, Govt. of NCT of Delhi during 2022.

Pusa Akanksha

2.3.6 Lilium

Evaluation of lilium hybrids: Hybrids from different cross combinations have been evaluated for growth, flowering and bulb traits. One progeny from cross 'Eyeliner x Brunello' was earliest to flower (165.6 days) as compared to Pusa Lily-1 (173.6 days) and produced more number of bulbs (1.25) with greater bulb size (38.36 mm) and bulb weight (32.86 g).

Eyeliner x Brunello

2.3.7 Ornamental Kale

Evaluation of ornamental kale genotypes: At ICAR-IARI Regional Station, Katrain, 20 inbred and 8 DH lines of cut stem types were evaluated with a standard check Crane Red (F_1) for different horticultural traits under open field conditions. The DH line 'DH-1-26' took minimum number of days to head formation (52.7 days) and attained maximum plant height of 35.5 cm over the check. Other better performing DH lines were 'DH-1-29' and 'DH-1-30'.

DH-1-30

DH-1-26

DH-1-29

CR-6

Entries contributed in AICRP (F) trials: Four open pollinated genotypes of ornamental kale *viz.*, KtOk-2-1, KtOk-3, KtOk-4 and KtOk-11 were contributed for AICRP (F) trials. Besides this, four entries of ornamental kale *viz.*, KtOk-2, KtOk-39, KtDH-57 and KtDH-19 were advanced to second year evaluation.

2.3.8 Antirrhinum

Varietal evaluation: Newly developed genotypes of Antirrhinum were evaluated for different horticultural traits. Among different genotypes, plant height varied from 40.45 to 111.44 cm. Maximum plant height was observed in KTANT-5 (111.44 cm), maximum plant spread in KTANT-2 (37.59 cm), minimum days taken to flowering in KTANT-6 (24 days) and highest duration of flowering in KTANT-5 (80 days). Rachis length was longest in KTANT-8 (15.42 cm), maximum number of flowers per stem in KTANT-5 (21) and thickest spike in KTANT-11 (7.34 mm).


KTANT-2 KTANT-5


KTANT-6 KTANT-8

2.3.9 Production Technology of Flower Crops

2.3.9.1 Lilium

Response of foliar application of micronutrients on production of LA hybrid lilium: Among various concentrations of zinc sulphate ($ZnSO_4$) and manganese sulphate ($MnSO_4$), plants sprayed with $ZnSO_4$ @ 6 g/l + $MnSO_4$ @ 6 g/l performed best in terms of growth, flowering and bulb characters.

2.3.9.2 Bougainvillea

Development of multi-colour bougainvillea using grafting technique: Whip grafting technique was used in summer season using hard as well as soft wood scions of different varieties like Asia, LMB, MPS, Mahara, Zakriana and Hawian White on Chitra rootstock to develop multi-colour bougainvillea. It was evident that soft wood scion graft of all the varieties gave better success (70%) compared to hard wood scion (40%).

2.3.9.3 Bird of Paradise

Nutritional requirement of Bird of Paradise *(Strelitzia reginae)*: NPK 30:15:10 g/plant/year improved plant growth in terms of height (75 cm), leaves length (40.35 cm), breadth (15.65 cm), sucker production (2.5) and number of leaves/clump (7.5).

2.3.9.4 Easter Lily

Effect of PGR on scale propagation of Ester Lily *(Lilium longiflorum)*: Easter Lily bulbs treated with 100 mgL^{-1} NAA and 100 mgL^{-1} GA_3 resulted in higher number of bulblets than control after 6 weeks. However, application of GA_3 at 75 and 100 mgL^{-1} increased the diameter of bulblets resulting in larger bulblets (Grade 1).

2.3.10 Post-harvest Management and Value Addition in Ornamental Crops

Evaluation of antioxidants for reducing postharvest leaf discoloration in chrysanthemum: The effect of antioxidant and anti-ethylene compounds such as ascorbic acid (50, 100, 150 ppm with 4% sucrose), thidiazuron (5, 7.5 and 10 µ mol) were studied in chrysanthemum cv. Yellow Star along with control. Maximum vase life, weight gain, flower diameter, volume of solution uptake, total chlorophyll content was recorded in flowers held in 100 ppm ascorbic acid + 4% sucrose solution which was at par with 5 µ mol thidiazuron pulsing.

AA (100 ppm) + sucrose (4%)

TDZ 5 μmol

Control

Studies on pH, thermo-and photo stability of dye extracted from rose petals: Dye was extracted from petals of rose cv. Rose Sherbet by acidic and aqueous method. The colour intensity was found to be more in acidic medium as compared to water. Dye was found stable in acidic pH solution and further increase in pH resulted in deterioration of dye hue. Dye solution kept under natural light deteriorated earliest whereas, in dark storage the dye colour was most stable. The dye colour was found stable at 5, 25 and 40^{o}C up to 4 hours while it was highly unstable at 70 and 100^{o}C.

Dye extracted from rose

3. GENETIC RESOURCES AND BIOSYSTEMATICS

Plant genetic resources have a pivotal role in crop improvement programmes. The institute has a vibrant programme for collection, maintenance, evaluation and utilization of germplasm in various crops. A large number of germplasm lines including some wild relatives of crops were maintained, evaluated, characterized and utilized in pre-breeding and genetic enhancement in various crops.

3.1 CROP GENETIC RESOURCES

3.1.1 Wheat and Barley

Germplasm registration:

- Wheat accessions, *viz*. HW 5067 (INGR 22072), HW 5068 (INGR 22069) and HW 5074 (INGR 22068) with stem and leaf rust resistance genes were registered at NBPGR, New Delhi.
- Two wheat genotypes *viz*. QBI20-20 (INGR 21183) and QBI19-09 (INGR22011) were registered at NBPGR for their low grain hardness index, low sedimentation value and higher level of grain zinc and iron concentration, respectively.
- Wheat genotype, HS661 (INGR 21181) possessing seedling resistance to all pathotypes of brown rust has been registered at NBPGR.
- Three barley genotypes *viz*., BHS 483 (INGR 22131) developed from BHS 352/BHS 366, BHS 485 (INGR 22129) developed from HBL 276/BH S369, and BHS 486 (INGR 22130) developed from HBL276/BHS 365 have been registered for at NBPGR their high resistance against stripe and leaf rust.

Germplasm conservation: More than 6000 genotypes of wheat, barley, oats, triticale lines, synthetics, CIMMYT-based advanced lines, RIL's carrying different leaf, stem, yellow, head scab and blight resistance genes, PHS sources and 1900 accessions of wild spp. have been maintained, evaluated and utilized. Gene sources for *Lr19/Sr25*, *Lr19/Sr25*, *Sr36/Pm6*, *Lr24/Sr24*, *Lr24/Sr24/Sr26*, *Sr27*, *Lr28*, *Lr32*, *Lr37/Sr38/Yr17*, *Lr45*, *Lr47*, *Lr34*, *Lr46*, *Lr67*, *Lr68*, *Yr10* and *Yr15* were also maintained.

Germplasm utilization

Genetic characterization of Indian dwarf wheat (*T. sphaerococcum*): 116 accessions of Indian dwarf wheat were characterized phenotypically for agronomic, physiological, and grain quality traits; and genotyped by a 35 K SNP array. Six accessions *viz*. TS 82 (Fe: 47.79 ppm, Zn: 59 ppm), TS 81 (Fe: 45.78 ppm, Zn: 63.89 ppm), TS 36 (Fe: 43.99 ppm, Zn: 60.26 ppm), TS 37 (Fe: 43.68 ppm, Zn: 60.48 ppm), TS 49 (Fe: 43.65 ppm, Zn: 49.46 ppm), TS 56 (Fe: 44.81 ppm, Zn: 58.64 ppm) had high Fe and Zn content across three environments.

Development of CMS (A) lines in the background of high-yielding varieties: *T. timopheevi*-derived CMS has been introgressed in the background of HW 3094, DBW 39, HD 2967 and HD 3086, and the material is in BC_3F_1 stage.

Resistance to FHB (*Fusarium* Head Blight) or head scab: The *'Sumai-3'* -derived QTL carrying *Fhb1*, *Fhb4* and *Fhb5* genes is currently being transferred to susceptible parents *viz*. WH 542, Sonalika, PBW 343, PBW 222 and HD 2967. The other sources *viz*. *'Frontana, Nobeoka* and *Ning1742'* is also being exploited for FHB resistance.

A biodegradable alternative to the single-use plastic straw: A promising bread wheat genotype, Pusa Srijan developed through the crossing of selected F_2 plants from NW 6049/HD 3059 and NW 6049/HD 2329 followed by pedigree selection has been identified as an excellent combination of lodging resistance, biofortified grain quality (protein: 14.59%, zinc: 58 ppm), and stem as a biodegradable alternative to the single-use plastic straw (5-6 straws of commercial length and diameter per tiller).

Introgression of *Aegilops ventricosa*-derived translocation: A segment (2NS) carrying *L37/Sr38/Yr17* genes and a source of resistance to wheat blast was transferred into popular cultivars *viz*., HD 2733, HD 2967, DBW 39, K 0307, HD 2824, HD 3118 and HD 2985.

Introgression of *Triticum timopheevii*-derived stem rust and powdery mildew resistance: A segment carrying *Sr36/Pm6* genes conferring resistance to stem rust and powdery mildew was transferred to a dicoccum variety, HW 1098. The material is in the BC_2F_2 stage.

Characterization of race-specific and non-race-specific rust resistance genes in elite wheat germplasm: Thirty-six elite wheat genotypes were characterized for race-specific (*Lr19/Sr25* and *Lr24/Sr24*) and non-race specific (*Lr34/Yr18/Pm38/Sr57* and *Lr46/Yr29/Pm39*) rust resistance genes using Sequence Tagged Site (STS) markers *viz*. *Sr24#12*, *Gb*, *csLV34* and SSR (*wmc44*). The marker analysis revealed the presence of *Lr24/Sr24* genes in 47% of the wheat genotypes, whereas 22.2% possessed *Lr24/Sr24* and *Lr34/Yr18/Pm38/Sr57* gene combinations. Two genotypes *viz*. G16 and G12 were confirmed to have (i) *Lr19/Sr25*, *Lr24/Sr24*, *Lr34/Yr18/Pm38/Sr57* and *Lr24/Sr24*, and (ii) *Lr34/Yr18/Pm38/Sr57* and*Lr46/Yr29/Pm39* gene combinations, respectively.

Doubled haploid (DH) lines: Twenty-six DH lines of wheat developed through *Imperata cylindrica* mediated chromosome elimination technique were evaluated for yield and yield traits like plant height, spike length and yield. All the lines showed high uniformity.

Maintenance of germplasm lines: Germplasm lines (125) with different *Lr, Sr* and *Pm* genes and NILs (36) of *T. aestivum* from CIMMYT were evaluated at Wellington (Nilgiris) under field conditions and few lines were identified with 'R' gene specific virulent isolates of leaf rust pathogen.

Wheat germplasm evaluation at ICAR-IARI, RS, Wellington

3.1.2 Rice

Pre-breeding - evaluation of wild rice accessions: A set of 100 different accessions of wild rice collections including *Oryze rufipogon, O. nivara* and *O. longistaminata* were evaluated. These lines were also utilized in wide crossing for introgression of useful traits and inoculated for screening resistance to bacterial blight (BB) by different isolates of *Xanthomonas oryzae pv. oryzae* (*Xoo*).

Evaluation of rice landraces for yield and other components: A set of 3750 rice landraces collected from different parts of the country were evaluated for yield and components traits such as several tillers per plant, plant height, panicle length, days to 50% flowering, days to maturity and number of grains per panicle.

Field evaluation of rice landraces during *Kharif* 2022

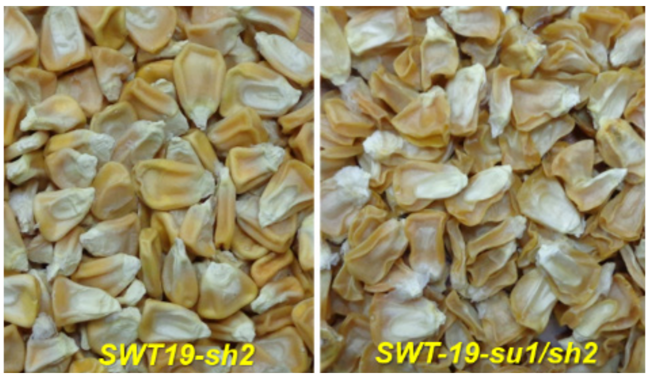
3.1.3 Maize

Registration of genetic stock at NBPGR: A maize inbred, PML 46 (INGR 22020) with tolerance to high plant density was registered at NBPGR, New Delhi. Under high-density planting, its grain yield potential is 3.80 t/ha.

Identification of trait-specific field corn germplasm: Maize inbreds *viz*. AI 502 (IC 638864) and AI 539 (IC 638867) with high kernel row numbers (KRN), and AI

505 (IC 638865) and AI 527 (IC 638866) with long ear were identified and deposited in NBPGR, New Delhi.

Development of inbreds with *sugary1* and *shrunken2* gene for higher kernel sweetness: Four sweet corn lines *viz*. SWT-16-su1/sh2, SWT-17-su1/sh2, SWT-19-su1/sh2 and SWT-20-su1/sh2 were developed through marker-assisted pyramiding of *sugary1* (*su1*) and *shrunken2* (*sh2*) genes. The seeds of the double mutant lines (*su1su1/sh2sh2*) were more crumbled upon maturity. They possessed 23-25% brix compared to 16-18% brix in *sh2*-based sweet corn inbreds. These newly developed inbreds would serve as a novel genetic resource in the breeding programme.



Seed characteristics of *sh2*- and *su1/sh2*- seeds upon maturity

Development of anthocyanin-rich maize inbreds: Two inbreds *viz*., MGU-ANTH-101 and MGU-ANTH-102 rich in anthocyanins (>500 ppm cyanindins) were developed through introgression of *A1*, *A2*, *C1*, *C2*, *R1*, *Pr1*, *Bz1* and *Bz2* genes. These inbreds would serve as donor in the breeding programme for enhancing antioxidants in maize kernels.

3.1.4 Pearl millet

Maintenance breeding of cytoplasmic male sterile lines: Twenty-four CMS lines were maintained by attempting 2352 paired crosses. Nucleus seed multiplication of eight promising CMS lines (411A/B, 431A/B, ICMA 843-22/B, ICMA 04999/B, ICMA 08666/B, ICMA 11222/B, ICMA 13222/B and ICMA 14222/B) was undertaken by the crossing of 2179 panicles.

Maintenance breeding of restorer inbreds: 1023 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. Some of them also possessed high lysine, tryptophan, Fe and Zn content.

Maintenance and evaluation of germplasm:

- **Minicore set:** A minicore set of 234 genotypes was evaluated under field conditions for morpho-physiological traits. Days to flowering ranged from 37-71 days, maximum tillers recorded were 6/plant and wide variability was observed for panicle length (12-85 cm). Fifty-two genotypes showed a blast severity score of 0-2.0 exhibiting highly resistant reactions under natural epiphytotic conditions.
- **Pearl millet inbred germplasm association panel (PMiGAP)**: Out of 250 lines evaluated, days to flowering ranged from 43-87 days, tillers per plant from 1-6/plant, and internodal length from 15.20-45.67 cm.
- **Wild accessions**: Eleven accessions of *Pennisetum mollissimum* and 31 of *P. violaceum* showed considerable variation for different traits. Earliest flowering was recorded in 43 days, while plant height varied from 135-320 cm, number of tillers ranged from 2.60-12.30.

Screening for terminal drought stress: Forty-two wild accessions were evaluated for terminal drought stress under phenomics facility maintained at 10% moisture content. Highest projected shoot area was recorded in IP 21708 and IP 21766, while high caliper length was observed in IP 21531 and IP 21578.

Screening for terminal drought tolerance under phenomics facility

3.1.5 Chickpea

Characterization for drought and seedling stage salt tolerance: One thousand accessions from the ICRISAT/NBPGR gene bank were screened for salinity tolerance under hydroponic conditions. After four weeks of saline treatment, plants were scored for salinity tolerance visually following a 1-5 scale based on visual detection of salt injury. ICC 4922, ICC 3377, ICC 4787, ICC 2800, ICC 1758 and ICC 1599 were some of the 18 accessions identified as tolerant to salinity stress. These 1000 accessions were also screened for drought tolerance along with four checks (ICC 4958 and BGM 10216 as tolerant, and ICC 1882 and ICC 8261 as susceptible). One set each of 1000 accessions was grown under normal irrigated as well as rainfed conditions (no irrigation). Based on MSI, RWC and yield under rainfed conditions, 15 accessions including ICC 1902, ICC 2774, ICC 11541 and ICC 3259 were found as tolerant genotypes.

Drought and seedling stage salt tolerance

3.1.6 Lentil and Mungbean

Germplasm lines registered: Three lentil germplasm lines *viz*. INGR 21223 for multiple flowering (15 FPP), INGR 22036 for bold seed size (7.1-7.83 gm/100 seed) and INGR 22037 for early flowering (51 days) and early maturity (93 days) were registered at NBPGR, New Delhi.

Identification of lines for phosphorus uptake: Seven mungbean genotypes (IC 251950, IC 585931, V1002532AG, IC 371653, IC 331615, V1001400AG, and V1000532BG) were found to be promising for phosphorus uptake and utilization efficiency under hydroponic conditions.

3.1.7 Mustard

Maintenance of germplasm: A total of 647 germplasm lines including *B. juncea* (388), *B. rapa* (27), *B. carinata* (171), *B. nigra* (8), *B. napus* (15) and 38 accessions of wild /related species were maintained through selfing/ sib-mating. A total of 89 germplasm lines of *B. juncea* possessing different quality traits were evaluated for fatty acid profile and/or glucosinolates content, and were maintained by selfing and used in the crossing programme.

Screening of Indian mustard core set against white rust: An acquired core set of Indian mustard (558 accessions) from NBPGR, New Delhi generated 540 accessions, of these 23 were identified accessions with white rust resistance at Wellington. Multiplied seeds of 490 accessions were sent back to NBPGR, New Delhi for conservation.

3.1.8 Soybean

Widening of the genetic base of soybean: To widen the genetic base of cultivated soybean, inter-specific crossings were attempted involving two new accessions of wild-type soybean (*Glycine soja*) and three landraces (Bhatt-black, Bhatt-yellow and Kalitur) with the high yielding varieties of soybean (SL 955, PS 1569, PS 1347 and DS 9712). The F_1 plants were selected and harvested individually to advance the generation.

Genetic improvement of vegetable soybean: A set of 18 vegetable soybean genotypes were field evaluated for their yield performance and reaction to the YMV disease. Crosses have been attempted to transfer tolerance to YMV disease to the vegetable soybean genotypes.

Maintenance and utilization of germplasm: A total of 700 germplasm lines of soybean (*Glycine max*) were maintained at RRC-IARI, Dharwad. The lines were screened against soybean rust and pink pod borer. The promising lines are being utilized in a breeding programme.

3.1.9 Vegetable Genetic Resources

1. Cabbage: Ninety two germplasm of cabbage including 10 DH lines, 50 OP genotypes and 32 CMS lines were purified and maintained.

2. Cauliflower: A total of 216 germplasm lines of white cauliflower (70 CMS and 70 maintainers, 30 OP, 20 EC lines, 8 DH based CMS lines and 8 DH based maintainers and 5 genotypes each of orange and purple coloured cauliflower) were purified and maintained.

A total of 178 newly developed inbred lines (80 early, 72 mid-early and 26 mid-late) were evaluated for horticultural and DUS traits in respective maturity groups. The promising genotypes in early group were DC-315-1-2-15, DC-315-6-7, DC-323-4-6, DC-108, DC-232-2 and DC-303, in mid-early were DC-30-7-1, DC-303-3-5, DC-30-3-10, DC-315-12 and DC-303-1-2, and in mid-late group were DC-15-30-1, DC-30-07, DC-33-1-11 and DC-303-1.

3. Chilli

Genetic stock registered: Two chilli genotypes *viz.* DLS-161-1 (INGR 22158) and DLS-152-1 (INGR 22159) were registered for its heat tolerance trait. DLS-161-1 and DLS-152-1 have the ability to set fruits during May to July months also. Using these genotypes, heat tolerant hybrids/varieties can be developed for commercial cultivation.

Germplasm maintenance: Thirty five chilli genotypes were maintained in *kharif* and thirty four chilli genotypes in spring summer. Seed multiplications of 11 advanced breeding lines of AICRP trials were also accomplished. In sweet pepper, 32 genotypes including advanced breeding lines were also maintained.

4. Capsicum: Eighty two open pollinated genotypes of capsicum [green (35), yellow (27), red (15) and orange (5)] and 10 advanced breeding lines of chilli were purified and maintained.

5. Temperate carrot: One Hundred and thirteen genotypes of temperate carrot including 73 OP lines and 20 CMS lines along with their respective maintainers were purified and maintained.

6. Carrot

Sixty five inbred lines were characterized, evaluated and planted for maintenance, seed multiplication and use in hybrid breeding.

7. Broccoli: Twenty germplasm and eight CMS lines of broccoli along with their maintainer lines were purified and maintained. Besides, 80 DH lines were also maintained.

8. Onion (long day): 40 advanced breeding lines of long day onion (red, yellow and white) were purified and maintained at ICAR-IARI RS, Katrain.

Collection, evaluation, purification and maintenance of germplasm: A set of 39 dark red selections, 48 red selections and 60 white selections were advanced based on marketable bulb formation by early December. Seventy six second generation inbreds were also developed. Non-bolting bulbs of 24 genotypes from late *kharif* trials were advanced through massing. Three allied *Allium* species were collected from Manipur and maintained.

Identification of a new semi cultivated *Allium* species: A semi-cultivated species was collected from North East and is in use since ages as vegetable and has high commercial value. Based on the morphological, SSR markers (nuclear and chloroplast), and DNA barcoding, it was confirmed that the semi-cultivated species is different from onion, multiplier onion, *Allium fistulosum* and other wild species.

9. Garden pea

Forty nine genotypes of garden pea/wild pea/sugar pea were introduced. *Pisum fulvum* produced seeds after 170-180 days after sowing. Besides, more than 100 accessions (wild/cultivated) of *P. elatius*, *P. sativum* ssp. *elatius* and *Pisum sativum* ssp. *hortense* were maintained.

Flowering in *Pisum fulvum*

10. Cucumber

Evaluation and maintenance of pre-breeding materials: In cucumber, 51 indigenous/exotic wild species of cucumber were maintained through selfing under net house. *Cucumis hardwickii* accessions *viz.* H-06 and H-16 were found to carry high degree of resistance to ToLCNDV and downy mildew. Six genotypes of cucumber with high β-carotene were collected and maintained through selfing. Apart from IC-420422 and LOM-402, new *β*-carotene rich lines *viz*. AZMC-1 and KP1291 collected from Mizoram through NBPGR were found to be very promising with dark orange flesh colour on ripening and were crossed with our released varieties for studying genetics, generated of mapping population and transfer of the high β-carotene trait into desirable backgrounds of cucumber.

Maintenance of gynoecious lines, wild accessions and long fruited genotypes of cucumber: Tropical gynoecious lines *viz*. DGC-102 and DGC-103 showed stable performance at an average day temperature of 40-45 ^{0}C. The genotypes *viz*. DC-77, DC-70 and DC-36-2 were found to be highly resistant to downy mildew both under field conditions and artificial inoculation. DC-77 and DC-70 are being used in developing mapping population with highly susceptible genotypes. F_4 progenies involving DC-77 (R) and DC-773 (S) were crossed for development of RIL population and QTL mapping of downy mildew resistance. Besides, F_1 and BC_1F_1 population were developed for introgression of downy mildew resistance into DGC-102, DGC-103 and DC-48.

11. Summer squash

11. Summer squash: Ten open pollinated genotypes of summer squash (green, orange, yellow and creamy white) were purified and maintained at ICAR-IARI RS, Katrain.

12. Muskmelon

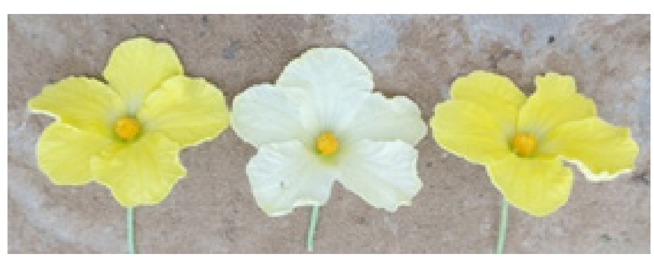
Two hundred eighty six germplasm of muskmelon and wild melons were evaluated for horticultural traits and resistance for *Fusarium* wilt, ToLCNDV, powdery mildew, and were maintained by controlled selfing. Sixty nine melon germplasm of muskmelon were screened in poly-house for resistance to powdery mildew and EC751844-3 and DOM 118 (*C. melo* var. *conomon*) could be identified as source of resistance. Forty nine RILs (F6) were evaluated from cross between *C. melo* var. *reticulatus* (Pusa Madhuras) and DHM 159 (*C. melo* var. *inodorous*) for yield and quality traits. DMM-207, DMM 216, DMM 208, DMM 230 and DMM 364 were found promising in net house.

13. Watermelon

Forty three genotypes of watermelon from *Citrullus lanatus* var. *lanatus*, var. *citroid* and *Citrullus colocynthis* were evaluated in open field and net house, and *C. colocynthis* line DWM-210 and DWM-222 were identified as highly resistant to WBNV. New source of resistance against WBNV was identified from DWM-45 (*C. lanatus* var. *citroid*) which was validated through artificial screening.

14. Bitter gourd

Promising germplasm: A total of 17 germplasm of *M. charantia* var. *muricata* were evaluated for earliness and yield traits. The three best germplasm for yield/plant were DBGS-100-0, CBM-12 and DBG-100.



Germplasm of M. charantia var. muricata

Unique germplasm: The unique trait of white flower colour in bitter gourd was recorded in DBGS-54-18. Fruits were medium (12-14 cm long, 5.0-5.5 cm fruit diameter with discontinuous narrow ridges). All F_1 plants of DBGS-54-18 (white flowered) × DBGS-2 (orange yellow) produced orange yellow flowers. F_1 plants were self-pollinated to generate F_2 segregating population. This is the first report of occurrence of white flower in bitter gourd which may be useful as a morphological marker.

15. Bottle gourd

Augmentation of exotic germplasm from USDA: A total of 32 genotypes were procured from USDA through NBPGR, New Delhi. The list are as follows: EC 1085231, EC 1085232, EC 1085233, EC 1085234, EC 1085235, EC 1085236, EC 1085237, EC 1085238, EC 1085239, EC 1085240, EC 1085241, EC 1085242, EC 1085243, EC 1085244, EC 1085245, EC 1085246, EC 1085247, EC 1085248, EC 1085249, EC 1085250, EC 1085251, EC 1085252, EC 1085253, EC 1085254, EC 1085255, EC 1085256, EC 1085257, EC 1085258, EC 1085259, EC 1085260, EC 1085261 and EC 1085262.

16. Long melon and round melon

Long melon lines *viz*. DLM 14-1 and DLM 24-1 having dark green skin colour and DLM 19-2 with segmented leaf were maintained. In DLM 19-2, the leaves were segmented with fruits being straight, light green, slightly ribbed, shiny with tender skin and crispy flesh. The fruits became ready for first harvesting in 50-55 days after sowing in spring summer season. The fruits of DLM 14-1 and DLM 24-1 were slightly curved, dark green with smooth non-prominent ridges, with tender skin and crispy flesh and became ready for first harvesting in 50-55 days after sowing in spring summer season.

17. Pumpkin

Fifty two genotypes/ advanced breeding lines of pumpkin were characterized, evaluated and maintained.

3.1.10 Flower Genetic Resources

18. Temperate flowers: Forty five cultivars and five species of *Lilium*, 22 species/varieties of *Iris*, 20 varieties of *Dahlia*, 25 varieties of *Alstroemeria*, 75 breeding lines of *Gladiolus*, 50 lines of ornamental kale, 15 inbred lines of *Eustoma* and other bulbous crops like, torch lily, *Wattsonia*, *Canna*, *Amaryllis*, *Crinum*, *Freesia*, wild tulip, *Cyclamen*, zinger lily, *Lycoris*, temperate orchids and some wild ornamentals were maintained and used for crop improvement programme at the station.

19. Rose: Garden display varieties *viz*. Supriya, Dr. Nashid Wadia, Somascilla, Black Delight, Radhanath, Aristocrat, Zina, Khudiran, Himangini and Coffee Country were collected from secondary sources to enrich the existing germplasm.

20. Marigold: Seven new genotypes of French marigold *viz*. Durango Bee, Durango Flame, Durango Yellow, Durango Orange, Durango Gold, Bonanza Harmony and Bonanza Yellow were collected from secondary sources to enrich the existing germplasm.

3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Insect biosystematics

Entomological identification service: A total of 1562 specimens were registered/ identified for various correspondents from all over India. The details are: Coleoptera: 210; Hymenoptera: 851; Diptera-: 11; Hemiptera: 123; and Lepidoptera: 367.

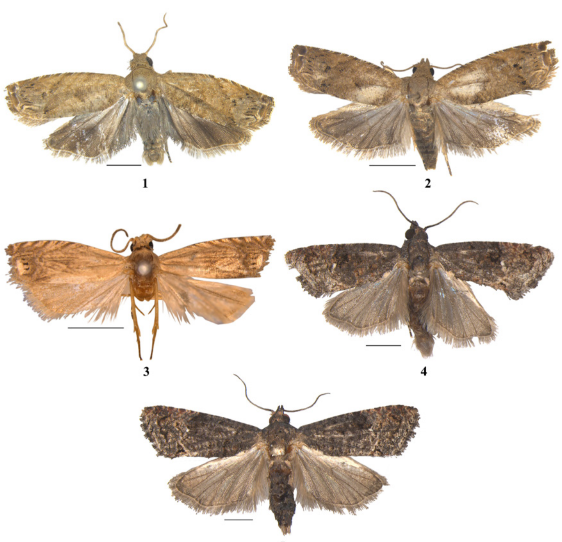
Collection and suitable processing of the collected material: Collections were made from 15 states of India. Around 15,000 specimens were collected and more than 700 field visuals on the various life stages and adults could be documented. There are 8 holotypes and 20 paratypes depositions to NPC.

Biosystematic studies

Biosystematic studies in Hymenoptera: New Records: Genera: *Agraulomyrmex* Prins Species: *Crabropus anoides*, *Dasyproctus agilis agilis*, *D. agilis orientalis*, *D. pentheri*, *Encopognathusbellulus*, *E. chapraensis*, *Lindeniuspanzer*, *Patalepsisreticulosa*, *Recurvidris recurvispinosa*; Two subgenera, *Thao* and *Ortocrabro* of genus Crossocerus. New species described: *Piyuma chapraensis* sp. nov., *Agraulomyrmex damohensis* sp. nov., Rhopalum (s. str.) *gulmargensen* sp, *Panjal*, a new subgenus of the genus *Crossoceruus.*

1. *Dasyproctus agilis*, 2. *D. agilis orientalis*, 3. *D. buddha*, 4. *D. pentheri*

Biosystematic studies in Lepidoptera: A total of 237 insect specimens were examined from 14 consignments received from more than nine different universities/research centres/institutions/organizations across the country. A host association for *Syncola crypsimorpha* (Meyrick, 1922) was discovered after 100 years, since its original description, and a lectotype for the same species was designated. Three new species of tribe Grapholitini from India *viz., Acanthoclita bengaluruensis* Reddy and Shashank, sp. nov., *Grapholita constricta* Reddy and Shashank sp. nov. and *Thaumatotibia ramamurthyi* Shashank and Reddy, sp. nov. are recorded.



1. *Acanthoclita bengaluruensis*, holotype male; 2. *A. bengaluruensis*, paratype female; 3. *Grapholita constricta*, holotype male; 4. *Thaumatotibia ramamurthyi*, holotype male; 5. *T. ramamurthyi*, paratype female.

Biosystematic studies in Coleoptera: New records: *Scymnus (Scymnus) arciformis* was from Jharkand, India. New records of *Pachyderes bengalensis* Candeze and *Lanelater maeistus* Candeze from Delhi. A new species, *Lamellipalpus umiamensis* (Coleoptera: Lampyridae: Ototretinae), from Northeast India is described. Taxonomic studies on *Euwallacea fornicatus* the cryptic species of ambrosia beetles shot hole borer of Pomegranate was done and submitted the sequences to gene bank.

A. *Scymnus* (*Scymnus*) *arciformis*, B. *Pachyderes bengalensis*, C. *Lanelater maeistus*

3.2.2 Nematode biosystematics and identification service

Population genetics of potato cyst nematodes in India: The spread of potato cyst nematodes to various states in India has been a long-standing question for nematologists. To determine the spread route of potato cyst nematodes in India, species-specific microsatellite markers were used to determine the genetic diversity of Indian PCNs. Indian populations of PCNs were found genetically identical. Based on the population-Q-matrix analysis, it was found that Indian populations of PCNs grouped with the B2 cluster from Bolivian PCN populations. Clustering analysis indicated a recent and single introduction of PCNs in to India and local level spread, most likely with the transportation of infested seed tubers. In addition, we propose two major (GrMa1 and GrMa2) and ten minor (GrMi1 to GrMi10) new clusters for all known global populations of *G. rostochiensis* and two major (GpMa1 and GpMa2) and six minor (GpMi1 to GpMi6) new clusters for all known global populations of *G. pallida.*

Morphological and molecular characterization of nematodes: Morphological and morphometric differences between four populations of the *Hemicriconemoides* species from different hosts (two from Delhi-*Polyalthia longifolia* and *Syzygium cumini,* and two from Himachal Pradesh-*Mangifera indica* and *Citrus pseudolimon* were studied. Population of Himachal Pradesh were characterized by large sized females and identified as *H. litchi*. It is the first record of the species from Himachal Pradesh. The nematode population from *Polyalthia longifolia* was identified as *H. mangiferae* and the one from *Syzygium cumini* was identified as *H. cummunis.* Both are the first host record for respective species.

In addition, more than 37 plant-parasitic and entomopathogenic nematodes were identified and characterized using morphological and molecular methods. Populations of *Xiphinema* and *Longidorus* recovered from the roots of hedge plant (*Euphorbia*sp.) and citrus grown at the Indian Agricultural Research Institute farm, New Delhi, were characterized morphologically and molecularly for identification of the species. New gene sequence information for all three Indian populations was generated and used for phylogenetic analysis. *Xiphinemabasiri* Siddiqi, 1959 was identified based on morphology and gene sequences of ITS rRNA (accession number MZ566842), D2-D3 expansion segment of 28S rRNA (MZ568465), and *COI* of mtDNA (MZ562890) from the roots of hedge plant. Similarly, *Longidoruspisi* Edward *et al*., 1964 was identified from the rhizosphere of citrus grown at the horticultural farm. We recorded a male from India, however, the male was different in respect of morphometrics, size of the spicule, and number and arrangement of supplemental papillae from the male reported from Malawi. Nematode diversity in drip versus surface irrigation under protected and open cultivation systems are being analysed at four sites of IARI farm. Nematode abundance varied significantly in both the crops ($F_{3,\ 152}$=4.9, $p < 0.05$) and irrigation type ($F_{1,\ 152}$=33.4, $p < 0.05$). Higher nematode abundance was observed in drip irrigation system across all crops *viz*., pomegranate, citrus, lettuce and chrysanthemum. Shannon diversity index varied significantly both across crops ($F_{3,\ 152}$=5.5, $p < 0.05$) and irrigation type ($F_{1,\ 152}$ = 6.4, $p < 0.05$) and their interaction ($F_{3,\ 152}$=6.2, $p < 0.05$). Nematode diversity was higher in drip irrigation system except in citrus. No significant differences were observed in terms of maturity index (t=-0.64, *p*=NS) or plant parasitic index (t=0.70, *p*=NS) over irrigation types.

Digitization of National Nematode Collection of India: Digitization of a part of type collection at National Nematode Collection of India was attempted. Fifteen types of specimen were digitized using programmable motorized Axioimager microscope. Digitization was done at 63 X oil objective at 0.5 um depth for average size nematodes and at 40 X for large nematodes.

3.2.3 Microbial genetic resources

Analysis of population dynamics and conservation of microbes associated with wheat: The population dynamics of culturable fungi and bacteria that harbour in rhizosphere and phyllosphere region of wheat and barley from different fields at Nilgiri hills were analysed. The isolates of mycoparasites *viz*., *Sphaerellopsis* sp. *Trichoderma* sp., *Acremonium* sp., *Cladosporium* sp., and the bacterial cultures of *Bacillus* sp., are being conserved for the management of rusts and other foliar diseases of cereal crops. The population dynamic studies revealed that among the mycoparasites, colonies of *Cladosporium* sp. was more and found in all the rust infected samples in both the seasons followed by *Acremonium* sp. Nearly 125 numbers of cultures belong to 12 genera of both pathogenic and biocontrol fungi comprising of different species are being maintained at ICAR-IARI, Regional Station Wellington. The different genera of fungi *viz*., *Trichoderma* sp., *Ustilago tritici*, *Acremonium* sp., *Alternaria* sp. *Fusarium* sp., from wheat phyllosphere were isolated and molecularly characterized by amplification and sequencing of ITS regions.

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

The School of Crop and Natural Resource Management has made significant stride/achievement through developing agricultural technologies/ techniques suited to the farming communities. The developed technologies, mainly, focus on the conservation of natural resources, enhancing input-use efficiency, reduction in environmental footprints, besides improving productivity, profitability and sustainability of crops and cropping systems. Crop and cropping systems diversification in conservation agriculture, need-based and scale-appropriate integrated farming systems, precision nutrient management using sensors/gadgets and nano-fertilizers have been developed for improving crop productivity, profitability, soil health, and climate resilience. The School has developed sea weed extract-based products for enhancing soil health and crop productivity, silicon-rich agro-wastes and phosphate-solubilizing bacteria for solubilization of recalcitrant soil P, soil organic carbon stability indicators, sensor-based automatic surface irrigation system, machine learning models for reference evapotranspiration, Jalopchar technology for wastewater treatment, IoT and sensor operated greenhouse vertical farming system, water saving models of vertical hydroponic systems, solar powered/ battery-operated harvester for leafy vegetables, sensor-based spraying system for Pusa decomposer, Pusa Farm Sun Fridge, Sensor-based site-specific sprayer for vegetable crops. It has also searched upon extracting biocolourant from food waste, iron fortification of fresh-cut beans using vacuum infusion, harnessing the potential of microorganisms for value added products, microbial based technologies for conversion of farm waste to wealth, assessing impact of greenhouse gas emission on crops and microbial community, and response of wheat varieties to elevated CO_2 and temperature.

4.1 AGRONOMY

4.1.1 Conservation agriculture (CA)-based rice-wheat system with mungbean intervention

It was observed from a long-term CA experiment (12 years) that a triple zero-till cropping system (TZT) involving ZT DSR with summer mungbean (SMB) residue (MBR)- ZT wheat (ZTW) with rice residue (RR)– ZT summer mungbean (ZTSMB) with wheat residue (WR) was consistently superior over other CA systems and puddled transplanted rice (PTR) - conventional till wheat (CTW) system on wheat yield, system productivity and net returns. It resulted in ~16% higher wheat yield, ~34% higher system productivity and ~9% lower rice yield than TPR-CTW system. This triple ZT system could save almost 60 kg N/ha in rice-wheat system per year. The TZT+R led to higher net returns (NR) and benefit: cost (B:C) ratio than PTR-CTW. This also gave 35% and 7% higher net returns with and without mungbean, respectively. This led to sustainable intensification of the R-W system with a legume mungbean, which proved to be a superior alternative and an important adaptation and mitigation strategy to climate change.

CA based rice-wheat system

4.1.2 Alternative cropping system to rice-wheat system

The long-term CA based maize-mustard cropping system revealed that, a triple zero-till cropping system

(TZT) involving zero-till maize (ZTMz) with summer mungbean residue (MBR)- ZT mustard (ZTMs) with maize residue (MzR)– ZT summer mungbean (ZTSMB) with mustard residue (MsR) was consistently superior to other CA systems on maize yield, mustard yield, system productivity, and net returns. This treatment led to ~20% higher maize yield, ~27% higher mustard yield, and ~65% higher system productivity than conventional till maize-conventional till mustard system. It also resulted in 25% N (~57.5 kg N/ha) and 50% S saving in maize-mustard system.

4.1.3 Cotton-wheat cropping system as an alternative to rice-wheat system

Under the CA-based cotton-wheat system (after 12 years), all the CA-based ZT permanent broad, narrow, and flat beds with residue resulted in significantly higher yields of cotton, wheat and system productivity than conventional tillage (CT) system. However, in contrast to previous years, the ZT flat bed with residue with 100% N led to significantly higher cotton yield (~54%), wheat yield (~22%), and system productivity (~37%) than CT system. This practice with 75% N was comparable and leading to a saving of 25% N. The cotton-wheat system under PFB+R led to 65% increase in net returns compared to CT. This CA-based system is an important adaptation and mitigation strategy to climate change.

CA based cotton-wheat cropping system

4.1.4 Crop residue quantification for CA-based cropping systems

Zero-tillage pigeonpea with 50% wheat residue (ZTP+50WR) followed by zero-tillage wheat with 50% pigeonpea residue (ZTW+50PR) resulted in a higher yield of pigeonpea (1.7 t/ha) as compared to ZTP+75WR-ZTW+75PR, ZTP+25WR-ZTW+25PR and conventional tillage pigeonpea-conventional tillage wheat (CTP-CTW) system, whereas, wheat yield was not significantly different among these treatments. System productivity (in terms of pigeonpea equivalent yield) was again significantly higher in ZTP+50WR-ZTW+50PR over other tested treatments. In maize-mustard cropping system, the yield of maize, mustard, productivity and system (in terms of maize equivalent yield) productivity were significantly higher in zero-tillage maize with 50% mustard residue (ZTMz+50MdR) followed by zero-tillage mustard with 50% maize residue (ZTMd+50MzR) compared to ZTMz+75MdR-ZTMd+75MzR, ZTMz+25MdR- ZTMd+25MzR and CTMz-CTMd treatment.

Maize-mustard cropping system

4.1.5 Cropping systems and land-configuration practices for higher yield and water use

Babycorn-chickpea system resulted in a maximum system productivity (5157 kg/ha) in terms of chickpea equivalent yield followed by maize (cob)-chickpea cropping system (4665 kg/ha). Highest net returns (₹167850/ha) and water use efficiency (6.25 kg/ha-mm) were also recorded with babycorn-chickpea cropping system. Among the land configuration practices with residue retention (3 t/ha) under drip system was superior for higher system productivity, net returns, and water use efficiency over flat bed and ridge and furrow with residue application.

4.1.6 Land configuration for higher productivity and resource use efficiency

Cowpea variety Pusa Dharni recorded higher nodules/plant (16.62/plant), pod yield (6.85 t/ha), green fodder yield (19.10 t/ha), water use efficiency (8.82 kg/ha-mm), and net returns (₹64700/ha). Green pod yield of Pusa Dharni increased by 8.47 and 18.24% compared with Kashi Kanchan and Pusa Sukomal, respectively. Cowpea on ridge and furrow method with the residue retention (3 t/ha) resulted in a maximum green pod yield (6.56 t/ha) followed by 6.44 t/ha under flatbed with 3 t/ha residue.

4.1.7 Conservation agriculture based rainfed cropping systems

A study conducted in different cropping systems under conservation agriculture in rainfed conditions showed that growing of different crops in zero tillage with residue produced highest system productivity in terms of chickpea equivalent yield (2109 kg/ha), net return (₹ 52300/ha), and economic efficiency (₹ 241.01/ha/day). Among the cropping systems, pearl millet-chickpea recorded a highest system productivity, water and nutrient use efficiency, net returns, and economic efficiency.

CA based rainfed cropping system

4.1.8 Nitrogen sources and zinc fertilization on wheat productivity

Five nitrogen sources, *i.e.* control, 130 kg N/ha, 97.5 kg N/ha+nano-urea 1.25 L/ha (2 foliar sprays), 65 kg N/ha + nano-urea 1.25 L/ha (2 foliar sprays), 65 kg N/ha+ 2% urea solution 500 L/ha (2 foliar sprays) combined with five zinc fertilization *i.e.* control (Zn_1), 0.5 % foliar sprays of $ZnSO_4.7H_2O$ (Zn_2), 0.1% foliar sprays of nano-Zn oxide (Zn_3), cyanobacterial priming of seeds, and foliar application (Zn_4) at maximum tillering stage, anthesis or pre-flowering stage and initiation of grain filling stage were evaluated for wheat (WB 02 biofortified) productivity. Highest wheat grain and straw yields were recorded with the application of 100% N through urea in 3 splits followed by 75% N through urea in 2 splits, and in 0.1% foliar spray of nano-Zn oxide at maximum tillering, anthesis or pre-flowering and initiation of grain filling stage followed by 0.5% foliar spray of $ZnSO_4.7H_2O$ at maximum tillering, anthesis or pre-flowering and initiation of grain filling stage.

4.1.9 Bio intensive crop diversification

Diversification with legumes and oilseeds reduced yield gap under integrated organic and other production scenarios. Among the management scenarios, integrated crop management (ICM) recorded the highest system productivity (12,621 kg/ha). The conservation agriculture (CA) and ICM systems had 10 and 17% higher system productivity, respectively over conventional system. The protein yield was estimated from component crops and management scenarios, where ICM and CA recorded significantly higher system protein yield (1097.28 and 1063.34 kg/ha, respectively).

4.1.10 POLY-4 (Polyhalite) enhanced yield and nutrient use efficiency

Poly 4 (polyhalite) evaluated as a multi-nutrient source (contains K, S, Ca, Mg and micronutrients). Highest system maize equivalent yield was obtained under polyhalites and was found superior over MoP and Bentonite –S in enhancing system productivity.

4.1.11 Urea-S as an alternative sulphur source

Pearl millet seed yield increased from 11.8-24.5% and 15.4-27.5% with the application of Sulpher (S) & Nitrogen (N) 40-0-0-13 and SN 11-0-0-7, respectively.

Similarly, net return (NR) increased by 21.5-59.4 and 60.3-96.0% with SN 40-0-0-13 and SN 11-0-0-75 sulfonated nitrogen application over bentonite-S. In maize-wheat system, maize seed yield increased from 7.8-10.4 and 8.5-14.8 under SN 40-0-0-13 and SN 11-0-0-75 over bentonite-S, respectively. The increase in NR from maize was 7.9-5.3 and 19.9-29.9% and in wheat varied from 4.0-5.3 and 16.7-22.1%, respectively under SN 40-0-0-13 and SN 11-0-0-75 sulfonated nitrogen application over bentonite-S application.

4.1.12 Organic amendment with and without liquid manure in pigeonpea-wheat system

The economic optimum wheat equivalent grain yield of 6.31 and 6.53 t/ha through nutrient enriched compost (NEC) with liquid manure (NEC + LM) and without liquid manure (LM – *Panchagavya* and *Jeevamrit*) (NEC). It indicated that to harvest the minimum profit, 2.33 and 0.53 t/ha for NEC + LM and NEC, respectively should be applied. The grain yield under zero budget natural farming (ZBNF) was almost equal to the yield of control plot without fertilization. Spraying of liquid manure didn't provide any significant yield advantage.

4.1.13 Bio-intensive cropping systems for profit maximization

Eight bio-intensive cropping systems were studied. Among the systsems, the maize+blackgram (raised bed) +soybean (furrow)-chickpea (raised bed) +wheat (furrow) (3: 2)-green gram (raised bed)+sunflower (furrow) (5: 1) recorded significantly higher system productivity, production efficiency, and the lowest greenhouse gas intensity (GHGI).

4.1.14 Effect of nano-urea and irrigation regimes on wheat

A field experiment was conducted during *rabi* season of 2021–2022 at IARI, Jharkhand, Gaurikarma. Result showed that both 5-recommended irrigations and 3-irrigations at priority basis (CRI, flowering & milking) recorded at par grain yield, which indicated that with foliar application of nitrogen one or two irrigations could be saved. Among the nitrogen management strategies RDN gave significantly higher grain yield over all nano urea treatments. There is 36.36, 6.49 and 17.31% yield reduction with NU treatments N_2, N_3 and N_4 as compared to RDN, respectively.

4.1.15 Urea-S on the productivity of Durum wheat–soybean cropping system

Although both Urea-S showed positive response on wheat yield but maximum grain (6.16 t/ha) and biological (14.65 t/ha) yields of durum wheat variety HI 8759 were observed under recommended doses of NPK + 60 kg S through Urea-S2 (10-0-0-75 of N-P-K-S). The soybean as succeeding crop recorded a highest grain (1.77 t/ha) and biological (3.66 t/ha) yield with NPK + 30 kg S through Urea-S1 (40-0-0-13 of N-P-K-S).

4.1.16 Yellow gypsum for wheat

Seven recent wheat varieties *viz*., bread wheat HI 1605, HI 1634 and HI 1636, and durum wheat HI 8823, HI 8802, HI 8805 and HI 8759 were tested under two levels of yellow gypsum @ 30 and 45 kg S/ha at 16 farmers' field in three villages of Dewas district, Madhya Pradesh. Results showed that grain yields of wheat were increased to the tune of 0.82 to 12.8 per

Bio-intensive cropping systems

cent and 0.86 to 14.6 per cent under application of 30 and 60 kg S/ha yellow gypsum.

4.1.17 CA technologies and pulse integration in rainfed regions of Eastern India

Zero tillage with residue mulch (ZT+RM) was found to be most effective to retain maximum soil moisture (7-14% at 0-15 and 15- 30 cm soil depth up to 30 DAS) compared to conventional tillage (CT). Application of 4 ton/ha residue retained maximum soil moisture and lowered soil profile temperature. The values of organic carbon, available N, P and K were recorded maximum with ZT+RM, residue application of 4 ton/ha. Significantly higher chickpea grain equivalent yield was recorded due to ZT+RM, which was higher than CT and zero tillage with standing residue retention (ZT+RSR). Among the residue rate, application of 4 ton/ha registered maximum chickpea grain equivalent yield, but remained significantly at par with 3 ton/ha. Chickpea recorded maximum chickpea grain equivalent yield followed by lentil.

4.1.18 Agronomic management practices for rainfed crops of Eastern India

Zero tillage along with residue mulch (ZT+RM) 3 ton/ha led to retention of 6 to 12% higher soil profile moisture compared to conventional tillage (CT). Chickpea and grasspea recorded a higher soil profile moisture over lentil. Higher chickpea grain equivalent yield was recorded for ZT+RM compared to CT. Growing of chickpea after rice recorded maximum chickpea grain equivalent yield, which was significantly higher over the yield obtained for lentil and grasspea.

4.1.19 Response of wheat to various management practices in North Eastern Plain Zone

Zero tillage-Flat bed (ZT-FB) followed by conventional tillage-Flat bed (CT-FB) resulted in a highest number of effective tillers/m^2, straw yield and grain yield. Although, all the yield attributing characters were higher in ZT- RB but, yields were higher in ZT-FB due to higher number of effective tillers. Among residue and nutrient management treatments highest growth, yield attributes and yield was recorded with the application of residue 3 t/ha + RDF over control followed by no residue + RDF.

4.2. SOIL MANAGEMENT

4.2.1 Soil organic carbon stability indicators under integrated farming system

The combined application of 50% N through organic manures, e.g., (FYM, green manure GM and crop residues CR) with 50% NPK showed a higher water stable aggregates (WSA) and the macro-and micro-aggregate associated C in Mollisol, Inceptisol and Alfisol, whereas in Vertisol, it was observed with 50% NPK+50% N-FYM/GM. The PCA based SOC stability index developed by integrating different sensitive SOC stability indicators was observed highest in 50% NPK+50% N-FYM followed by 50% NPK+50% N-FYM in all the soil orders. Overall the stability index was higher in Mollisol followed by Vertisol, and Inceptisol being at par with Alfisol. The maximum C carrying capacity (Cm) of Inceptisol, Mollisol, Vertisol, and Alfisol, were estimated as 49.7, 66.6, 56.8, and 50.7 Mg ha^{-1} in 0–60 cm soil depth, respectively.

4.2.2 pH and temperature on the stability of metal humus complex in different soil orders

Stability of metal humic acid complex (Log K) was significantly influenced by pH and temperature. The log K values showed significantly higher stability of metal humic acid complexes at pH 7.5 and 35˚C. The Log K values of Cu-HA complex were significantly higher due to higher affinity of Cu to bind the HA. The data on stability constants of metal humic acid complexes showed the following trend *i.e.* Cu>Fe>Pb>Cd>Zn>>Ni>Mn. Humic acid showed a higher stability constant under vertisol as compared to soil orders like Inceptisol, Alfisol, and Entisol.

4.2.3 Dynamics of SOC under conservation agriculture

CA experiments on diversified intensive maize based crop rotations, indicated that SOC content was in the order maize-chickpea-*Sesbania*> maize-wheat-mungbean> maize-maize-*Sesbania*> maize-mustard-mungbean. Decay rate of SOC mineralization was drastically reduced by implementation of ZT with residue retention, indicating higher C stability by means of greater physical protection through soil aggregates, especially through C associated with macro-aggregates. In another experiment, rice residue retention with Pusa decomposer application registered higher values of decay constants of carbon mineralization than burning and residue incorporation which revealed that Pusa decomposer can effectively decompose rice residues.

4.2.4 Soil organic C fractions and C cycling enzymes under sludge amended Inceptisol

Sludge application significantly improved labile and non-labile pools of SOC. Sludge application decreased moisture sensitivity (Ms) of C mineralization by 19.1 and 16.9% as compared to control and 100% NPK, respectively. The temperature sensitivity (Q_{10}) value at SOC decomposition in sludge treated plots was 13.8% higher than the control. Irrespective of treatments, activities of β-glucosidase and dehyrogenase increased while phenol oxidase activity decreased in soil with increasing moisture and temperature level.

4.2.5 Soil quality and resilience

Soil quality indices varied from 0.42 to 0.93 under conceptual framework-based method and 0.34 to 0.98 under PCA based method. Among the different integrated treatments, the performance of NPK + FYM was the best followed by NPK + *in situ* green manuring + biofertilizer and NPK + *in situ* green manuring treatment. Soil quality index values ranged from 0.61 in maize-potato cropping system to 0.85 in rice-chickpea system of Hazaribagh plateau. The soil quality index followed the trend as rice- chickpea > agroforestry > rice-fallow >urd-mustard > rice-wheat > maize-potato.

4.2.6 Phosphorus dynamics in conservation agriculture

The average distribution of soil P fractions in soil under conservation agriculture (CA) followed the order: residual-P (35.4%)> HCl-P (33.5%)> NaOH-Po (16.7%)> $NaHCO_3$-Po (6.87%)> NaOH-Pi (4.46%)> $NaHCO_3$-Pi (1.91%)> WSP (0.92%). Retention of 4 ton ha^{-1} crop residue along with application of 50% recommended P dose, phosphate solubilizing bacteria and arbuscular mycorrhizal fungi significantly increased macro aggregate associated P which was at par with 100% recommended dose of P. In another experiment, the soluble and loosely bound P was higher under zero tillage (ZT), whereas Al- bound P, Fe- bound P, reductant soluble P and Ca- bound P were higher in CT. Distribution of organic P fractions in moderately labile and non-labile P were found higher in PB (permanent bed) and ZT. Phosphorus adsorption capacity and maximum phosphate buffering capacity under CA was lower as compared with CT plots. Desorption studies showed that CA maintained lowest percentage of adsorbed P than of CT.

4.2.7 Solubilization of native phosphorus (P) in soil

To solubilize the built-up P by Si, sodium silicate ($Na_2SiO_3.10H_2O$) and Si-rich crop residues *viz*., rice straw and sugarcane leaf were used in a greenhouse pot experiment in wheat. The available P (Olsen-P) content was significantly increased from 6.53 mg kg^{-1} in control to 6.77 and 7.09 mg kg^{-1} under 50 and 100 mg kg^{-1} of applied Si. In marginally medium P soil of IARI, New Delhi, the combined application of 75% RDP along with rice straw or sugarcane leaf or sodium silicate was capable to produce grain yield comparable ot full dose of P (100% RDP).

4.2.8 Suitability of extractants to release potassium (K) from soil

Solutions of (0.1 N) acetate and chloride salts of barium (Ba^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), ammonium (NH_4^{+}), and hydrogen (H^{+}) were evaluated separately for their effectiveness in releasing soil K. The 0.1 N $BaCl_2$ was found to be the most suitable extractant for exhaustive K release from soil as the release was mainly through solid-solution exchange.

4.2.9 Boron availability under long-term organic management

The application of farm yard manure (FYM) alone or in combination with other organics (green manure and biofertilizer) increased the B availability and uptake of B by wheat. Among the B fractions, specifically adsorbed and organically bound B were 40.0 and 47.8% higher and oxide bound B was 24.9% lower in organically treated soils compared to the control.

4.2.10 Organic and inorganic amendments for reducing arsenic (As) in soil and plants

A green house pot experiment was conducted with rice cultivar IR-36 as the test crop to assess the effect of organic and inorganic amendments on available As content in soil and its uptake by rice in As contaminated soil collected from Nadia district, West Bengal. Arsenic content in rice grain was 256, 158, 128 and 178 µg/kg grown on control, flyash, steel lag, sugarcane bagasse and vermicompost-amended soils, respectively, indicating that sugarcane bagasse was most effective in arresting the transfer of As from soil to rice grain.

4.2.11 Zero–valentiron for remediating arsenic (As) contaminated drinking water

To develop a low cost and efficient sorbent product for remediating As contaminated drinking water, bentonite supported nano zero valentiron (nZVI-Bento) was synthesized through the reactions of bentonite clay, ferrous sulphate heptahydrate ($FeSO_4.7H_2O$), NaOH, and sodium borohydride ($NaBH_4$) solution under gaseous N_2 environment. Results revealed that bentonite clay-based nano zero valentiron showed super-adsorbent features of removing As from water at a very low dose (0.25 g L^{-1} in 30 mL of solution) of application.

4.2.12 Metal uptake by crop as influenced by sludge application

The pH of surface soil (0-15 cm) reduced significantly due to continuous application of sludge @ 30 t/ha after 8 years. The DTPA extractable Zn, Ni, and Cd in soil increased with sludge application. Hazard quotients (HQ) were far below the permissible limit indicating the safe consumption of the edible part of baby corn. In view of the build-up of metals in soil, the treatment combinations of 25% N substituted by sludge+NPK (150:60:50) and 100% NPK +2.5 t sludge/ha are recommended for growing crops.

4.2.13 Aluminium dynamics under long-term organic practices in Inceptisol

Fertilization with enriched compost @ 5 t ha^{-1} was most effective in decreasing exchangeable and total acidity, and exchangeable Al, whereas total potential acidity, pH dependable acidity, weak organically bound and amorphous Al were highest in the same treatment. Application of compost and biofertilizers consortia did not alter organically bound Al interlayer Al, and free Al fractions as compared to the control.

4.2.14 Bio-bed preparation for dye remediation

The capacity of maize cob and cob husk for reactive azo dyes remediation (RB-5 and RB-19) from simulate diffluent was carried out in order to select the adsorbent for bio-bed preparation. The bio-bed was prepared with *P. chrysosporium*, the white rot fungus immobilized on maize cob and used for dye remediation. The results showed that at pH 6 and dose 15 g/L, the bio-bed maximally removed RB-5 (Concentration 10 mg/L) up to 3 cycles. For RB-19, the optimized dose for maximum dye removal was 10 g/L which was also able to remove the dye successfully upto 3 cycles.

4.2.15. Nutrient management

4.2.15.1 Evaluation of novel nitrogenous fertilizer products

Nano clay polymer and biopolymer composites (NCBPC), as well as slow-release coated urea fertilizer product significantly controlled the N release than that form normal urea. The 75% N application through coated urea products as well as 20% N supplied through NCBPC as basal+50% urea (2 splits) recorded on par grain N and total N uptake by maize with that of 100% N applied through urea.

4.2.15.2 Silicon-rich agro-wastes and PSB for solubilization of recalcitrant soil P

Phosphate-solubilizing bacteria (PSB) and silicon (Si)-rich agro-wastes (sugarcane bagasse ash, rice husk ash, and corn cob ash) were used with to solubilize the recalcitrant soil P. The PSB (*Lactococcus lactis*) was efficient in solubilizing Si and P by ~ 1.46% and ~ 17%, respectively, over no PSB; whereas Si @ 125 and 250 mg kg^{-1} increased soluble Si by ~ 39% and ~ 51% along with solution P by ~ 44% and ~ 57%, respectively, over no Si.

4.2.15.3 Evaluation of oxalic acid treated waste mica for K source

Oxalic-acid-treated waste mica (OAWM) was evaluated as a potent supplement to conventional K-fertilizer. In a pot experiment, muriate of potash (MOP) @ 30 mg K kg^{-1} along with OAWM @ 60 mg K kg^{-1} maintained significantly higher water-soluble K, plant available K, and non-exchangeable K over control and untreated waste mica at different growth stages of wheat. Application of MOP (30 mg K kg^{-1}) along with oxalic acid treated waste mica (60 mg K kg^{-1}) also increased wheat grain yield (9.61 g pot^{-1}) and total K uptake (402.5 mg pot^{-1}) over application of waste mica @ 120 mg K kg^{-1} soil (grain yield 2.98 g pot^{-1} and 297.3 mg pot^{-1}, respectively) and maintained positive soil K balance at post-harvest wheat.

4.2.15.4 Effect of long-term fertilizer and manure application on crop productivity

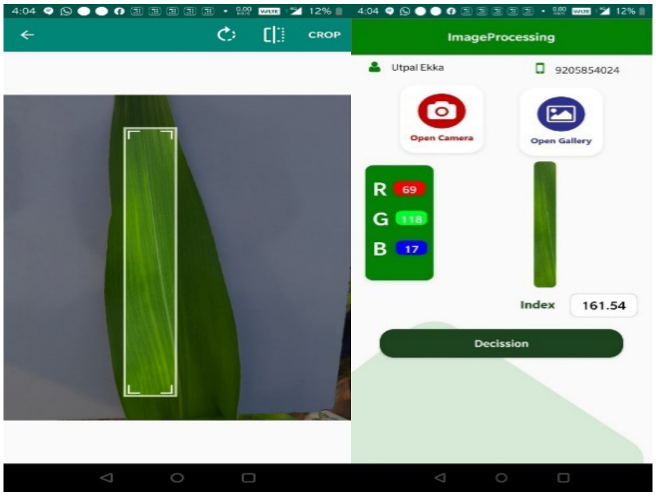
Fifty years of continuous application of 150% NPK and 100% NPK+FYM registered significantly higher grain yield compared to the recommended dose of NPK in an Inceptisol. Application of Zn and S alongwith NPK had similar grain yield compared with recommended NPK in almost all the years. The balanced application of NPK registered significantly greater yields compared to unbalanced or sub-optimal dose treatments *i.e.* N, NP, and 50% NPK.

4.2.15.5 Sea weed extract-based products for enhanced soil health and crop productivity

Granules and liquid of a sea weed extract-based product named *Sagarika* was evaluated under maize-wheat-mungbean cropping system in a field experiment. Highest grain and straw yields were observed with NPK (150:60:60) + Sagarika foliar @ 5 mL/L and NPK + Sagarika granules @ 24.7 kg/ha, respectively. The 75% NPK + Sagarika granules @ 24.7 kg/ha alongwith Sagarika foliar 2.5 mL/L or 5 mL/L produced maize yield comparable to recommended NPK dose.

4.2.15.6 Mobile-based nitrogen predictor application software for maize and wheat

Six varieties of maize (AH4271, DKC9164, PC3, PC4, PJMH1 and PMH1) were grown with the application of graded levels of N fertilizer (from 0 kg to 240 kg/ha). Images of maize leaves were captured at a fixed interval through a smartphone camera, and N content and normalized difference vegetation index (NDVI) were measured. An android-based application was developed which could predict the greenness of the captured leaves, based on the red-green-blue pixel



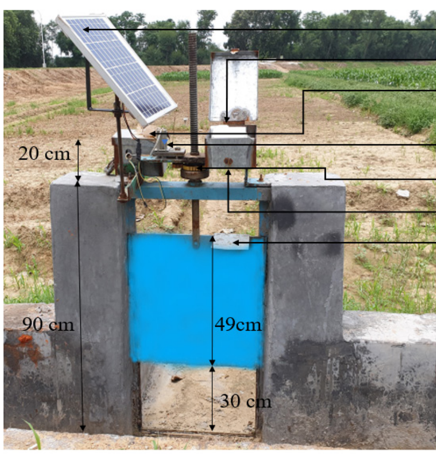
Android-based application

values of leaf images. Based on the greenness value, real-time N recommendation could be made through the android-based smart phone application.

4.3 WATER MANAGEMENT

4.3.1 Sensor-based automatic basin irrigation system

A soil moisture sensor-based automatic basin irrigation system was developed. The results revealed that two soil moisture sensors are required to open and close the check gate automatically. The placement of SMS-2 was suitable for opening the check gate compared to SMS-1 for soil moisture depletion ≥40% and SMS-3 for soil moisture depletion ≥20%. This automatic irrigation system achieved irrigation application efficiency of >85%, distribution uniformity of >0.85 and water requirement efficiency of >95% in wheat crop.



Solar Powered sensor based automatic basin irrigation system

4.3.2 DSSAT CERES model for drip fertigated wheat

CERES-wheat model of DSSAT was calibrated and validated using data obtained from the field experiment with two wheat cultivars (HD 3086, HD 2967) irrigated at 70, 85 and 100% ETC and fertilized with 75, 100, and 125% recommended dose of nitrogen. The observed anthesis and maturity dates of wheat grown under minimum stress treatments were found to advance by 2-3 days than the simulated dates when the crop was grown under water and nitrogen deficit conditions. The CERES model predicted the grain yield with good accuracy for both the cultivars as indicated by normalized root mean square error and index of agreement values of 2.16% and 0.97 for HD 3086 and 6.25% and 0.86 for HD 2967. The coefficient of residual mass values of 0.168 and 0.078 for HD 3086 and HD 2967 cultivars indicated that the wheat biomass was slightly underestimated by the model.

4.3.3 Machine learning models for reference evapotranspiration estimation

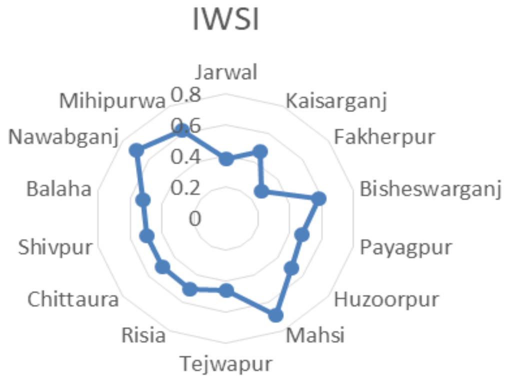
Different machine learning models based (ML) on Random Forest (RF), support vector machine (SVM), Neural Network (NN) and Linear Regression (LR) were developed to estimate ET_0 with minimal climatic inputs keeping the FAO-56 Penman-Monteith model as a reference. The results indicated that the SVM performed better than other ML models followed by NN, LR, and RF. Even though excellent performance can be achieved when all input variables are used, the study found that even a combination of four-parameter (Tmax, RH, WS, SSH and Tmax, Tmin, WS, SSH), a combination of three-parameter (Tmax, WS, SSH) or a combination of two-parameter (Tmax, WS) could be promising in ET_0 estimation.

4.3.4 Water productivity enhancement in drought prone Nanded, Maharashtra

Water Resource Planning and Management (WEAP) Hydrologic model based analysis of water availability and demand for agricultural, livestock, and domestic sectors was carried in Nanded district. The monthly net and gross irrigation requirements (MNIR and MGIR) for major crops grown varied from 49 to 1093 mm/year and 141 to 3123 mm/year, respectively. The total annual irrigation water requirement for the Nanded district of Maharashtra was 689 Mm^3. The average annual water demand, supply delivered, unmet demand and stream flow during 2002-20 using WEAP model were estimated to be 696, 302, 243 and 294 Mm^3, respectively.

4.3.5 Irrigation water security index for Northern India

An irrigation water security index (IWSI) was developed for Bahraich district of Uttar Pradesh taking into account water availability, water productivity, environment and ecology, water-related disasters and water governance using analytical hierarchical process (AHP). The highest green water use was observed for sugarcane in Huzoorpur block followed by paddy in Jarwal block, whereas corresponding blue water use in Bisheswarganj and Shivpur, respectively. Economic water productivity was found to be medium except Chittaur block (poor). Integrated water footprint was the highest for Mahsi block (947 m^3/tons). It was found that Fakherpur block followed by Jarwal block have the lowest IWSI (0.28 and 0.38) values with priority class 1, and the highest values in Mahsi and Nawabganj blocks (0.69 and 0.7) with priority class 5.



Map of irrigation water security index (IWSI)

4.3.6 Drip fertigation in maize-wheat under different nutrient management options

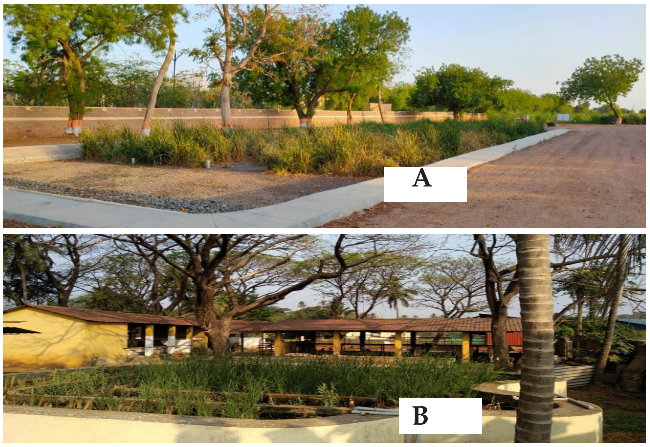
The highest grain yields were obtained with the integrated use of nutrients followed by 100% NPK through chemical fertilizer and organics, whereas the lowest was in case of natural farming. The grain yield of maize harvested from conventional system plots were equal to the grain yields produced from the plots having integrated nutrient use or drip fertigated with 100% RDF of NPK. The grain yield of maize irrigated at 80 and 100% ETc were equal. Both surface drip and sub-surface drip fertigation also resulted in similar grain yields of maize.

4.3.7 Water conservation and nutrient management practices for a horti-pasture system

Higher soil moisture content in the trenches (15.8%) followed by micro-catchment (14.7%) and control (with no moisture conservation measure) (12%) was observed under different water conservation techniques. Highest fresh biomass was recorded in the trenches compared to the micro catchment. Also, application of 50% recommended doses of fertilizer (RDF) + biofertilizers (BF) + FYM produced the highest fodder yield of sorghum compared to that obtained with the use of 100% RDF or 75% RDF + biofertilizers. Tree height, tree canopy, area and fruit yield of lemon were also significantly influenced by the trench moisture conservation technique.

4.3.8 Jalopchar technology for waste water treatment

During the reporting period, four Jalopchar technology-based waste-water treatment facilities were designed and developed for CCARI (Goa), IIHR (Bengaluru), SKNAU(Jobner) and KVK (Shikhopur) while the fifth one developed and commissioned at CAZRI, Jodhpur in 2019 continued to be assessed for its performance efficiency showing a reduction of 83-100% in heavy metal contents in treated wastewater compared to that of untreated wastewater. Similarly, turbidity was reduced by 93% whereas the contents of nitrate, sulphate and phosphate were reduced by 31-55%.



Treatment cells at A. CAZRI, Jodhpur B. CCARI, Goa

4.4 CPCT

4.4.1. Irrigation and fertigation scheduling

4.4.1.1. IoT and sensor operated greenhouse vertical farming system

Six layers hydroponic NFT based vertical farming systems as 'A Type' and 'Flat type' with and without artificial LED light were installed inside 1000 sq meter climate-controlled greenhouse. Each structure with 12 frames was designed with automatic fertigation and could accommodate 200 plants. Fertigation and climatic sensors were used for developing IoT based control system. Leafy green vegetables mainly lettuce and Pak-Choi were used for growing and evaluation of the structures.

Vertical farming systems

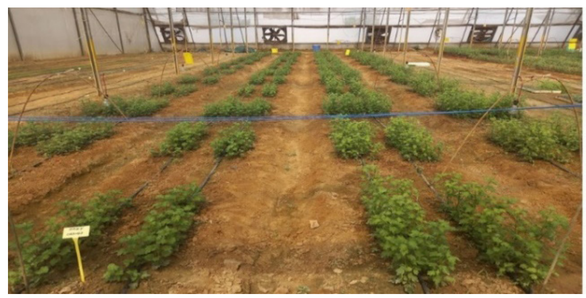
4.4.1.2. Water saving in vertical hydroponic systems

The average water consumption in A-frame hydroponic NFT structure was 24.5 litre/kg fresh leaves whereas in Table top NFT structure, it was 20.5 litre/kg fresh leaves. However, the water consumption in A-frame structure was 18.36% higher compared than in Table top structure due to receipt of more uniform sunlight through all the production layers.

4.4. 2. Flower crops

4.4.2.1. PGR mediated growth and flowering in potted ornamental plants

Gerbera, chrysanthemum, and foliage plants were tested with 2 ppm homo-brassinosteroid (Br) for growth put on significant spray effect was observed, However, early flowering was recorded in chrysanthemum varieties (by 07 days in Autumn White and 11 days in Dian Orange). The number of branches were significantly higher in the plants treated with 4 ppm Br in Autumn White (37) and Diana Orange (19) compared with plants under control (13).



Homo-brassinosteroid mediated growth and flower

4.4.2.2. PAR compact plants in flowers crops for flower induction using smart LEDs

Seedlings exposed to long day PAR for 7-10 days were useful to grow uniform and compact crop of chrysanthemum. On the other hand, the crop took 72

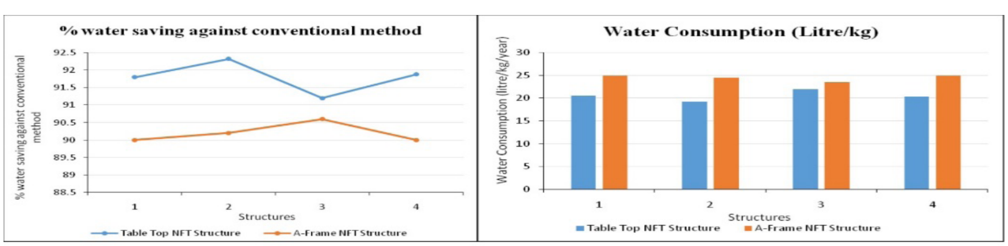
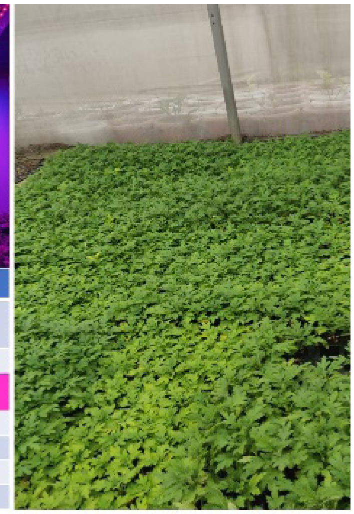


Fig.1.2. Water saving and water consumption vertical farming systems

Light Treatments	Components of irradiance			
	Solar Radiation (W/m)	PAR-Sun (μM)	UV-A&B (μM)	PAR Electric (μM)
Florescent light	38.5	79.3	17.9	72.8
Red (80%)+ Blue (20%) LEDs	64.3	128.2	10.6	119.3
Blue (100%) LEDs	66.0	104.0	13.6	111.5
Red (100%) LEDs	52.0	104.5	12.3	98.3
White (100%) LEDs	58.3	118.2	11.8	107.0
Greenhouse (NVPH)	191.0	38.6	38.4	345



PAR compact plants in flowers crops using smart LEDs

days for harvest as compared with the un-exposed plants of Autumn White which could be harvested at 93 days after transplanting with uneven flowering stems.

4.4.2.3. Evaluation of chrysanthemum varieties for off-season production

Spray (5) and standard (2) varieties of chrysanthemum were grown under greenhouse from the self-rooted cuttings raised under long days exposed with LEDs @ 160 μ mol $sec^{-1}m^{-2}$. Autumn White could produce longer stems (98.3 cm) with maximum number of primary (9) and secondary branches (21) and buds (57) per stem. However, among the standard varieties, Yellow Stone could produce acceptable stem length (76 cm) with lartest flower size (13.5 cm diameter across) followed by White Moon which remained stunted (57.4 cm) with short stem length (51 cm) and a flower size of 9.2 cm diameter across.

Chrysanthemum varieties for off-season production

4.4.3. Vegetable crops

4.4.3.1. Variety/hybrid combinations in tomato for protected condition

Twenty Seven crosses were found promising in cherry tomato. 23 genotypes were characterized for quality parameters and No. 206, No. 57-1, No. 304, No.123, No. 249, No. 9-1-7, No. 9-1-8 and No.207 were found suitable for processing. Crosses H-347, H-337, H-352, H-375, H-362, H-378 and H-352 were found suitable for

Hybrid combinations in tomato for protected condition

processing traits. Forty-eight tomato germplasm lines were genotyped for TOLCV and late blight resistance genes and entries 28-1, 277, 9-1-7, 9-1-8, 101 Yellow were found resistant to TOLCV (Ty3gene) and no. 214, 312 and Z-292 for late blight resistance. Two entries of indeterminate tomato no.177 and 206 have been promoted to AVT-II on the basis of multi-location testing. Three more entries of tomato are nominated for IET trials. Five trials on protected cultivation were conducted and data compiled and submitted to ICAR-IIVR, Varanasi.

4.4.3.2. Capsicum genotypes for protected cultivation

In Capsicum, 48 entries including segregating lines were evaluated and no. 30, 32, 31-1, 34, 35 yellow, 8 Pb, KTRC- 6, KTGC-13 were found suitable for cultivation in open as well as protected conditions.

4.4.3.3. Pusa Bitter gourd versus Private Bitter Gourd Varieties under protected structures

Polyhouse and net-house experiments on off and early season production showed that, the variety Pusa Rasdar had maximum marketable yield ranging from 11.41 to 18.75 kg/m^2 during September, October, and January month planting under Polyhouse and Net house conditions as compared to S-57, S-32 new lines of Pusa Bitter gourd. On the other hand, private bitter gourd var. Unnat CT-208, Prachi, Altaf-Raja exhibited lower yield ranging from 8.55 to 10.25 kg/m^2 as compared Var. Pusa Rasdar and other new lines.

4.4.3.4. Pusa Cucumber versus Private Cucumber varieties under Protected Structures

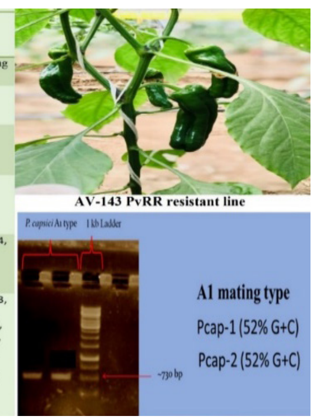
Cucumber varieties were evaluated under Polyhouse and Net-house conditions for off and early season and observed that higher fruit yield and income was recorded from the 7 new lines of Pusa cucumber with good rank in other structures. Pusa cucumber line DPACH-7 and DPACH-4 produced higher 16.65 and 16.2 kg/m^2 yield as compared to a private variety. Maximum yield and income was obtained in September and January planting in Polyhouse as compared to net house structure.

4.4.4. Breeding capsicum/ tomato for protected cultivationand root crops

4.4.4.1 Leaf blight and Phytophthora root rot resistance in capsicum

Four resistant (0-5%) and one moderately resistant line (5-10%) were identified from AVRDC (World Vegetable Centre, Taiwan) collection and two from F2 segregating population against the *Phytophthora capsici* accession no. SUB9932055 Belgaum MZ479061 collected from IIHR, Karnataka.

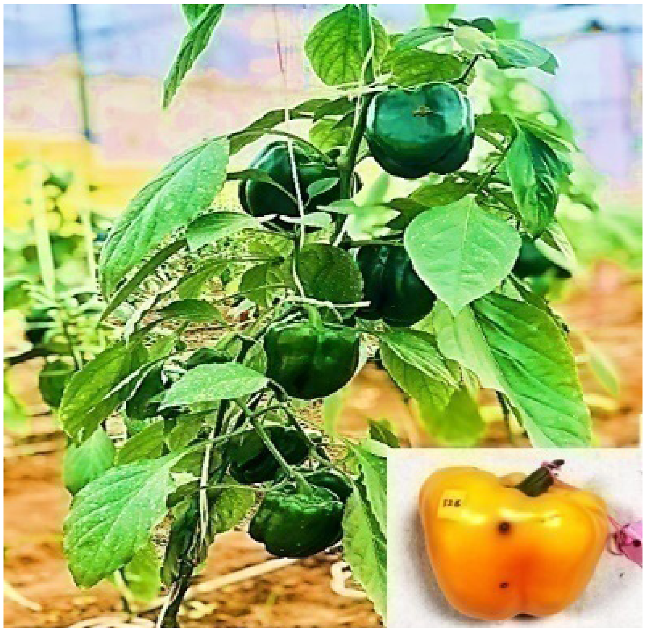
Disease Rating	Disease Severity	Reaction Type	Genotypes	
			AVRDC	F2 segregating population
1	0-5%	Resistant	143, 116, 132, 133,	84, 35 B, check 144
2	5.1-10.0%	Moderately Resistant	144	31, 102A
3	10.1-25.0%	Moderately Susceptible	120, 127,	100, 103
4	25.1-50.0%	Susceptible	148, 130, 131, 134, 139, 128, 152,	79, 89, 90, 34, 37A, 115, check CW
5	>50%	Highly Susceptible	149, 150, 151, 153, 154, 147, 146, 145, 135, 136, 137, 138, 140, 141, 117, 118, 119, 126, 142, 129	78, 80, 81, 83, 87, 32, 33, 35B, 36, 37B, 67, 112, 118, 119, 97, 94, 95, 99, 98, 102B, check 152



Leaf blight and Phytophthora root rot resistance in capsicum

4.4.4.2. Resistance against *Colletotrichum capsicin* F2 segregating population of capsicum.

Anthracnose (*Colletotrichum capsici*) is a seed as well as soil born disease in Capsicum with significant loss of 20-80% in post and pre-harvest marketable yield and reported to affect all the aerial parts at both green and ripe fruit stage. The outbreak of the fruit rot started from June to September, early to middle season in open field conditions whereas fruit lesions begins during December in protected structure. Fruits 32b segregate population showed high resistance against *Colletotrichum capsica* with 0-5% disease severity while rest of the population was observed to be susceptible.



Resistance against *Colletotrichum* capsicin

4.4.5. IPM management in greenhouse crops

4.4.5.1. Integrated nematode management in greenhouse tomato variety, NS 4266

Treatment involving organic amendment as combined organic using bio-agent with *Trichoderma harzianum* along with fungicide matalaxyl and nematicide, fluopyram gave best results in terms of reducing the root knot nematode gall index to 1 as compared to 2.75 in the plants under control, besides giving better yields of 9.78 kg/m^2 as compared with 2.42 kg/m^2 in untreated plants.

4.5 AGRICULTURAL ENGINEERING

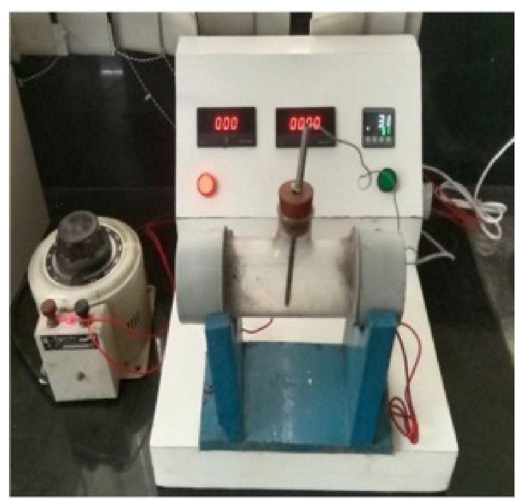
4.5.1 Electric Agri Prime Mover with its attachment

Small electric agri-prime mover has been developed to enhance the efficiency of human beings in farm operations. The small electric agri-prime mover consists of C-type ladder chassis, three-phase BLDC motor, controller, power transmission unit, drive wheels, front cover of chassis, handle, accelerator, battery power pack of 48V 33Ah, and central hitch for attaching equipment as per operational need. The operational speed of the prime over is up to 2.5 km h^{-1}. The field capacity of 250mm MB plough in tillage operation per pass was found to be 0.03 ha h^{-1} at speed of 1.5 km h^{-1}.

Electric Agri Prime Mover

4.5.2 Ohmic assisted extraction technology

An eco-friendly and cost-effective ohmic assisted extraction technology was developed for enzymatically hydrolyzed black cumin seed. Different unit operations involved in the extraction process and the process variables responsible for oil yield



Ohmic assisted extraction technology

were also standardized. A laboratory model of ohmic heating apparatus for an increase in oil yield from enzymatically hydrolyzed black cumin seed was also designed and developed.

4.5.3 Solar powered/battery-operated harvester for leafy vegetables

Solar powered/battery-operated harvester was designed and developed for leafy vegetables consisting of cutting mechanism, Conveying mechanism, adjustable reel (suitable for different crop heights) and propelling unit of the harvester (350-watt 24 V DC motor). Preliminary testing of this device was done in the field and the performance was found satisfactory.

Solar powered harvester

4.5.4 Ergo-compliant two-wheel battery-assisted weeder

The existing battery assisted 350W DC motor operated weeder was assessed as per ergonomic parameter (anthropometric and safety). The modified battery-assisted weeder with U-type handle with telescopic arrangement to increase the height, safety cover, gear box, hutch type drive wheel, 350W DC motor, rear hitch, aluminium frame, motor -controller, accelerator on the handle, pack of 24V, 24Ah batteries weighed 42 kg. The effective field capacity of three tines cultivator was 0.0522 ha h^{-1}. Oxygen consumption rate of worker in operation of three tine cultivator and sweep type tool reduced by 21.77 and 14.96%, respectively compared to existing system. Ergo-compliant weeder had shifted workload from "heavy category" to "medium category".

4.5.5 Overload protection alarm for Pusa Mini Electric agri prime mover

The developed protection alarm for current has a hall sensor module with a facility adjustable over the current indicator as LED glow. While RTD sensor was used in overload protection alarm for sensing temperature. The trend of current drawl and voltage drop suggest for maximum loading of Pusa mini electric agri prime mover up to 490N at 9A current. Thus, alarm was set at 12A.

Pusa Mini Electric agri prime mover

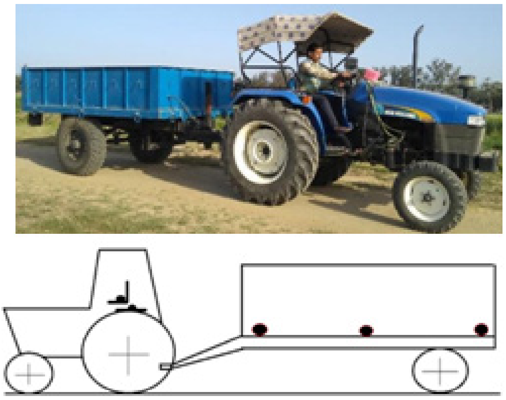
4.5.6 Interventions to enhance the productivity of disabled farmers in agricultural activities

A potato planter for the disabled farm worker was developed, which can be operated using the body weight. It has one pedal to insert the planter in the soil and one mechanism for pressing, which opens and closes the planter cone. With one hand, the disabled person can hold the planter and use the body weight to open the conical portion inserted in the soil to leave the potato tuber and then close the opened portion again with a pedal.

Pedal assisted potato planter

4.5.7 Studies on tractor-trailer vibration

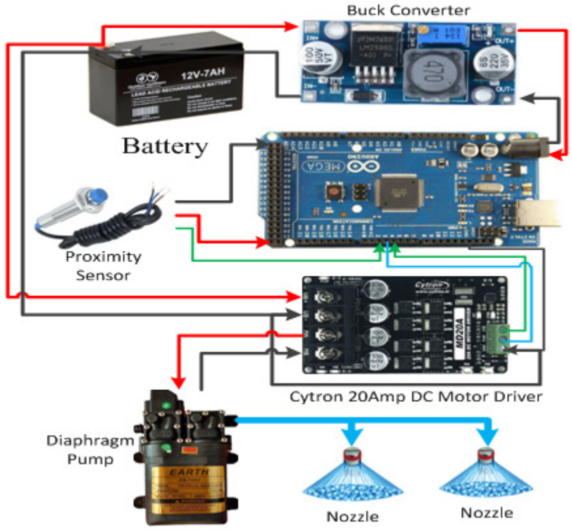
The vector sum of vibration (av) for different positions in tractor-trailer showed maximum values at the rear position in both empty and loaded single-axle trailer. The maximum value of av was observed as 1.52 m/s^{-2} at rear position of empty single axle trailer on village terrain with upper and lower health limit of 2.59 h and 0.65 h, respectively, at 14 km/h speed, whereas minimum value was observed for asphalt terrain at the front position of loaded single axle trailer at 10 km/h speed. Power Spectral density curves showed that critical frequency for tractor-trailer whole body vibration lied in the range of 1-10 Hz.



Tractor-trailer vibration

4.5.8 Sensor based spraying system for Pusa Decomposer

A speed sensor-based microbial inoculum spraying system for combine harvester was designed for developed simultaneous application of microbial inoculum over rice residue during combine harvesting. The spray deposition in terms of the VMD, NMD and droplet density were observed to be in the range of 347 to 243µm, 87.08 to 75.41 µm and 250.2 to 403.9 droplets/cm^2 for effective application of microbial inoculum (Pusa Decomposer) at three selected pressures levels (1.5, 2.5 and 3.5 kg/cm^2).



Sensor-based spraying system for Pusa Decomposer

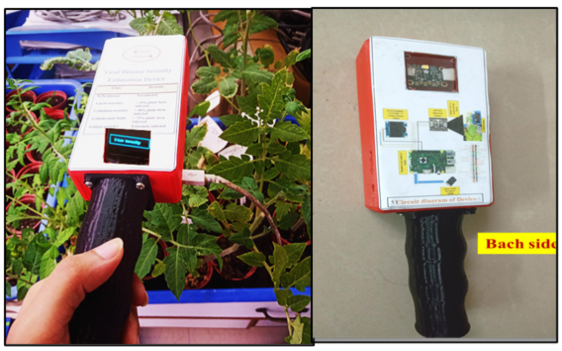
4.5.9 Pusa Farm SunFridge at village Cullakpur, New Delhi

The Farm SunFridge at village Cullakpur is operational and indoor temperatures are around ~3-4°C. Interestingly, the temperatures are so low at some points of the day that there is a need to install a thermostat to keep perishables from chilling injury.

Pusa Farm SunFridge at village Cullakpur

4.5.10 Sensor-based device for estimation of crop disease severity

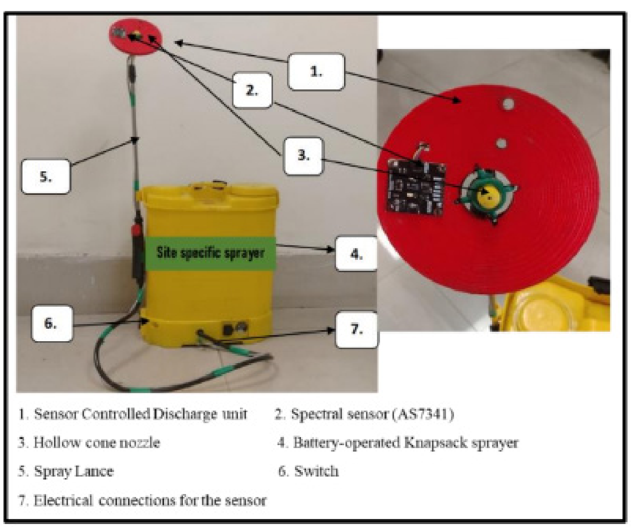
Developed a reliable and affordable handheld sensor-based device that can provide quantified information on viral disease (GBNV) severity of tomato and cowpea crop. The decision tree-based machine learning algorithm resulted in 93.65% accuracy for disease classification in tomato and 87.50% for cowpea. The developed sensor-based device had capability to distinguish the disease severity into five major classes representing a disease severity range of <1%, (1-25%), (26-50%), (51-75%) and >75 per cent.



Sensor based device for estimation of crop disease severity

4.5.11 Sensor-based site-specific sprayer for vegetable crops

A sensor-based site-specific sprayer was developed for vegetable crops (cauliflower and brinjal). Developed site-specific sprayer resulted in saving chemical by 72.5% in black rot diseased vegetable crop and 69.04% in leaf spot disease infested crop compared to a conventional sprayer.



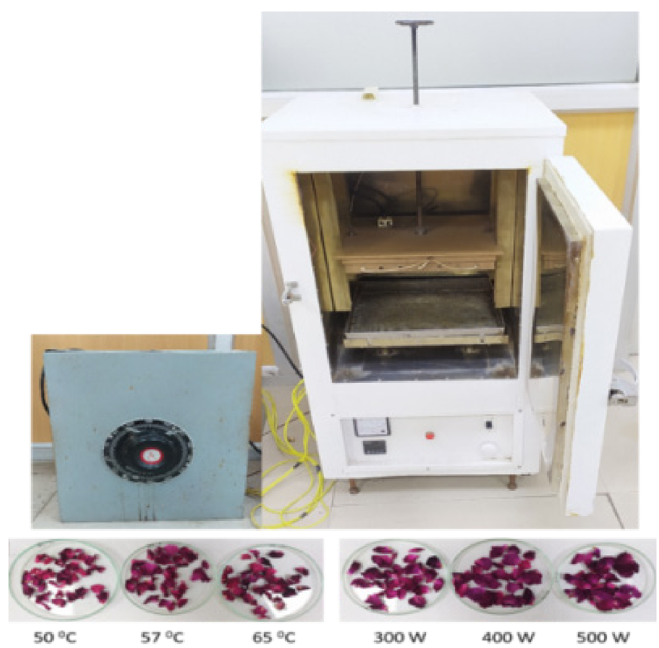
Sensor-based site-specific sprayer for vegetable crops

4.5.12 Modified portable hybrid dryer

A portable hybrid dryer (solar-cum-biomass fired) has been modified with the replacement of poly-sheet with more durable acrylic material (0.2 cm) to enhance greenhouse effect. Time taken to reduce moisture content of turmeric slices from 90 to 8% (w.b) was 6 h and 3.5 h for solar and steam assisted drying, respectively. Cost of developed dryer (24×18×2 in; 12 trays) was estimated to be ₹ 25,000/-.

4.5.13 Infrared drying of rose flower

Infrared drying requires 50-52% less time as compared with forced convective drying. Samples dried at 500 W infrared drying for 18 min. showed higher retention of color, ascorbic acid (61.03 ± 2.6 mg/100g), total phenols (46.80± 4.1 mg/gm), flavonoids (124.45± 12.45 mg/gm), total antioxidants (200.00± 12.2 mM) and anthocyanin content (295.75 ± 65.70 mg/100g) in the rose petals.

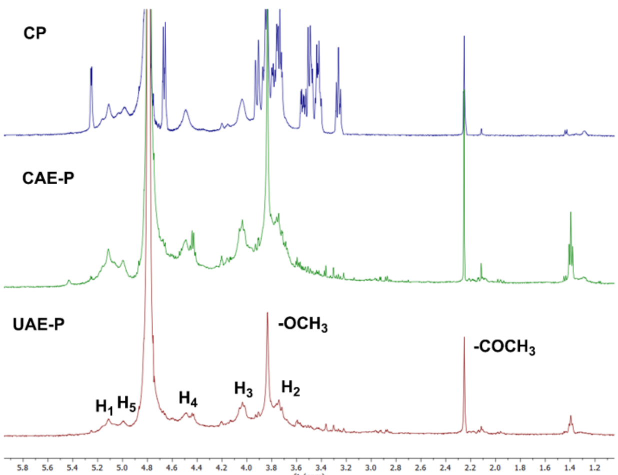


Modified portable hybrid dryer

4.6 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.6.1 Anti-diabetic potential of pectin from Jackfruit peel waste

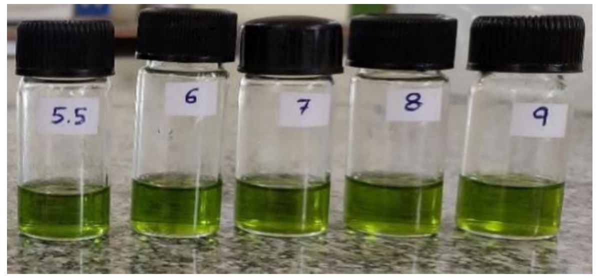
Pectin extracted through ultrasound assisted extraction (UAE-P) had a low degree of esterification (38.11%) and categorized as low methoxyl pectin (LMP). The structural properties were characterized using FTIR, XRD, and NMR. The FTIR spectra of UAE-P showed striking differences from pectin extracted through conventional method (CAE-P). Emulsifying property, functional property and hypoglycemic potential of UAE-P was superior to CP and CAE-P.



HNMR spectrum of commercial (CP) and jackfruit pectin extracted through conventional (CAE-P) and ultrasound (UAE-P) methods

4.6.2 Biocolourant from food waste

The ultrasound-assisted extraction parameters were optimized using Box–Behnken design which gave 92.85% ethanol, 27.7 min sonication time and 46.05 h soaking time as optimized parameters for enhancing the pigment

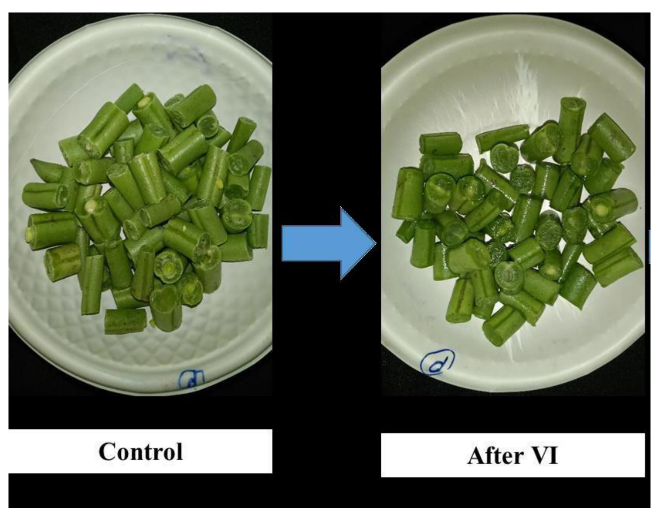


pH stability of extracted pigment

yield by 37.4%. Spectral analysis of data obtained through Fourier Transformation Infrared (FTIR) spectroscopy confirmed the presence of functional groups characteristic of chlorophyll in the extract.

4.6.3 Iron fortification of fresh-cut beans using vacuum infusion

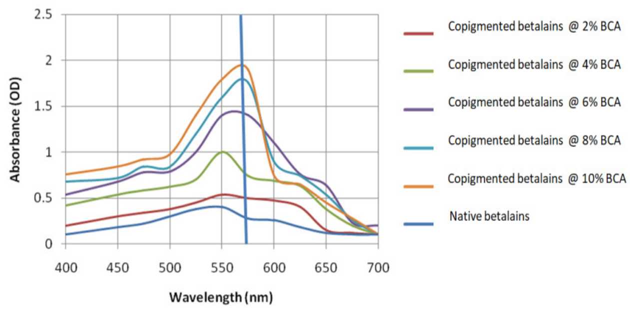
Five iron salts were screened for their suitability as iron fortificant in fresh cut beans. On basis of maximum iron absorption and least colour change observed, ammonium ferrous sulphate was selected at 0.025% concentration. From the experiments, 50 mm Hg vacuum pressure, 6 min vacuum time in absence of ascorbic acid was found to be the optimized condition for the vacuum infusion (VI) process. Optimized condition of the vacuum infusion process was able to increase the iron content of the bean by 38.4% as compared to control.



Iron fortification of fresh-cut beans

4.6.4 Improving stability of betalains through copigmentation

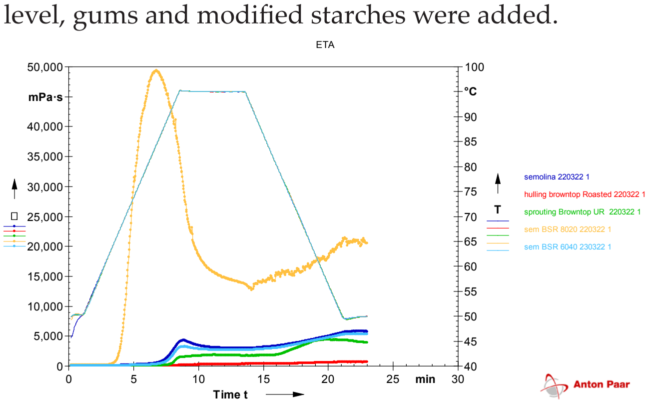
Copigmentation can be explored to address an issue of reduced stability of betalains. Black carrot anthocyanins were used for the first time as copigment with betalains so that copigmented betalains with enhanced stability could be developed to withstand deteriorative processing and storage conditions. For maximum recorded bathochromic shift, 0.8 mL L^{-1} addition was optimized for copigmentation.



Hyperchromic and bathochromic shift in copigmented betalains

4.6.5 Pasta from Kodo, Little and Browntop Millets

Kodo, Browntop and Little millets were used to prepare pasta with semolina at 20-60% replacement levels. While dehulled millets could be used in pasta upto 20% levels, substitution beyond this level lead to higher gruel and cooking loss. Modification of millets through roasting, sprouting and malting treatments lead to better functionality of these millets for pasta making process. For higher incorporation upto 60% level, gums and modified starches were added.



Pasting profile of native and modified millets flours

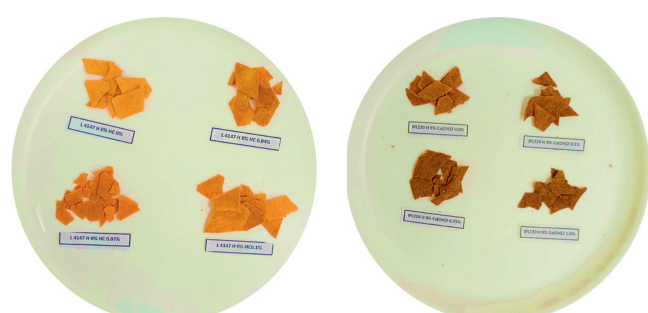
Further, digestibility and minerals profile of 60% substituted pasta was determined and was found to be superior to that of semolina. Gluten free pasta from the three millets was formulated and for colour and nutritional improvement moringa leaves paste was added. The developed gluten free pasta had acceptable cooking quality and taste.

Composition of the developed pasta

Variant	Carbohydrates (%)	Protein (%)	Fat (%)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
Semolina pasta	72.83	12.68	1.05	17	1.23	0.7
Kodo millet pasta	66.60	9.80	3.60	34	2.34	0.7
Little millet pasta	60.90	9.70	5.20	17	9.30	3.7
Browntop millet pasta	71.32	8.89	1.89	28	7.72	2.5

4.6.6 Development of crisps from biofortified lentil varieties

Crisps were prepared from the lentil flour mixed with 3% husk flour. In crisps from L 4147 and L 4717, the proportion of essential amino acids was found higher when the dough was chemically treated with calcium hydroxide prior to crisps formulation; however, for IPL 220 crisps, higher essential amino acids were recorded in the enzymatically-treated dough. Total phenolic content and antioxidant activity in crisps ranged from 11.42 to 18.25 mg GAE/100 g and 0.61 to 1.54 nmol Troloxeq/ g, respectively. The shelf life of lentil crisps

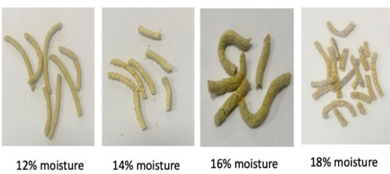


Crisps developed from different formulations

was studied for up to 90 days in ambient conditions in vacuum-packed aluminium laminates. With increasing storage duration, there was an increase in moisture content and free fatty acids (within acceptable limits) with a slight decrease in crispness.

4.6.7 Development of chickpea based high protein breakfast cereal

For chickpea based high protein breakfast cereal feed 16% moisture was observed to be the best for maximum expansion in chickpea extrudates.



Physical properties of extrudates

S.No	Feed moisture content (%)	Radial expansion ratio	Porosity (%)
1	12	1.1±0.01	9.17±0.85
2	14	1.1±0.01	14.25±0.92
3	16	3.7±0.03	71.92±2.11
4	18	1.3±0.01	22.26±1.09

Types of chickpea extrudates

4.6.8 Development of oat based beverages

The starchy solids in oat based dairy analogue beverages tend to settle down during storage decreasing the products appeal. Sodium hexametaphosphate as chelating agent and lecithin as emulsifier was tested to prevent the solids separation in oat-based beverages. Combination of chelating agent and lecithin resulted in increased product viscosity and delayed separation. These are preliminary results and further evaluation of additives is to be done for optimization.

4.7 MICROBIOLOGY

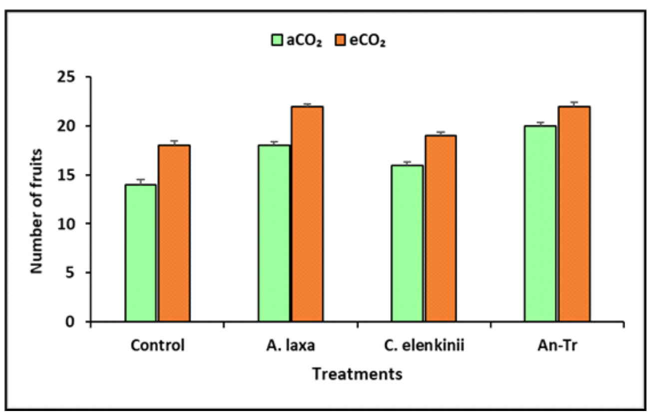
4.7.1 Microbial Resources for improving agricultural productivity

4.7.1.1 Microbial strategies for stress tolerance and nutrient management

Rhizobacterial inoculation activities under moisture stress conditions: Inoculation with rhizobacteria MRD 17 and NSRSSS-1 had beneficial influence on soil biological activities and soil physicochemical properties, including dehydrogenase activity, MBC, and glomalin and CHO content of water-stable aggregates, under rainfed condition. Similarly, *Bacillus megaterium* inoculation in Cowpea (Pusa Sukomal) subjected to simulated moisture stress enhanced the plant root mycorrhizal infection significantly (12%) over the uninoculated control plants under optimum moisture conditions along with ~21.46% higher glycoprotein levels and changes to soil micro- and macro-aggregation.

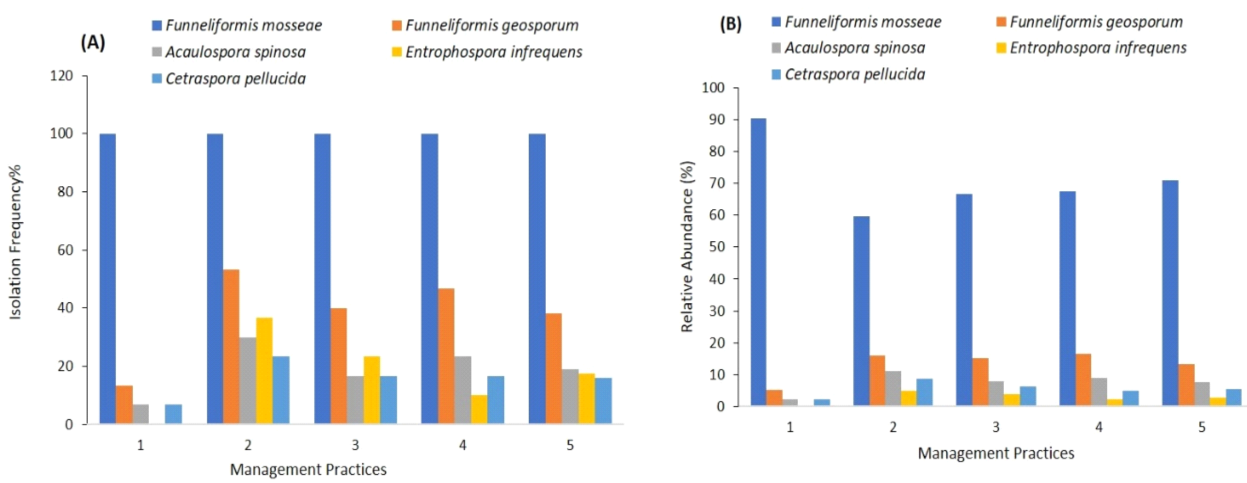
Influence of plant genotype on microbial biomolecules and soil carbon dynamics: Lentil, Fungal biomass measured in terms of ergosterol ranged from 7.2-12.54 µg/g and was highest in the rhizosphere of Lentil followed by Bajra and Chickpea. A similar trend was observed in phenol oxidase activity (1.32- 0.31 µg/g) suggesting that the fungus is the primary agent for the synthesis of the phenol oxidase. Soils under Bajra recorded the highest FDA, Glomalin and water-soluble phenols but low phenol oxidase activity. These parameters suggest that the crop rhizosphere supports microbial activities with differential impact on the build up of recalcitrant C. Among the three crops recalcitrant C contribution in the soil followed the pattern Bajra> Lentil > Chick pea.

Growth and metabolic activities of tomato crop influenced cyanobacterial cultures: Study showed that dehydrogenase activity, leaf chlorophyll and proteins were highest with *Anabaena laxa* formulation, however, An-Tr biofilm was the top performer in terms of the number of flowers and fruits. Overall, elevated CO_2 conditions were more stimulatory for all the soil and plant parameters evaluated.



Influence of cyanobacterial cultures/biofilm inoculation under ambient/elevated CO_2 environment on fruit yield of tomato

AMF communities from various agricultural activity sites: Plant rhizosphere samples from the rice-wheat



Community structure of native AMF in Rice-Wheat cropping system under various management regime A) Isolation frequency of AMF species and B) relative abundance of AMF species under different management regime
(*1*=TPR-CTW, *2*=ZTDSR+WR-ZTW, *3*=ZTDSR-ZTW, *4*=ZTDSR+MBR-ZTW+RR-ZTMB+WR, *5*=Mean; where ZTDSR = Zero tillage direct sowing rice, ZTW = Zero tillage wheat, WR = Wheat residue, BM = Brown manure, ZTW = Zero tillage wheat, Rice residue, MBR = Moong bean residue, ZTMB = Zero tillage moong bean, TPR = Transplanted rice, CTW = Conventional tillage wheat)

cropping system under conservation and conventional agriculture revealed that the inoculum level was 623 spores per 100 g soil and it was mainly represented by four genera and five different species of AM fungi. Rhizosphere samples of rice recorded the highest species richness than wheat. AMF species of *Acaulospora* (1), *Cetraspora* (1), *Entrophospora* (1), *Funneliformis* (2- *F. geosporum* and *F. mosseae*) were found to inhabit the rhizosphere of crops. *Funneliformis mosseae* was the most widely distributed whereas the distribution of *Entrophos porainfrequens* was narrow. Percent share of indigenous AMF based on population was *Funneliformis mosseae* (71.1%), *Funneliformis geosporum* (13.2%), *Acaulospora spinosa* (7.5%), *Cetraspora pellucida* (5.5%), *Entrophos porainfrequens* (2.7%). Isolation frequency of AMF species was of the order CA2 > CA4 > CA1 > TA.

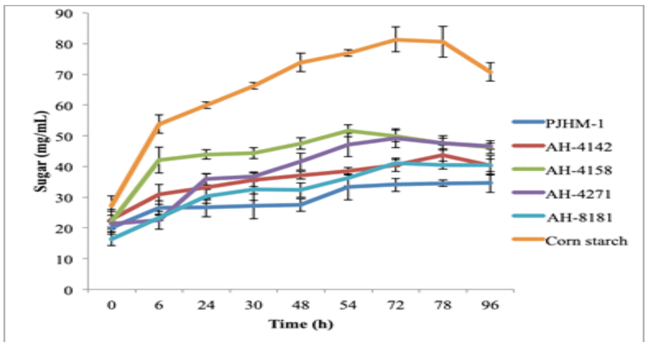
4.7.1.2 Harnessing the potential of micro-organisms for value added products

Phycobiliproteins of selected cyanobacteria: Three cyanobacteria, *viz. Phormidium* sp. CCC317, *Plectonema* sp. CCC316 and *Phormidium* sp. CCC112 were found to produce cyanobacterial phycocyanin (C-PC) biopigment at the rate of 191.1 ± 4.42, 158.1 ± 4.13 and 140.6 ± 4.04 mg g^{-1} CDW. A simple improved purification protocol employing weak anion exchanger and two NaCl concentrations (0.12 and 0.18 M) yielded 5.56 and 5.63 purity grade C-PC with 56.41% and 32.41% recovery for *Phormidium* sp. CCC317 and *Plectonema* sp. CCC316, respectively and analytical grade purity of 4.25 with 95.32% recovery was obtained in *Phormidium* sp. CCC317 with only NH_4SO_4 precipitation. Higher antioxidant activity of purified C-PC was recorded in both isolates.

4.7.1.3 Microbial based technologies for the conversion of farm waste to wealth

Water Dispersible (WP) form of Pusa decomposer for decomposition of paddy straw: Five wettable powder formulations were prepared for ready-to-use Pusa Decomposer. On the basis of shelf life of the microbial consortium, formulation 5 was found to be the best in terms of maintaining the maximum count (9.27 x 10^{20} cfu/g) for three months. Dose optimization studies for paddy straw decomposition at varied doses (0, 100, 200, 300, 400, 500 and 600g WP / t paddy straw) of formulation 5 revealed that the maximum weight loss of substrate with T6 (1 t Paddy straw +500g WP) was from 7 (79.32%) to 21 (92.37%) days. Maximum decrease in the lignin, cellulose and hemi-cellulose content was also observed in the T6 treatment.

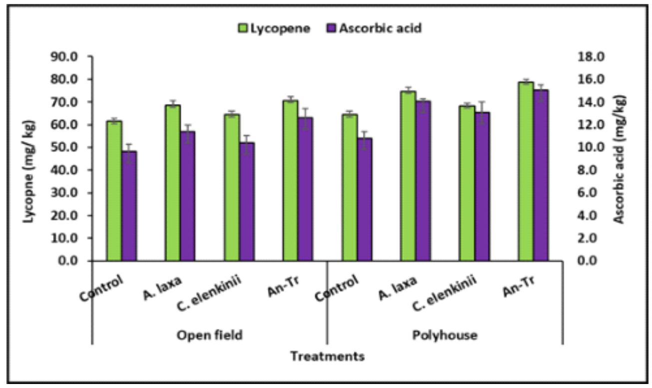
Utilization of biomass as feed and other value-added products: The production of ethanol from corn is found to be cheaper, than rice. Starch, amylose and amylopectin content in rice varieties ranged from 59.9-71.6%, 28.75-46.54% and 13.38-38.38%, respectively. Amylose/Amylopectin ratio, an index of saccharification potential and yield of lower fermentable sugars ranged between 0.84- 3.48. Variety AH4158 showed highest ratio (3.48) but recorded lowest starch content in flour, while variety PJHM-1 showed highest starch content (71.6%) but lower amylose content and ratio (0.84). Variety AH 4271 showed higher sugar yield upon hydrolysis with amylase/diastase.



Sugar contant in corn varieties

4.7.1.4 High quality bioinoculants and delivery systems for agri- management practices

Bioinoculant formulations in vegetable and cereal crops: Study revealed that cyanobacterial consortium (BF1-4) was the better performer, recording significant enhancement of 20-30% in terms of dehydrogenase activity and available N, along with 12-13% enhancement in soil Fe/Zn, SOC. Both these formulations provided 25% N savings along with significantly high yield indices, equivalent to RDF. A similar trend was recorded in wheat (*rabi* 2021-22, varieties: HD 3086, HD 2967, HD 3171). Comparative evaluation of three cyanobacterial formulations (*Anabaena laxa, Calothrixelenkinii*, *Anabaena torulosa-Trichoderma viride*-An-Tr biofilm) in tomato crop grown in polyhouse and adjacent open field in CPCT, IARI, New Delhi illustrated the superior performance of An-Tr biofilm, which brought about an enhancement of 19-20% over control and 10-15% over the other formulations, in terms of available N in soil under polyhouse conditions.



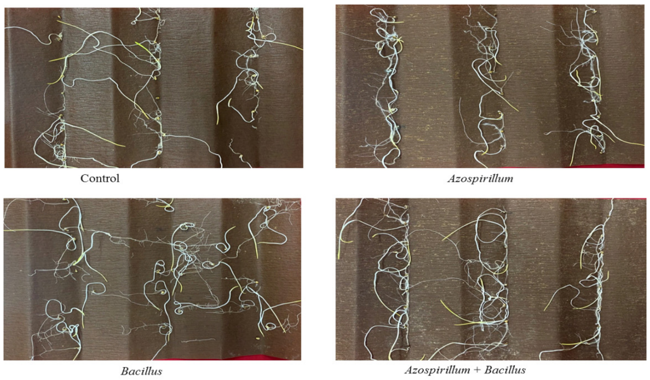
Evaluation of cyanobacterial biofilm formulations on tomato crop under poly house and open field conditions

Arbuscular mycorrhizal root inoculum for mass multiplication and improved P uptake: M-medium was found to possess high effectiveness in terms of % increase in root length. The application of crude starter inoculum (spore + root inoculum) of multiple AM species over performed monospecies inoculum (*G. margarita)* in colonization of transformed roots *in vitro*. These results confirmed the efficacy of multiple species inoculum over monospecies inoculum (*G. margarita)* in the establishment of an AM-ROC dual culture system.

Mass multiplication of arbuscular mycorrhizal root inoculum under in-vitro conditions

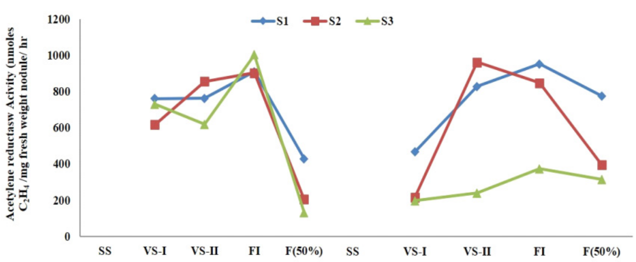
4.7.1.5 *Azospirillum*- *Bacillus* synergistic microbial association for multifunctional benefits

Azospirillum formosense strains AIM57 and *Bacillus* spp. in co-culture system significantly increased PGP traits (nitrogenase, P-solubilization, siderophore). Co-inoculation (75% FC+75% RDN +*Azospirillum*+*Bacillus*) showed improved growth of pearl millet over single inoculations. Field experiment conducted under rainfed conditions also indicated that the co-inoculation treatment (AIM57 + RP24 + 75% RDN) resulted in highest increase in yield (8%) over uninoculated control and was on par with individual (*Azospirillum* AIM57 + 75% RDN) treatment and 100% RDN, thereby suggesting the potential of bioinoculants to save nearly 25% of nitrogenous fertilizers.

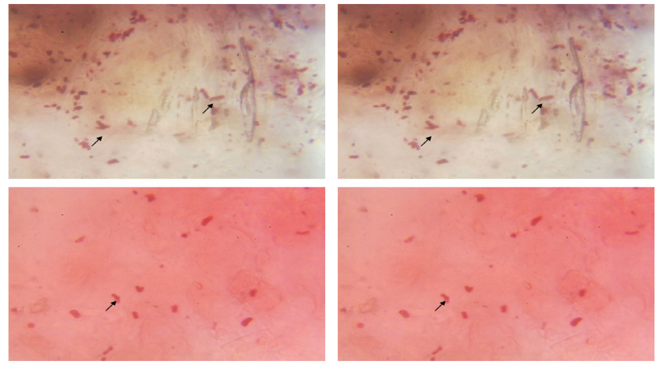


Seed germination and root traits as influenced by individual and combined bacterial treatments (*Azospirillum- Bacillus*)

***Mesorhizobium* strains on root nodule morphology and function in chickpea:** Inoculation effect of three mesorhizobial strains namely *Mesorhizobium ciceri*, *Mesorhizobium mediterraneum* and *Mesorhizobium* sp. evaluated in chickpea genotypes (BG 372 and BG 3022) under pot experiment using sterilized sand and vermiculite as a growth medium revealed that nodule fresh weight was maximum at 50% flowering with *Mesorhizobium* sp. inoculation in BG 372 whereas in BG 3022, highest nodule fresh weight was observed at flower initiation stage. *In-planta* acetylene reduction activity of chickpea root nodules showed higher activity with *Mesorhizobium* sp. with BG-372 genotype (1003.33 nmoles of C_2H_4 /mg fresh weight nodule/ hr) and *M. ciceri* with BG-3022 genotype (958.47 nmoles of C_2H_4/mg fresh weight nodule/ hr) at flower initiation stage.

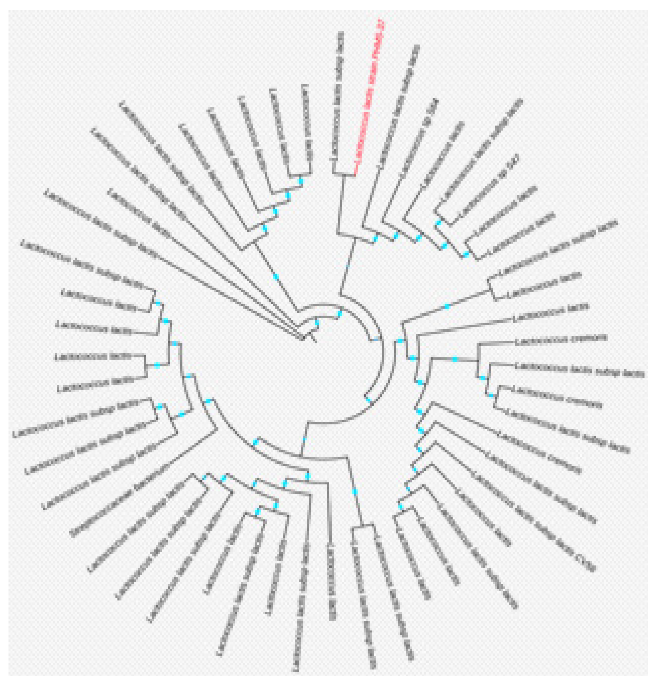


***Mesorhizobium* species showed differential response on nodule nitrogenase activity of chickpea at different growth stages under sterile conditions**



Light microscopic image of chickpea nodules showing bacteroid differentiation

***Lactococcus lactis* whole genome:** Genome–based bioprospecting was carried out of multi-PGP isolate *Lactococcus lactis* strain PHM5-37 which is being used in biofertilizer programme. Besides its efficiency of P solubilization, it has multiple plant growth promoting traits *viz*. N-fixation, IAA and siderophore production, Zn, and K solubilization. The draft genome annotation using NCBI- PGAP (Ver 4.11) revealed 2277 coding CDS and comparative genomic study using more than 70 genome sequences placed this isolate as *Lactococcus lactis* subsp. *Lactis*.



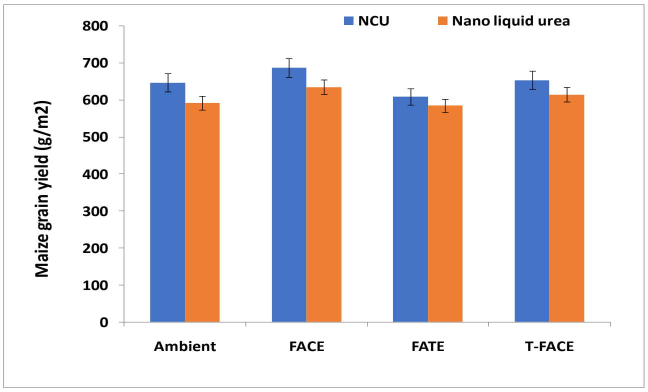
Genome–based bioprospecting used in biofertilizer programme

4.8. ENVIRONMENT SCIENCE

4.8.1. Impact assessment of greenhouse gas mission on crops and microbial community

4.8.1.1. Nano urea application on maize under elevated carbon dioxide and temperature

PJHM-1 maize variety was grown under ambient, elevated temperature (1.5-2.0^o C), elevated carbon dioxide (565 ppm) and elevated temperature and carbon dioxide interaction (565 ppm CO_2 and 2.5^o C) taking neem coated urea (NCU, 120 kg N/ha) and liquid nano urea (IFFCO, equivalent to 120 kg N/ha). The basal soil application of N fertilizer was made using NCU in both the fertilizer treatments, subsequently in the LCU treatment, the remaining N was applied as a foliar application of liquid nano urea. The grain yield of maize was observed to be lower in all the nano urea applied plots under the different treatments. The decrease in yield ranged from 3.9% under elevated temperature treatment to 8.5% under ambient control.



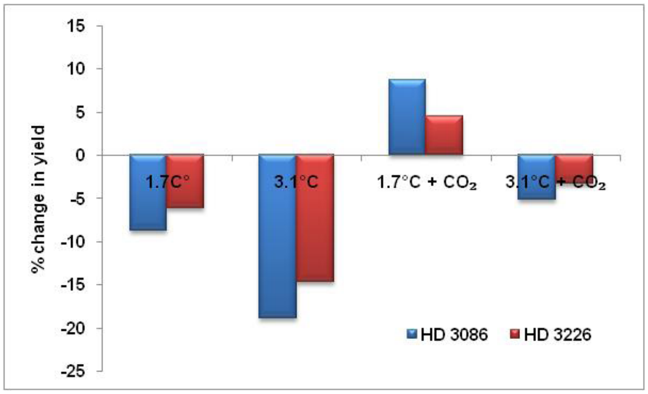
Effect of elevated carbon dioxide and temperature interaction on maize yield under nano liquid urea in T-FACE

4.8.1.2. Nitrous oxide and greenhouse gas intensity from cauliflower cultivation systems

The monitoring of nitrous oxide emission in cauliflower under different cultivation practices was carried out in IARI field. The nitrous oxide fluxes were quantified under flat bed and ridge-furrow system of cauliflower cultivation. The emission was monitored under standard fertilizer and irrigation practices. The emission factor (EF) of N_2O-N from flatbed cultivation (0.72%) was higher than the emission factor (EF) of N_2O-N under ridge and furrow cultivation (0.67%). The emission factor (EF) of N_2O-N from ridge (0.56%) lower than furrow (0.77%). The greenhouse gas intensity (GHGI) was also higher in flat bed system (0.019 kg CO_2 eq/kg curd yield) as compared to ridge & furrow system (0.012 kg CO_2 eq/kg curd yield).

4.8.1.3. Response of wheat varieties to elevated carbon dioxide (CO_2) and temperature

Rise in temperature by 3.1°C reduced grain yield by 18.9% in HD 3086 and 14.7% in HD 3226 variety. In elevated CO_2 plus temperature treatment yield reduction was 5.2% and 3.3%, respectively.

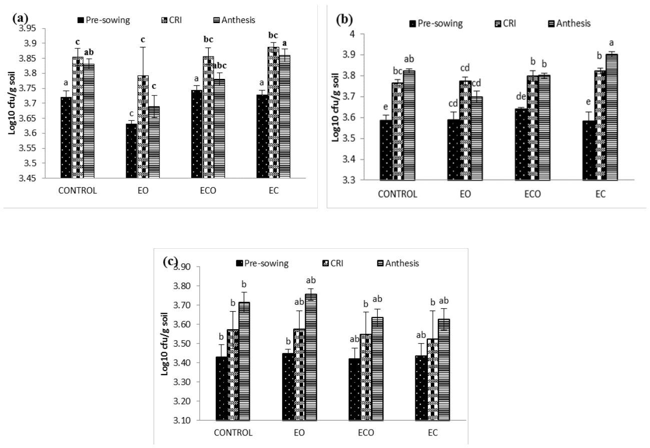


Change in yield in different wheat varieties in elevated CO_2 and temperature treatments

4.8.1.4. Elevated CO_2 and O_3 exposure on soil microbial community structure in wheat crop

Elevated carbon dioxide (e[CO_2]) and elevated ozone (e[O_3]) has significant impact on natural and managed ecosystems, through modified plant growth rate, net primary productivity, species richness, root turnover and rate of decomposition. The e[CO_2]

and e[O_3] effects the microbial communities in the terrestrial ecosystems via modifications in the microbial population, soil enzyme activity, mineralization/immobilization of nitrogen due to altered carbon input in soil.

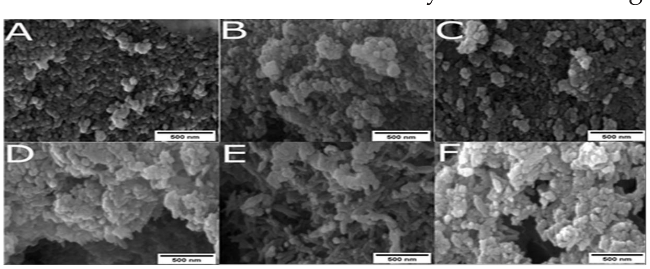


Impact of e [CO_2], e [O_3] and e [CO_2] [O_3] on growth dynamics of microbial population involved in N-cycling at different sampling stages: (a) AOB, (b) NOB, (c)Denitrifiers. Bars with different letters indicate significant difference at (*p*< 0.05)

4.8.2. Elevation of resource use efficiency of nitrogen using novel products

4.8.2.1. To development of novel products and their utilization in agriculture

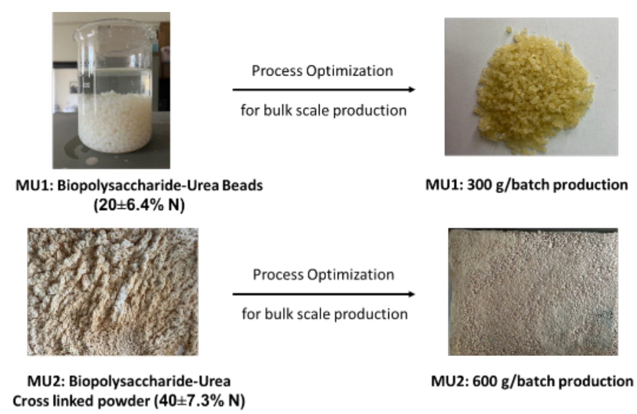
Doping with Zn and Mg reduces the hydroxyl apatite nano particles' size and accommodates higher amount of urea molecules. With zinc and magnesium integrated into hydroxyl apatite, the synthesized nano hybrids serve as multi-nutrient complex fertilizers of nitrogen, calcium, phosphorus, magnesium, and zinc nutrients. We found that nano hybrids containing 50% nitrogen doses maintained wheat crop yield and nitrogen nutrient uptake equivalent to a urea fertilizer containing 100% nitrogen doses. The nano hybrid-supplemented soil enhanced the soil dehydrogenase and urease enzyme levels, suggesting no adverse impact of nano hybrids on soil health.



Scanning electron microscopy (SEM) images of the synthesized nano particles. (A) Hydroxy apatite (HAP), (B) Magnesium-doped hydroxyl apatite (MgHAP), (C) Zinc-doped hydroxyl apatite (ZnHAP),(D) Hydroxy apatite–urea (HAU), (E) Magnesium-doped hydroxyl apatite–urea (MgHAU), and (F) Zinc-doped hydroxyl apatite–urea (ZnHAU)

4.8.2.2. Scale up of optimized modified urea and their performance in wheat crop

Process for slow release nitrogenous fertilizer based on bio-polysaccharide grafted modified nitrogenous bead (MU1-300g/batch) and bio-polysaccharide cross linked modified nitrogenous powder (MU2- 600g/batch) were optimized and total 9 kg MU1 and 4 kg MU2 were developed for application in experimental wheat (HD 3086) field during rabi season 2021.



4.8.3. Waste valorization and its impact on environment

4.8.3.1. Biomethanation of rice straw and cattle dung after pre-treatment of rice straw

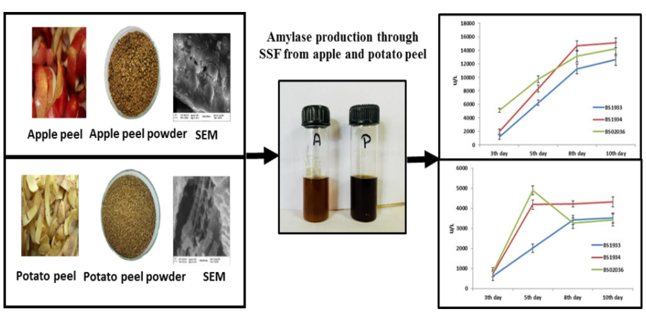
Application of bioslurry and urea in 1: 3 ratio resulted in higher green pea pod yield of 6.49 t/ha, plant height, number of leaves per plant, leaf area index, average number of branches per plant, days to 50% flowering, number of nodules per plant, number of pods per plant, number of seeds per pod, number of grains per plant and pod length observed after 60 days of sowing. Microbial activity was also found to be improved in bioslurry and urea substituted by bioslurry treated plots compared to RDF applied

Biomethanation (Laboratory Experimental Set-up)

field. Nutritional quality attributes like total soluble solids, crude protein, total sugar, reducing sugar and non-reducing sugar were more in bioslurry applied treatments and were maximum in the field when bioslurry and urea were applied in 1: 3 ratio.

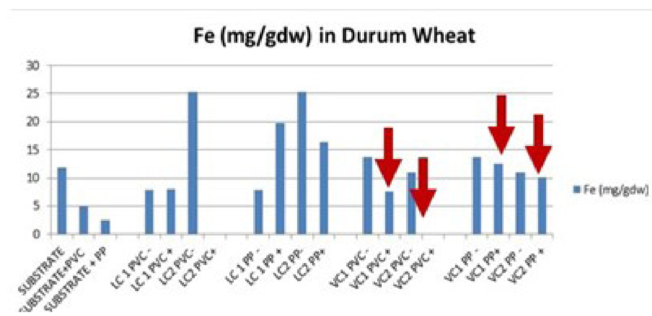
4.8.3.2. Production of Alpha-amylase using *Bacillus subtilis* from apple peel

The *Bacillus subtilis* BS1934 strain was identified as a promising strain that could produce alpha-amylase efficiently at 50°C in locally sourced apple and potato peel. The obtained values *i.e.*, 17468 and 5229 U/L of alpha- amylase from apple and potato peel, respectively through solid state fermentation in eight days were considered as optimum.



4.8.3.3. Microplastic dynamics in soil-plant continuum

The results showed a higher sensitivity of durum than bread wheat towards presence of microplastics, irrespective of their type and source. Further, the Fourier transform infrared (FTIR) spectroscopy provided clear cut evidence for the accumulation of both PP and PVC in shoot tissue of both the bread and the durum wheat species. It will be important to determine whether or not the nano/micro plastics also enter the edible agri-produce. The study clearly shows that microplastics in the farm inputs will alter the nutrient availability and uptake.



Effect of microplastics (PVC, PP) enrichment of farm inputs (leaf and vermi compost, LC and VC respectively) on shoot Fe content of durum wheat (HD-4728)

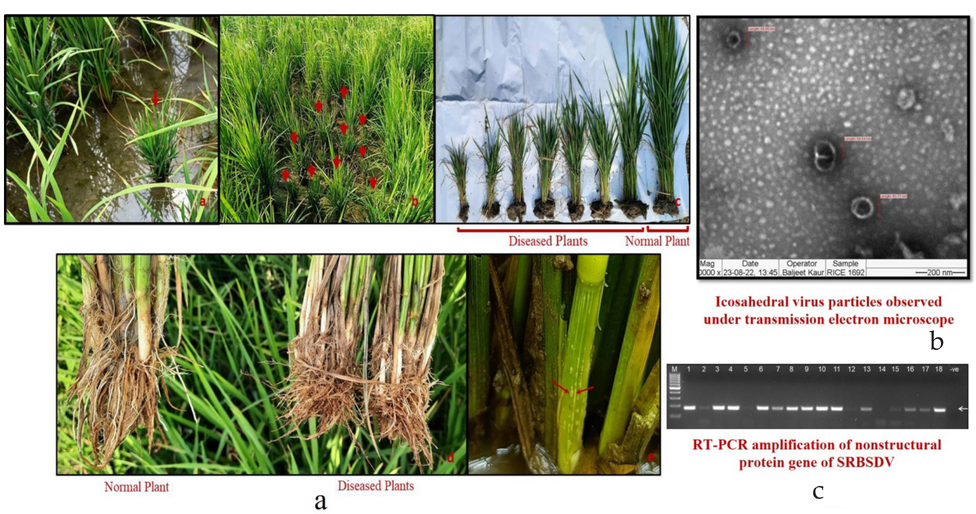
5. CROP PROTECTION

The school of Crop Protection develops and employs innovative management options to minimize the losses in field and horticultural crops due to pest and pathogens. Pests and pathogens scenario in different crops is affected by changing climatic scenario. During the year under report, studies on diversity, host-pathogen interaction, epidemiology, new disease reports and development of new diagnostic tools were undertaken. Besides biological control agents, novel chemicals molecules were identified to form a part of integrated management. Identification of resistant sources will certainly help the breeders in developing insect pest and disease resistant varieties.

5.1 PLANT PATHOLOGY

5.1.1 Pathogen diagnostics and genetic variability

Evidence for association of Southern rice black-streaked dwarf virus with the recently emerged stunting disease of rice in North-west India: Survey of different rice fields recorded an incidence of stunting disease in the range of 1-20% in the affected fields. A systematic investigation employing three independent methods was undertaken. Under the electron microscope, icosahedral virions of ~65-75 nm were observed. Based on the shape and size of virion particles and symptoms of the disease, reverse transcription-PCR and quantitative-RT-PCR of stunted rice plants and prevalent white-backed planthopper (WBPH) were performed using specific primers targeting two genomic components (S9 and S10) of Southern rice black-streaked dwarf virus (SRBSDV), a double stranded RNA virus of genus *Fiji virus* and the results indicated its specific association with the stunting disease of rice. Sequencing of the amplified S9 and S10 genomic components showed the maximum identity of 97.90-100.00% and 98.04-99.48%, respectively with SRBSDV isolates from South Korea and Vietnam. The complete genome sequence of all the 10 genomic segments (S1-S10) of SRBSDV was obtained by high throughput RNA sequencing. A high copy number



(a) Severely stunted rice plants under field conditions at different locations of Haryana; (b) Icosahedral particles under TEM; (c) RT-PCR amplification of non-structural protein gene of SRBSDV

of S1-S10 genomic ranging from 3158.5- 138851.9 was obtained. This is the first conclusive evidence of the association of SRBSDV with the stunting disease of rice from India.

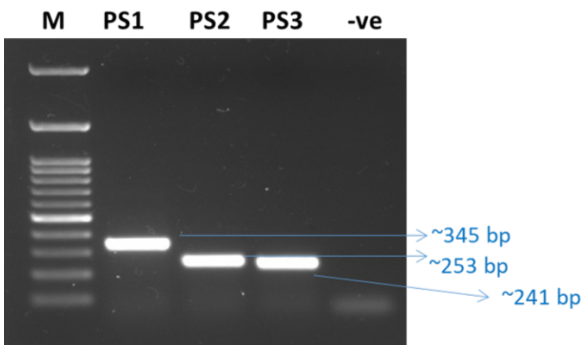
Molecular detection and full genome characterization of chilli leaf curl virus infecting bell pepper variety "California Wonder": During November, 2021, leaf curl disease symptoms were observed in California Wonder variety of bell pepper at the Centre for Protected Cultivation Technology (CPCT) of ICAR-IARI, New Delhi with a disease incidence of 38%. The characteristic symptoms were upward leaf curling, thickening of veins, shortening of internodes and petioles, leaf puckering and stunted growth of plants. Electron microscopy showed the presence of typical geminate virus particles in infected samples. The 520 bp amplicon obtained in PCR, was cloned and sequenced. The sequence analysis revealed the highest identity of 97.63% with chilli leaf curl virus (Accession: JN663846 and MH577035) reported from chilli and tomato from Ahmedabad and Pune respectively.

Occurrence of a begomovirus infection in blue-snakeweed in India: The presence of a whitefly transmitted begomovirus - *Chilli leaf curl India virus* (ChiLCINV) in the infected blue-snakeweed (*Stachytarpheta jamaicensis*) plants showing symptoms such as crinkling, yellowing, mottling, reduction in leaf size and downward curling was confirmed by PCR assay and sequence analysis. The sequence analysis of the amplicon revealed that it shared 95.55% identity with ChiLCINV and the sequence also clustered with ChiLCINV isolates reported from various hosts. ChiLCINV is known to significantly affect the production of several economically important crops. The invasive *S. jamaicensis* can serve as a perennial host for the virus aiding its transmission to crops growing in the vicinity. This is the first report of natural infection of a begomovirus (ChiLCINV) in *S. jamaicensis* from India.

Molecular characterization of Cucumber mosaic virus IB associated with papaya: Papaya samples with mild mosaic and mottling symptoms collected from Pune were confirmed for Cucumber mosaic virus (CMV) infection by various molecular and biological methods. Further, association of CMV with papaya was confirmed by RT-PCR amplification of coat protein gene. The CP gene sequence data revealed the papaya isolate of CMV shares 97-98% with several CMV strains. Based on phylogenetic analysis, this isolate clustered with CMV strains belonging to IB subgroup. This is the first report on molecular characterization of natural infection of CMV subgroup IB in papaya.

Occurrence of Cucurbit aphid-borne yellows virus infection in muskmelon in India: Muskmelon plants showing interveinal chlorosis, yellowing and thickening of mature leaves were sampled from Pune (Maharashtra) in June 2021. Association of cucurbit aphid borne yellows virus (CABYV) with infected muskmelon plants was established using ELISA. Further confirmation was carried using RT-PCR employing CABYV specific primers. Presence of CABYV was confirmed by sequence comparison and phylogenetic analysis. The present study holds significant epidemiological importance as CABYV is known to reduce yield in melons by 40%. This is the first report of CABYV infecting muskmelon in India.

Development of reverse transcription-recombinase polymerase amplification (RT-RPA) assay for the diagnosis of citrus yellow vein clearing virus (CYVCV) in Citrus plants: Citrus is one of the most important fruit crops grown worldwide. Among the viral diseases, yellow vein clearing is an emerging and rapidly spreading disease in major citrus-growing areas of Punjab and Delhi. PCR based assays are often known for their high sensitivity, and specificity but they are time consuming and require costly equipment and specific technical expertise. To overcome these difficulties, a simple and rapid RT-RPA assay for the detection of CYVCV was developed. For the amplification of the RdRp region of CYVCV, 3 pairs of primers were designed to perform RT-PCR and RT-RPA. Both asymptomatic and symptomatic samples of citrus were collected from the Horticulture farm and evaluated for CYVCV infection using RT-RPA along with RT-PCR assay.



Agarose gel electrophoresis showing RT-PCR amplification of RdRp gene of CYVCV. Lane M: marker, lane 1,2,3: Infected sample with Primer set 1, 2 3, lane 4: Healthy sample

Diversity analysis of false smut pathogen *Ustilaginoidea virens* of rice: Different isolates of *Ustilaginoidea virens* collected from eight different states were characterized morphologically and molecular level. Morphologically, isolates showed variation in the size of the spore, colour and shape of the hyphae. Genetic diversity was analyzed by using SSR primers. The Dendrogram generated based on polymorphic data revealed a considerable amount of diversity among the isolates grouping them in three clusters. The PIC ranged from .079 to 0.90. The value of Shannon information index ranged from 2.99 to 4.52.

Identification and characterization of *Fusarium fujikuroi* pathotypes, causal agent of bakanae disease of rice: Based on disease response and screening, a set of five rice genotypes were selected for further characterization of the pathogen. Ninety-seven *Fusarium fujikuroi* isolates collected from different rice growing areas of the country during the years 2011 to 2020 were characterized and evaluated for bakanae disease of rice. Rice genotypes PB1509 and C101A51 were found to be highly susceptible and highly resistant respectively. Further, based on disease response isolates were grouped into 15 pathotypes. Similarly, a positive correlation could be established between six pathotype groups and virulence- related gene expression analysis.

Pathogenic and genetic diversity analysis of *Bipolaris sorokiniana*: Pathogenic variation among the 40 *Bipolaris sorokiniana* isolates, average disease index (ADI) ranged from 6.86 - 87.97% between BS isolates, showing variability in virulence level. Isolates BS-21, BS-22, BS-16, BS-36, BS-37 and BS-20 from Pusa, Bihar, and BS-34 and BS-35 from Varanasi, Uttar Pradesh were found to be highly pathogenic. Multigene analysis was performed using a concatenated sequence of five housekeeping genes *viz*., TEF1α, GAPDH, RPB2, BT, and ITS. Forty *B. sorokiniana* isolates were grouped into six clades, showing genetic diversity among the *B. sorokiniana* population in India. Based on virulence genes, isolates from Ujjain, Kanpur and Panipat districts showed distinct variations in the nucleotide sequence of the SCD1 gene, correlating with a significant reduction in pathogenicity. The 1, 3, 8-napthalenetriol reductase (BRN1) gene was found to be highly conserved in all *B. sorokiniana* isolates.

***Collectotrichum* species associated with different diseases:** *Colletotrichum siamense* and *C. dianense* were found to be the causal agent of anthracnose disease of ornamental plants like *Dracaena* and *Dieffenbachia*. *Colletotrichum musae* and *C. siamense* were found to be associated with the anthracnose symptoms of banana which was confirmed through morphological and molecular parameters.

Maintenance, identification, culture supply and accession services: About 50,600 fungal specimens at HCIO; 4150 fungal cultures at ITCC were maintained under different preservative methods. A total of 448 authentic fungal cultures and 37 bacterial cultures were supplied to various scientific and industrial institutions on request. Eleven cryptic species of *Fusarium* (*F. falciforme*, *F. solanisensustricto*, *F. striatum*, *F. keratoplasticum*, *F. vanettenii*, *F. metavorans*, *F. petroliphilum*, *F. breve*, *F. cyanescens*, *F. solani* f. sp. *mori* and *F. solani* f. sp. *radicicola*) were identified first time from India under *Fusarium solani* species complex through multi locus sequence analysis and their taxonomic description was established.

Characterization of virulent strain of *Xanthomonas campestris* pv. *campestris* causing black rot in mustard: The black rot disease was observed in

Brassica juncea cv. Pusa Bold grown in IARI, New Delhi. The pathogenicity of the isolate was tested twice on the youngest leaves of 30-day-old plants of Pusa Bold to convey Koch's postulates. The nucleotide BLAST analysis of 16S rRNA, *AvrBs1*, *AvrGf1* showed a 100% identity with different Xcc strains reported. The nucleotide sequences were deposited in GenBank (16S rRNA: OM839780; *AvrBs1*:OM994397; *AvrGf1*: OM994398; xcc-b100_4389:OM994399).

First report of '*Candidatus* phytoplasma asteris' (16SrI) from *Cassia fistula* and *Clarkia unguiculata*: Typical flat stem symptoms observed on a *Cassia fistula* plant were amplified in nested PCR using the R16F2n/R2 primer combination and an amplicon of size 1.25 kb was obtained in symptomatic leaf samples. No amplification was observed in non-symptomatic plant samples either in first round or nested round of PCR assays with phytoplasma specific primer pairs. The 16S rDNA sequences of the phytoplasma strain of this study showed 100% sequence identity with the strains belonging to the aster yellows (AY) group (16SrI). Phylogenetic and virtual RFLP analysis of 16S rDNA sequences of the identified phytoplasma strain ornamental plant further confirmed their clustering and grouping with members trains of 'aster yellows' subgroup-B. This is the first report of the association of phytoplasma 'Candidatus Phytoplasma asteris' (16SrI-B) subgroup with *Cassia fistula* in the world.

Suspected phytoplasma symptoms of the flat stem, little leaf, witches' broom and apical fasciation were observed on *Clarkia unguiculata*, an ornamental plant species planted in the Division of Plant Pathology, IARI, New Delhi during the month of March, 2022. Using nested PCR with the R16F2n/R2 primers an amplicon of 1.25 kb size was obtained in symptomatic leaf samples. For further confirmation of phytoplasma, a multilocus gene protein translocase subunit A, sec A gene was amplified using universal primers. When the 16S rDNA and sec A gene sequences of the phytoplasma strain of this study were compared with the strains belonging to the asteryellows group (16SrI), they indicated 99.7% identity with 16S rRNA and 99.13–100% sequence identity with thesec A gene sequences. This is the first report of the phytoplasma association of *Candidatus* Phytoplasma asteris (16SrI-B) sub-group with *Clarkia unguiculata* in the world.

Association of a 16SrII-V phytoplasma with peanut phyllody in India: Peanut plants exhibiting phyllody, little leaf, excessive shoot proliferation, negative geotropism of pegs with absence of pod formation symptoms, indicative of a phytoplasma infection were observed in Pune (Maharashtra) in February 2021. The average disease incidence recorded was 4%. The phytoplasma association was confirmed by PCR and nested PCR using phytoplasma-specific primer pairs P1/P7 and R16F2n/R2 which yielded amplicons of expected sizes c. 1.8 kb and c. 1.2 kb, respectively. Sequence comparison, phylogenetic and virtual RFLP analysis confirmed the identification and enabled taxonomic assignment of the phytoplasma strain into 16SrII-V subgroup. This the first report of a 16SrII-V phytoplasma associated with phyllody in peanut as well as the first report of the occurrence of a 16SrII-V phytoplasma in India.

5.1.2 Host-pathogen interaction and genomics

Metabolomic analysis of sheath blight disease of rice (*Oryza sativa* L.) induced by *Rhizoctonia solani* phytotoxin: Metabolomic changes induced by the phytotoxic metabolite in a ShB susceptible rice cultivar were elucidated by gas chromatography–mass spectrometry analysis and compared with that of the pathogen to identify rice metabolites targeted by the phytotoxin. The study concluded that though certain metabolites induced by the phytotoxin in the susceptible variety during necrosis share with that of the pathogen, the identification of metabolites specific to the phytotoxin in comparison to the pathogenic and sterile distilled water controls indicated that the phytotoxin modulates the host metabolism differently and hence can be a potential pathogenicity factor of the ShB fungus.

Editing rice gene (Phospholipase-D β1 (*OsPLDβ1;* LOC_Os10g38060) through CRISPR/Cas9 technology for blast resistance: Developed and validated genome edited rice plants (*OsPLDβ1* gene) in BPT 5204 (Samba Mahsuri) background for blast resistance. CRISPR/Cas9 edited *OsPLDβ1-KO1, OsPLDβ1-KO2* knock out rice lines showed high level susceptibility to blast disease and bacterial blight disease. Phenotyping of edited lines (*OsCKX2* and *OsSBE1)* and parental line, MTU1010 with highly virulent 6 basmati isolates (Mo-ni-0123, Mo-ni-00125, Mo-ni-0122, Mo-ni-0124, Mo-ni-0028 and Mo-ni-0025) and a non-basmati isolate (Gudalur 2NB) revealed that the lines showed resistant reaction to blast infection under artificial epiphytotic conditions. Analysing the process of infection and monitoring the physiological & biochemical responses and relative expression of innate defense related genes in Δ*OsCKX2* and Δ*OsSBE1* rice lines during host pathogen interaction were also supported that edited lines (*OsCKX2* and *OsSBE1)* and parental line, MTU1010 showed resistant response to blast disease.

Characterization of *Fusarium graminearum* isolates with toxin specific primers: Head blight of wheat caused by *Fusarium graminearum* is emerging disease posing major threat to the grain production throughout the world including India. Twenty-two pure cultures of pathogen were established from the 114 diseased wheat spikes collected from the Wellington (Tamilnadu). Morphological and cultural characterization coupled with molecular characterization with species specific markers and TEF1*α* gene were carried out to confirm the *Fusarium* species associated with the disease. Genetic/molecular chemotyping of *F. graminearum* isolates was accomplished with toxin specific primers for toxins such as DON, NIV, 15-ADON and 3-ADON and PCR assays were carried out. All *F. graminearum* isolates were inoculated in susceptible wheat variety (HI 8627) and AUDPC values ranged from 657.09 to 1068.13.Fg-W21-22 isolate was the most aggressive among all the isolates which caused spikelet bleaching severity of 93% at 21 DAI. All the twenty-two isolates were tested negative for the genes responsible to produce DON toxin whereas all the isolates showed a positive result for genes responsible for 15-ADON, 3-ADON and NIV toxin. UPLC analysis of fungal culture filtrates for tracing DON, 15-ADON, 3-ADON, NIV, Fu-X and ZEA detected the presence of all toxins except DON and showed congruence with genetic chemotyping results.

Quantification of fusaric acid in culture filtrate of *Fusarium oxysporum* f. sp. *Ciceris isolates* infecting chickpea: Quantitative estimation of fusaric acid was carried out using HPLC from the crude culture filtrate of 14 different isolates of *Fusarium oxysporum* f. sp. *ciceris* infecting chickpea. It was evident that *in vitro* productions of fusaric acid in the Czapek Dox medium by different isolates of Foc in culture filtrate were variable (126.88-820.51mg/L). Among them, New Delhi isolate (ITCC 7681) was recorded to produce the lowest quantity of fusaric acid (126.88 ± 5.56mg/L); whereas Sri Ganganagar isolate (ITCC7682) produced the highest quantity of fusaric acid (820.51 ± 13.37 mg/L). It was found that isolates which produced a lesser quantity of fusaric acid in culture filtrate took a long time for wilt initiation. Peroxidase activity was 3.28 and 2.30-fold higher in WR 315 and JG 62 respectively treated with culture filtrate of ITC 7682. PPO activity was higher in both resistant and susceptible cultivars in all treatments. SOD activity was estimated 32.48, 22.33 and 17.76% more in RW 314; and 41.02, 35.89 and 24.35% more in JG 62 after 1 day of treatment with culture filtrate of ITCC 7682, ITCC 7681 and pure fusaric acid standard respectively. The PAL activity increased by 1.66, 1.61 and 1.39-fold at 1 Dai (days after inoculation) in resistant cv. WR 315 treated with culture filtrate of ITCC 7682, ITCC 7681 and pure fusaric acid respectively.

Genome-wide characterisation of Cytokinin-O-Glucosyl transferase genes of rice specific to pathogens: Cytokinin glucosy ltransferases (CGTs) are key enzymes of plants for regulating the level and function of cytokinins. In a genomic identification of rice CGTs, 41 genes with the plant secondary product glycosyl transferases (PSPG) motif of 44-amino-acid consensus sequence characteristic of plant uridinediphosphate (UDP)-glycosyl transferases (UGTs) were identified. Phylogenetic analysis of the CGTs revealed that their evolutionary relatedness ranged from 70–100%, and they aligned themselves into two major clusters. In a comprehensive analysis of the available transcriptomics data of rice samples representing different growth stages only the CGT, Os04g25440.1 was significantly expressed at the vegetative stage, whereas 16 other genes were highly expressed only at the reproductive growth stage. On the contrary, six genes, *LOC_Os07g30610.1, LOC_Os04g25440.1, LOC_Os07g30620.1, LOC_Os04g25490.1, LOC_Os04g37820.1,* and *LOC_Os04g25800*.1, were significantly upregulated in rice plants inoculated with *Rhizoctonia solani* (RS), Xoo (*Xanthomonas oryzae* pv. *oryzae*) and Mor (*Magnaporthe oryzae*). qRT-PCR analysis revealed the expression of genes *LOC_Os07g30610.1, LOC_Os04g25440, LOC_Os04g25490*, and *LOC_Os04g25800* were observed to be pathogen-specific. These genes were identified as candidate-responsive CGT genes and could serve as potential susceptibility genes for facilitating pathogen infection.

Genome-wide association mapping of virulence genes in *Tilletia indica*: Double digest restriction-site associated-DNA genotyping by sequencing was carried out for 39 *T. indica* isolates collected from different locations in India. The generated libraries upon sequencing were with 3,346,759 raw reads on average, and 151 x 2 nucleotides read length. The obtained bases per read ranged from 87 Mb in Ti 25 to 1,708 Mb in Ti 39, with 505 Mb on average per read. Trait association mapping was performed using 41,473 SNPs, infection phenotyping data, population structure, and Kinship matrix, to find single nucleotide polymorphisms (SNPs) linked to virulence genes. Population structure analysis divided the *T. indica* population in India into three sub populations with genetic mixing in each sub population. Trait association mapping revealed the presence of 13 SNPs associated with virulence. Using sequences analysis tools, one gene (g4132) near a significant SNP was predicted to be an effector, and its relative expression was assessed and found upregulated upon infection.

Discovery of small RNA in *Tilletia indica* causing Karnal bunt of wheat: Small RNA sequencing (smRNA) libraries were constructed using QIAseq® miRNA Library Kit protocol (Qiagen). These libraries were sequenced on Illumina NovaSeq 6000 using a 75x1 read length. An average of 16.15 million reads were obtained as raw reads and after length filtering (16-40nt), an average of 11.5 million high quality reads were retained for analysis. The sequences were submitted to the NCBI database. Small RNA sequenced reads were mapped against *Tilletia indica* and wheat genome. A total of 127 known miRNAs were identified in wheat and 172 in *T. indica*. 69 families were reported for both wheat and fungal miRNA analysis. 193 novel miRNAs were predicted in fungi and 2327 in wheat. Further gene ontology and target prediction are in progress.

Genome sequencing of *Tilletia caries* causing common bunt of wheat: *Tilletia caries* TC_MSG_1 genome was sequenced using the Illumina HiSeq 2500 and Nanopore PromethION Flow Cell (R9.4.1) platforms. The paired-end DNA libraries of an average of 496 bp inserts were prepared using the NEB Next Ultra DNA Library Prep Kit and sequenced using 2 × 150 bp chemistry to generate ~ 50 GB data for sequencing. The PromethION Flow Cell (R9.4.1) library was prepared using the ligation sequencing kit SQK-LSK110 to generate ~24 GB for sequencing. The reads were obtained from both the platforms of Illumina Hiseq 2500 and ONT. The Illumina reads were filtered using Adapter Removal V2 with an average quality score of less than 30. The d*e novo* assembly was performed with the nanopore data using the flye assembler and the resulting assembly was polished with Illumina data using the POLCA polishing tool. The assembly size of 38.18 Mb was generated with a GC content of 56.10%. The whole genome shotgun project was deposited at DDBJ/ENA/*GenBank* under the accession JALUTQ000000000. 46 contigs were obtained with N_{50} of 1,798,756 bp. According to BUSCO analyses, the assembly was completed at 86.01%. 10,698 genes were predicted in the assembled genome using Augustus. Out of 10,698 genes, the significant BLASTX match was 10,255 genes.

Genome sequencing of *Bipolaris maydis* causing southern corn leaf blight: The whole genome of *Bipolaris maydis* sequenced using Illumina HiSeq 2500 & PromethION Flow Cell (R9.4.1) platform. *De* *novo* assembly was performed with the ONT data using the Flye assembler and the resulting assembly was polished with Illumina data using the POLCA polishing tool. Genome size was 36.05 Mb with GC content 49.21% having 56 contigs. The majority of the top BLASTX hit belong to *Cochliobolus heterostrophus* (strain C4 / ATCC 48331 / race T) (Southern corn leaf blight fungus) (*Bipolaris maydis*). 8,866 genes were predicted with significant BLASTX match (E-value <=1e-3 and Similarity score >=40%) with Uniprot. Gene ontology (GO) terms (molecular function (MF), cellular component (CC), biological Process (BP)) genes were 338, 865, 1 and 121, respectively in the genome. This Whole Genome Shotgun project has been deposited at DDBJ/ENA/GenBank under the accession JAMFQD000000000 (SRA: SRR19262264, SRR19262263).

Genome reassembly of *Ralstonia solanacearum* CaRs_Mep: The genome of *Ralstonia solanacearum* CaRs_Mep was reassembled using CLC Genomics and improved using MeDuSA (Multi-Draft based Scaffolder). The current assembly has 13 contigs with fewer gaps. This is a significant improvement over the previous assembly which had 253 contigs. The reassembled genome is now updated in GenBank by replacing the previous draft genome of *Ralstonia solanacearum* CaRs-Mep/SUB1712951/ PRJNA203439/ SAMN02152298/ MCBM00000000.

Genome sequencing of *Pantoea*: Two epiphytic *Pantoea* isolates isolated from adaxial and abaxial rice leaves showed antimicrobial activity on phytopathogens. The polyphasic taxonomy of isolates revealed the identity as *Pantoea agglomerans* and *Pantoea deleyi*. Draft genomes of isolates were assembled into three and ten scaffolds covering a genome of 4.44 Mb and 4.57 Mb. The genome annotation revealed 4297 and 4389 CDS and 133 biosynthetic pathways. Pathways for the biosynthesis of polyketides and non-ribosomal peptides and secondary metabolites were observed. The genome data coupled with the metabolome profiling would elucidate the antagonistic mechanism of *Pantoea* for microbe-assisted rice disease management in the future.

5.1.3 Disease epidemiology

Survival studies of *Fusarium fujikuroi* under field conditions: The population structure and survivability of this fungus under field conditions were investigated and collected month wise soil samples starting with July from *Fusarium fujikuroi* inoculated rice field of Indian Agricultural Research Institute, New Delhi and processed further for population counting, q-PCR, analysis with specific primers and metagenomic analysis of few samples. The results obtained from the serial dilution method reflected that the maximum number of colonies was found in the month of July and the minimum was in the month of June. Similar trend was found in q-PCR. The metagenomic analysis showed 1.84, 0.22, 0.24 and 0.09 abundance per cent of the *Fusarium* spp. in soil in the month of July, September, December and March, respectively. The findings indicated that soil is not a potential source of inoculum for the bakanae disease.

Host-vector contact rate dynamics and leaf curl epidemic in chilli: Host-vector contact rate dynamics have been predicted based on host density and succulence status of the plant indicating contact is likely to reach peak level at six weeks after transplantation. The virus transfer rate estimated from the experiment was noted transmission rate was maximum at about 8 weeks after transplantation and reduced afterwards. Unimodal dynamics characterized in the two-process indicated virus transmission is influenced by host density which tends to increase with time and then decrease after sometime.Vector interception (plant cover) till the four weeks protected the plants from virus infection till nine weeks ($P<0.05$). Host-vector contact rate dynamics plays a critical role and integrates the host factor (succulence level). Contact rate dynamics as the major driver of the epidemic has been proved and translated into rules for evolving management strategies.

Climate change risk assessment for sheath rot in rice: For assessing sheath rot risk in response to climate change, non-linear temperature response on the growth rate of the pathogen has been captured into an impact model. Kinetics of disease growth has indicated a greater impact of temperature change is around 22.7°C of the growth rate function. A high risk of sheath rot across all agro-climatic zones particularly during the kharif season (July-August-September-October) has been noted as compared to low risk in winter season crops (Jan-Feb-Mar). Marked yearly variation in disease risk across north western agro-climatic zones during the winter rice period has been in correspondence with the predominant temperature profile which is below 22.7°C. In winter months high fluctuation of infection risk in the north western agro-climatic zones is an indicator of probable temperature rise impact on the disease. Based on the principle of temperature influence on infection, a climate change impact estimator has been developed to identify the time and location of high annual variation in disease risk. Sheath rot risk predicted based on the estimator has corresponded well with the disease risk scenario predicted in climate scenarios. Prediction of sheath rot risk could help in adaptation strategies as winter rice is projected to be increased in future climates for some agro-climatic zones.

5.1.4 Host resistance

Rice: Out of 500 germplasm accessions screened against sheath blight disease of rice, 35 accessions were found to be moderately resistant Out of 500 accessions screened against bakanae disease of rice, 50 accessions were found to be resistant. Out of 500 germplasm evaluated against blast resistance,16 entries (RL-248, RL-372, RL-1020, RL-1346, RL-1439, RL-1504, RL-1956, RL-2222, RL-2537, RL-2550, RL-2802, RL-3855, RL-3896, RL-4035, RL-4163, RL-5479) were found to be resistant. Out of 406 entries [NSN 1- Screening for Leaf Blast Resistance (Screening Nursery), Field monitoring of virulence of *Pyricularia oryzae* and NSN 1 and NSN 2 Basmati entries against Leaf Blast resistance] were evaluated against rice blast disease, genotypes, Raminad STR-3, *O. minuta*, Zenith, Tetep and Rasi were found to be resistant.

Pearl Millet: Out of 56 entries evaluated, 6 entries (ICPMBL 56, ICPMBL 2, ICPMBL 7, ICPMBL 33, ICPMBL 37, ICPMBL 55) were identified as resistant and under Disease Screening of Advance Pearl Millet Hybrids and Varieties (PMPT II) trial, out of 34 entries evaluated, 10 were identified moderately resistant (PAT 227, PAT 221, PAT 206, PAT 207, PAT 208, PAT 209, PAT 210, PAT 204, PAT 205, PAT 202).

Wheat: Among 196 wheat genotypes, seven genotypes *viz*., IC321889, IC619432, IC619435, IC346060, IC260894, IC589295, and IC145983 were found moderately resistant to spot blotch disease under field conditions. Out of 200 lines evaluated against Karnal bunt disease, five accessions *viz*., IC107915, IC398280, IC585652, IC573145, IC347884 were found resistant based on artificial evaluation at IARI New Delhi under artificially inoculated conditions during 2020-21 and 2021-22. Out of 200 genotypes evaluated against head scab disease genotypes IC573164, IC 356111, IC 273946 were categorized as resistant (disease score 1). Genotypes, IC 079009, IC 079025, IC 079040, IC 252507, IC 145983, IC 138554, IC 310041, IC 398284, IC 444246, IC 40688, IC 0112053 and IC 0111899 were categorized as moderately resistant.

Maize: A total of 674 maize genotypes were evaluated to find the resistance sources for maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*) diseases in 4 trials comprising genotypes of early and medium maturity, Late maturity group and specialty corns *viz*., QPM, Sweet corn and Baby corn. Of these, 258 genotypes were resistant to MLB disease and 100 genotypes were resistant to BLSB disease. Ten maize genotypes were evaluated in the trap nursery. The MLB disease was recorded in all the test entries by showing the disease score ranged from 2.0-8.0 and of these, two entries were resistant (score 2.0) and five entries were moderately resistant.

5.1.5 Disease management

Rice leaf endophytic *Microbacterium*: unexplored bacterial genus with potential for blast disease suppression: Rice leaf endophytic and pigmented bacterial species belonging to *Microbacterium* showed promise for blast disease suppression in field trials conducted in the farmers' field. Upon seedling bacterization, *Microbacterium testaceum* not only triggered altered growth patterns of rice seedlings but also suppressed blast disease (80.0% reduction of blast severity over mock) under greenhouse conditions. qPCR based transcriptional analysis showed enhanced expression of defense genes such as OsCERK, OsPAD4, OsNPR1.3, and OsFMO1. *Microbacterium testaceum* OsEnb-ALM-D18 mediated antifungal activity, and host defense induction can be a potential alternative to fungicide-based blast management. Chemical profiling of volatiles emitted by *Microbacterium* indicated the abundance of 9-Octadecenoic acid, Hexadecanoic acid, 4- Methyl-2-pentanol, 2, 5-Dihydro-thiophene, and another antimicrobial compound.

Chemical profiling of *Pantoea*: Metabolome profiling of secondary metabolites of *Pantoea* through UPLC-QToF-ESI-MS indicated the presence of antimicrobial Agglomerin A, Herbicolin A, Pantocin B, Methoxyphenazine, and Dapdiamide.

Microbiome formulations and their evaluation for blast management: Microbiome formulation for blast suppression: Two phyllomicrobiome formulations named PMF1 and PMF2 were developed based on antifungal and biostimulant activities of phyllosphere bacterial communities. Multi-location evaluation trial of phyllosphere microbiome formulations conducted during 2021-22 in different geographical locations in four states (Haryana, Uttar Pradesh, Tamilnadu and Andhra Pradesh) confirmed the superior performance of formulation PMF2 for disease control, plant growth promotion and grain yield parameters over check, BioCure (T- Stanes Company Ltd, Coimbatore).

Functional characterization of maize-associated bacteria: Microbial metagenome of maize-associated niches sampled from Bihar and Delhi representing diverse cropping systems and tillage practices culminated in the identification of 99 bacteria with potential for management of maize pathogens *Rhizoctonia solani*, *Macrophomina phaseolina* and *Bipolaris maydis*. Whole-genome sequences of 13 maize microbiome-associated bacteria suchas *Pseudomonas* (3), *Serratia* (2), *Klebsiella* (2), *Pantoea* (2), *Enterobacter* (1), *Burkholderia* (1), *Acinetobacter* (1), and *Beijerinckia* (1) were generated.

Mycobiome of maize for management of banded leaf and sheath blight caused by *Rhizoctonia solani* f. sp. *sasakii* under conservative agriculture system: Based on an experiment conducted on disease management in maize by using the members of cultivable fungi included in mycobiome in which more than 84 fungal isolates have been isolated from initial dilution plates (10^{-4} and 10^{-5}) to pure cultures. The characterization of isolates by ITS marker showed that the most diverse groups of fungal community *viz*., *Aspergillus sp*., *Penicillium chrysogenum, Alternaria* spp., *Penicillium chermesium, Fusarium proliferatum, Collectotrichum gloeosporioides, Aspergillus niger, Aspergillus terreus, Alternaria alternate, Cladosporium xanthochromaticum,* and *Cladosporium cladosporioide, Fusarium neocosmosporiellum* and *Curvularia spp.* have associated with maize system. In *Kharif* and *Rabi* seasons, maize organs were differently predominated by *Aspergillus* spp. and *Penicillium* spp. respectively. As many as 29 isolates were selected on a background of both dual culture assay and references of infectivity on maize cultivars. Meanwhile, the disease suppression of fungal isolates occurring in the range of 22-53% has been found by dual culture assay as well as in vitro plant assay.

Comparative analysis of phyllospheric bacteria of black rot infected and healthy leaves of cauliflower: Phyllospheric microbiota of resistant line BR161 and susceptible cv. Pusa Sharad of cauliflower was identified by both 16s rRNA gene sequencing and metagenomics next generation sequencing. In the 16s rRNA gene sequencing, the more frequent occurrence of *Xanthomonas*, *Bacillus*, *Pseudomonas*, *Staphylococcus*, *Sphingomonas*, *Stenotrophomonas*, *Pseudomonas*, *Microbacterium*, *Arthrobacter*, *Curtobacterium*, *Glutamicibacter*, *Micrococcus*, *Chryseobacterium*, *Psychrobacter*, *Brachybacterium*, *Enterococcus*, *Acinetobacter* and *Moraxella* was recorded in both BR-161 and Pusa Sharad. In metagenomics next generation sequencing, the maximum diversity was observed in BR-161 leaf infected with black rot, followed by the healthy leaf. BR-161 had more bacterial diversity than Pusa Sharad. Both BR-161 and Pusa Sharad had dominant *Proteobacteria*, Firmicutes, Actinobacteria, and Bacteroidetes among 37 classes. Among them, eight classes, such as *Gammaproteobacteria*, *Alphaproteobacteria, Bacilli, Bacteroidia, Betaproteobacteria, Clostridia, Actinobacteria, Fusobacteriia,* were over represented in both BR-161 and Pusa Sharad. Comparative analysis between genera obtained by the culture-based method and metagenomics method revealed that nine genera such as *Acinetobacter, Curtobacterium, Xanthomonas, Bacillus, Staphylococcus, Stenotrophomonas, Sphingomonas, Pseudomonas* and *Enterococcus* were present in both metagenomics and culture-based method.

Potassium phosphite (Phi) – a defense elicitor against rice blast disease: The Phi was evaluated both preventively and curatively on rice genotypes where the preventive spray of Phi outperformed the Phi curative application with significant reductions in both rice blast severity (35.67-60.49%) and incidence (22.27-53.25%). Moreover, the application of Phi increased the levels of photosynthetic pigments (Chlorophyll and Carotenoids) coupled with increased activity of defense enzymes (PAL, SOD, and APx). Besides, the Phi application also induced the expression of defense-associated genes (OsCEBiP and OsPDF2.2) in the rice leaf. Furthermore, the Phi application reduced the reactive Malondialdehyde (lipid peroxidation) to minimize the cellular damage incited by *Magnaporthe* in rice. Overall, the present study showed the potential of Phi for blast suppression on rice as an alternative to the current excessive use of toxic fungicides.

Identification of potential *Beauveria bassiana against Tetranychus truncates*: Thirty *Beauveria bassiana* isolates from 11 different geographical areas were identified using morphological characteristics and multilocus sequence data in this investigation. The pathogenicity of *B. bassiana* isolates from various hosts along with one commercial formulation (Beveroz) was assessed against *Tetranychus truncatus* under in vitro conditions and showed Bb6, Bb15 and Bb12 isolates caused significantly higher mortality of *T. truncatus*, *i.e.*, 97.73, 96.73 and 94.50%, respectively, than the other isolates.

Glyphosate for management of rice blast disease: The glyphosate foliar spray on *Osm* EPSPS transgenic rice lines showed both prophylactic and curative suppression of blast disease comparable to a blasticide, tricyclazole. The glyphosate displayed direct antifungal activity on *Magnaporthe oryzae* as well as enhanced the levels of antioxidant enzymes and photosynthetic pigments in rice.

Evaluation of bioagents, organic materials and fungicides for management of charcoal rot of maize: A field experiment was conducted during *kharif* 2022 to evaluate various biological (seed treatment or soil application of *Trichoderma harzianum*); organic (sprays of humic acid and chitosan) and chemical (sprays of the fungicides hexaconazole and Azoxystrobin 18.2% w/w + Difenoconazole 11.4%) disease control measures for the management of charcoal rot of maize. Among the various treatments; a single spray of the fungicide Azoxystrobin 18.2% w/w + Difenoconazole 11.4% @ 0.1% at 30 days after sowing (DAS) and two sprays with chitosan @ 5 ml/l at 35 and 45 DAS showed the highest reduction in charcoal rot incidence (49.1 & 51.8% reduction respectively) along with a significant increase in yield relative to control (water spray).

Evaluation of new fungicides for management of MLB disease: Four new fungicides, namely, (1) Kresoxim methyl 44.3% SC @ 0.1% spray at 3 days & 18 days after inoculation (Ergon), (2) Azoxystrobin 18.2% w/w + Difenoconozole 11.4% w/w SC @ 0.10% spray at 3 days & 18 days after inoculation (Amistar top), (3) Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.20% spray at 3 days & 18 days after inoculation (AmpectXtra), and (4) Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE @ 0.15% spray at 3 days & 18 days after inoculation (Opera) were evaluated comparing with standard recommended fungicides Mancozeb 75% WP @ 0.20% and Zineb 75% WP @ 0.20%. Of these, the 5th fungicide was found best followed by the 1st and 4th fungicides with respect to the percent disease control. On the other hand, as compared to the untreated control, the yield was found the highest in the 1st fungicide followed by 4th and 5th fungicides which were at par.

Evaluation of durum wheat germplasm at seedling stage at Indore: A total of 200 durum germplasm comprising released varieties, land races, exotic germplasm and advance generation lines were evaluated at seedling stage against stem rust (40-3 and 117-6) and leaf rust (104-2) pathotypes. Out of 200,a total of 67 genotypes were found to be resistant to both stem and leaf rust pathotypes. A total of 1929 entries included in PPSN (471), IPPSN (1362), MDSN (40), and Elite PPSN (56) were evaluated for field resistance to stem and leaf rusts under artificial inoculations using mixtures of important pathotypes. Of these, 631 entries (~33% of the total) showed resistance (Coefficient of Infection value up to 15.0) to both stem and leaf rusts at Indore. The Indore entries *viz*., HI 1636, HI 1650, HI 1651, HI 1655, HI 1667, HI 8826, HI 8827, HI 8828, HI 8830, HI 8832 and HI 8833 possess high degree of resistance to both stem rust pathotypes. The genotypes like HI 8802, HI 8807, HI 8808, HI 8881 and HI 8812 were found to be resistant to all three rust diseases at multi-location testing. A total of 767 genotypes of Preliminary disease screening nursery (PDSN) were evaluated for field resistance to stem and leaf rusts under artificial inoculations using mixtures of important pathotypes during *rabi* 2020-21. Of these, 374 entries (48.7% of the total) showed resistance to both stem and leaf rusts at Indore.

Integrated management of seedling blight in apple: Surveyed apple nurseries in Kullu, Mandi region of North-western Himalaya. Seedling blight infected seedlings were collected and pure culture of the causal fungus was isolated. Koch-postulate was validated and fungus was identified as *Sclerotium rolfsii* on the basis of morphology and molecular sequencing. Eighteen fungicides, were tested *in-vitro* through poisoned food technique of which Carboxin 37.5% + Thiram 37.5% DS, Fluopyram 17.7%+ Tebuconazole17.7% w/w SC, Fluxapyroxad 250 G/L + Pyraclostrobin 250 G/L and Propiconazole 25% EC were found to give best control. For ecofriendly management of seedling blight 09 botanicals and 01 bio-control agent (*Trichoderma longibrachiatum*) was also evaluated. Among botanicals, garlic was found most effective at 5% (W/V) concentration for the management of *S. rolfsii in-vtro. Trichoderma longibrachiatum* reduced the growth of fungus effectively.

5.2 ENTOMOLOGY

5.2.1 Integrated pest management

5.2.1.1 Cereals

Evaluation of rice germplasms against brown plant hopper (BPH): Out of 176 rice germplasm lines screened against brown plant hopper, *Nilaparvata lugens*, only seven lines were in resistant category with a mean score < 2.00. Plant hopper special screening trial in 22 rice germplasms against BPH resistance showed that RP 2068-18-3-5 with *Bph33 gene*, PTB33 with *Bph2+Bph3* genes and T12 with *Bph7* gene found to be promising with a mean score value of 2.32, 3.79 and 3.17, respectively.

Integrated effect of elevated temperature (eTEMP) and CO_2 (eCO_2) on brown plant hopper population: BPH population per hill reached peak during 40[th] (2021) and 41[st] (2022) SMW in all the treatments. The BPH population in eCO2+eTEMP significantly differed from all other treatments in 2021 (4.245±0.135) and 2022 (4.145±0.152). The female longevity (6.61±0.88), fecundity (97.65±1.46) was significantly different under eCO_2+eTEMP condition. Nymphal duration (6.61±0.88) was found longest in the ambient condition.

Bio-intensive management of invasive fall armyworm, *Spodoptera frugiperda* in maize: A total of eight different parasitoid species attacking the different stages of FAW *viz*., eggs and larvae were found with total parasitism rate of 28.37 to 42.44 percent. The egg-larval parasitoid, *Chelonus formosanus Sonan* was the most dominant parasitoid (12.55%). About 36.58 percent of the egg masses collected during the study period was parasitized by egg parasitoids, among which *Telenomusremus (Nixon, 1937)* was the dominant egg parasitoid. The maize intercropped with lady's finger recorded significantly lowest percent plant and cob damage resulting in significantly higher grain yield (6.17 q/ha) than other intercropping systems and control (5.10 q/ha). The overall bioefficacy of biopesticides against the larvae of *S. frugiperda* was in the following order azadirachtin > *Metarhizium anisopliae* > *Beauveria bassiana* at 168 HAT.

5.2.1.2 Vegetables

Ecological engineering for conservation of natural enemies and insect pest management in cauliflower: The effect of intercrops *viz*., candytuft, calendula, marigold, white daisy, cineraria, mix of flower crops and monocrop of cauliflower on the incidence of insect pests and their natural enemies was studied under field conditions. The calendula intercropping system had the lowest number of *Plutella xylostella* larvae and was most effective in reducing the pest damage (6.58±1.84 larvae/plant) followed by the marigold intercropping system. The maximum larvae of *P. xylostella* parasitized by *Cotesiavestalis* were recovered from the calendula intercropping system (4.56±0.19 cocoons/ plant). The lowest incidence of aphids was recorded in cineraria (103.27±20.91/plant) and calendula intercropping systems (106.05±10.00/ plant). The mean data showed that the calendula intercropping had attracted the maximum syrphid population (5.75±0.50), coccinellids (7.67±3.33/plant) and *Diaeretiella rapae* population (205.00±25.51 mummies/plant).

5.2.1.3 Oilseeds

Establishment of avoidable yield losses and management of mustard aphid: The insecticide applications reduced the aphid population from 51.4 to 99.6% across cultivars and seasons. Spray application of dimethoate 30 EC was effective over the biopesticide treatments, and *Beauveria bassiana* performed best among the test biopesticides. Thiamethoxam 25 WG and imidacloprid 17.8 SL were best among the neonicotinoids for reduction in aphid population, protection of potential seed yield, and incremental benefit-cost ratio in cv. PM 30. The control of aphid populations could prevent 10.2 to 61.1% yield loss.

Soybean: Field screening of IVT, AVT-I and AVT-II entries against major insect-pests in soybean were conducted. Among 50 IVT and 12 AVT entries, 3 entries were found resistant, 13 were shown moderate resistance against stem tunnelling. Against whiteflies, three and two entries were designated as highly resistant and resistant, respectively.

5.2.1.4 Pulses

Monitoring of pod borer, *Helicoverpa armigera* and beet armyworm *Spodoptera exigua* moths in chickpea using pheromone traps: Monitoring of insect pests plays an important in insect pest management programmes for judicious use of insecticides. The adult population of chickpea pod borer, andbeet armyworm were monitored using pheromone traps in chickpea during 2015-16 to 2021-22. Data revealed that the activity of *H. armigera* started from 3rd standard meteorological week (SMW) with highest activity during 8th to 15th SMW during the crop season in all seven years. The peak activity was observed in between 10th and 14th SMW in all the years surveyed. In case of *S. exigua* the moth activity was observed from 50th SMW with maximum activity during 9th to 15th SMW. The peak *S. exigua* activity was observed between 12th and 14th SMW in all the years surveyed.

Pigeon pea: Monitoring of pod borer, *Helicoverpa armigera* through pheromone traps: Monitoring of *H. armigera* was done using pheromone traps@ 4 per acre. Pheromone trap catches were started in 34th SMW and maximum catches (8.78 and 8.67 adults/trap) were recorded during 42nd and 43th SMW, respectively. The trap catches revealed the positive correlation with maximum temperature.

Mung bean: Atotal 277 mung bean germplasms were screened against thrips and bud necrosis disease during summer and kharif season of 2021. Among these germplasm, 96 germplasm were found resistant to moderately resistant category. These were further evaluated during summer season, 2022, among which 47 were found resistant, 36 were moderately resistant and 12 were found moderately susceptible, remaining were categorised as highly susceptible. Seasonal dynamics of thrips, *Maruca* and pod bugs in mung bean crop during summer and kharif season showed that higher pest infestation was observed during reproductive stage (flowering to pod maturity) in summer crop; especially thrips infestation was decreased at crop maturity.

5.2.2 Storage entomology

Evaluation of insecticides against *Oryzae philussurinamensis* and *Cadra cautella*: Fumigant toxicity of phosphine revealed adult stage of *O. surinamensis* as comparative tolerant stage with LC_{50}= 111.55, 57.90, 36.84 ppm for 24, 48, and 72 h respectively whereas for *C. cautella,* egg stage (LC_{50}=172.80, 151.80 ppm for 24 and 72 h) was found to be more tolerant. The insecticides contact toxicity studies revealed insecticides *viz*., chlorfenapyr and lambda-cyhalothrin to be promising alternative insecticides for malathion and deltamethrin.

Screening of cowpea genotypes against pulse bruchid, *Callosobruchus chinensis*: Cowpea genotypes were screened with choice and no choice test in acrylic olfactometer under lab conditions. Based on growth index (GI) of bruchids, 13 genotypes were found resistant, 18 moderately resistant, 28 moderately susceptible, 49 were susceptible. Further, these genotypes will be categorised by biochemical analysis of phenols, tannins and sugars.

5.2.3. Biological control

Feeding potential and foraging behaviour of *Chilo menessexmaculata* (F.) against *Bemisia tabaci*: Predatory potential of each instar grub and adult stages of *C. sexmaculata* was investigated against different developmental stages (nymph, pupae and adult) of cotton whitefly *B. tabaci*. The fourth instar grub registered the highest feeding potential (41.74±8.13 adult, 33.41±3.95 pupae and 31.33±3.95 nymphs) and the lowest by the first instar (10.15±1.70 adult, 9.15±1.35 pupae and 7±1.45 nymphs) among the grub instars. Among the adults, the female beetle consumed the highest prey (1445.29±312.77 adult, 1364.88±294.38 pupae and 1374.35±296.20 nymphs) followed by male beetle (1390.12±229.35 adult, 1308.18±270.51 pupae and 1325.35±275.81 nymphs) on *B. tabaci*. The foraging behavior of *C. sexmaculata* at different densities *viz*., 05, 10, 15, 20, 25, 30, 35 and 40 indicated that all the grub and adult stages showed a type-II functional response.

First report of cotton mealybug parasitoid, *Allotropa phenacocca* (Hymenoptera: Platygastridae) from India: The *Allotropa phenacocca* (identified from ICAR-NBAIR, Bengaluru) was reported on cotton mealy bug (*P. solenopsis*) for the first time from China. Now, we report it for the first report time from India and second from oriental region after China. This is considered as new weapon for the augmentative biological control of dreaded cotton mealybug. It prefers to attack on II instar of mealybug and III instar is effectively attacked by another primary parasitoid, *Aenasius arizonensis*

Development of water dispersible granules of *Metarhiziumrileyi*: *Metarhizium rileyi* strains were isolated from the cadavers of *Spodoptera frugiperda* collected from farmers' field. To prepare water dispersible granules five carrier materials were chosen *viz*., kaolin, calcite, talc, bentonite and dolomite. The physic-chemical properties have been worked out

5.2.4 Insect physiology

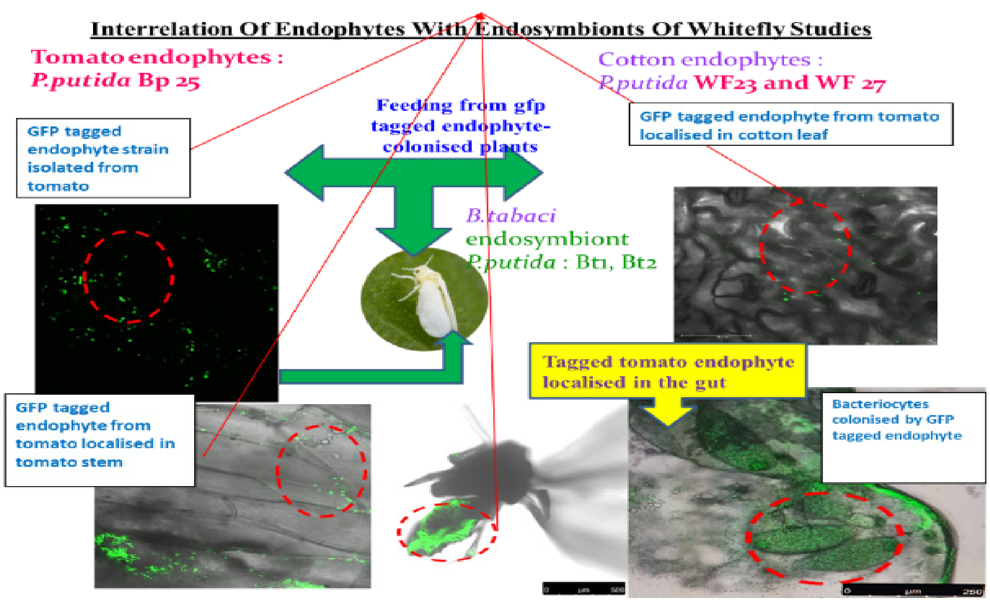
Molecular characterization of different populations for putative functional genes in *Chilo partellus*: Spotted stem borer, *Chilo partellus* is the most important pest having the ability to detoxify insecticides varies across insect populations, hence six larval samples from three different cohorts of *C. partellus* obtained from three diverse sources were sequenced using Illumina HiSeq 2500 platform with the mean read length of 150 bp and obtained 5.12, 6.65 and 5.99 GB sequencing data, respectively. These studies resulted in identification of 64 Cytochrome P450 genes, and 36 glutathione S-transferases genes encoding metabolic detoxification. In addition, target receptors related to insecticide action, 4 acetylcholinesterase, 14 γ-aminobutyric acid and 15 nicotinic acetylcholine receptors were also detected. These findings will be useful for understanding mechanisms of detoxification and designing target-specific insecticides to develop appropriate management strategies against *C. partellus* for sustainable crop production.

A single hot event impairs the expression of heat responsive and reproductive genes in *Spodoptera frugiperda*:

The freshly-emerged male and female adults of *S. frugiperda* were exposed to 42^{0}C for 2, 4 and 6 h and studied the expression profiling of heat responsive reproductive genes. The sex-specific expression of *Sf-hsp70* gene was recorded in male and female adults with peak expression in male adults under 2 h duration heat stress. The *Sf-SOD* expression was found to increase with increase in exposure duration. The expression pattern of *Sf-JHE* was found similar in both sexes with peak expression at longer exposure duration. The vitellogenin gene expression in female adults was drastically down regulated on exposure to hot events. The expression pattern of *Sf-USP* in the adults of *S. frugiperda* showed initial down regulation followed by up-regulation at longer exposure duration. The up regulation of heat responsive genes (*Sf-hsp70* and *Sf-SOD*) indicates its role in heat tolerance, while the down regulation of *Sf-Vg* and *Sf-USP* under heat stress has major impact on oocyte development.

Establishment of native *Bacillus thuringiensis* strains efficacy against *Spodoptera frugiperda:* The colonization of potential native Bt strain VKK5 (BtVKK5) as endophyte in five maize cultivars by seed treatment (ST), soil drenching (SD), foliar application (FA) and combination of all methods (ST+SD+FA) against *S. frugiperda*. Establishment of inoculated BtVKK5 strain as endophytes in five maize cultivars *viz*., Pusa HQPM7 Improved (PHQPM7I), Pusa Jawahar Hybrid Maize1 (PJHM 1), Pusa Vivek hybrid 27 improved (PVH27I), Pusa HQPM5 Improved (PHQM5I) and DMRH 1301 was confirmed by re-isolating from leaves of the plant on ampicillin selected agar plates. Bio-efficacy studies showed highest mortality (50%) in ST+FA+SD inoculation method followed by ST (40%) in PVH27I. Weight attained by survived larvae on inoculated plants was significantly low as compared to control in all the cultivars on 7th day after bioassay. Establishment of native *Bt* strain as an endophyte in maize plants complemented with insecticidal activity could possibly lead to an innovative approach to the management of *S. frugiperda* and other borers.

Gut bacterial diversity in honeybee, *Apis mellifera* and interrelation of endophytes with endosymbionts of whitefly, *Bem esia tabaci*: Studies have identified and characterized 51 and 32 aerobic gut bacterial isolates associated with forager and hive bees of *A. mellifera,* respectively. Enzymatic analysis has shown



Apis mellifera* and interrelation of endophytes with endosymbionts of whitefly, *Bemesia tabaci

that these gut bacterial isolates possess cellulase, hemicellulose, lipase, invertase and pectinases activity essential for digestion of pollen grain and honey synthesis in the gut of honeybees. Some of the gut bacterial isolates like *Bacillus altitudinis* (HAmf05) and *Enterobacter ludwigii* (HAmf28) have shown probiotic potential. Demonstrated horizontal transmission of two *Pseudomonas putida* strains WF23 and WF27 as endosymbiont and endophytes across plant and insect systems in cotton /tomato- *B. tabaci* system. This proof of concept could be utilized for developing novel control strategies against whitefly.

5.2.5 Insect toxicology

Virus induced volatiles in cotton modulate the orientation and oviposition behaviour of *Bemisia tabaci*: GC-MS analysis revealed subtle quantitative/ qualitative changes in volatile organic compounds (VOCs) between the healthy and selected CLCuV infection stages. Validation studies with eight synthetic VOCs indicated that γ terpinene elicited attraction to *B. tabaci* (Olfactometric Preference Index (OPI) = 1.65), while β-ocimene exhibited strong repellence (OPI = 0.64) and oviposition reduction (66.01%–92.55%). Our studies have demonstrated that progression of CLCuV disease in cotton was associated with dynamic changes in volatile profile which influences the behavior alresponses of *B. tabaci*. Results have shown that VOCs such as (+)-α-pinene, (−)-β-pinene γ-Terpinene, α-guaiene; 4- hydroxy- 4 methyl-2- pentanone and β-ocimene emitted from Begomovirus infected plants could be the driving force for early attraction and later repellence/oviposition deterrence of *B. tabaci* on virus infected plants.

Efficacy of triflumezopyrim in imidaclorpid tolerant brown plant hopper (*Nilaparvata lugens*) population: The LC_{50} value of triflumezopyrim was 0.103 and 0.192 mg/l, respectively in lab-reared and field-collected populations, whereas for imidacloprid the LC_{50} was 15.37 and 85.93 mg/l, respectively. Relative toxicity of triflumezopyrim was found as 198 compared to imidacloprid confirming high susceptibility of *N. lugens* to triflumezopyrim. A significant difference in the detoxifying enzymes, *viz.*, cytochrome P450 monoxygenase, and GST was observed when treated with the LC_{50} of the triflumezopyrim whereas no significant difference was observed in esterase activity. Imidacloprid-treated insects showed a considerable difference in esterase and cytochrome P450 monoxygenase activity, whereas no difference in GST was observed.

Efficacy of *Ad hoc* insecticides and botanical extracts against invasive fall armyworm, *S. frugiperda*: The efficacy of *Ad hoc* insecticides tested against invasive fall armyworm, *S. frugiperda* under laboratory and field conditions revealed that 3rd instar larvae showed moderate level of tolerance and comparatively less susceptible to chlorantraniliprole (18.5% SC), emamectin benzoate 5% SG. Field efficacy study revealed that, combi-product chlorantraniliprole (9.3%) + Lambda-cyhalothrin (4.6% ZC), and spinetoram (11.7% w/w SC), found as effective with less whorl damage (9.65%) and higher larval mortality (94-95%) as compared to other insecticides tested. Efficacy of botanical extracts (0.5%, 1.0%, 1.5%, 2.0%) of neem, garlic, karanja, clove oil, turmeric oil toxicity was tested against different life stages of *S. frugiperda viz.*, eggs and larval instars. All these botanicals inhibited egg hatching (100%) and also found effective against I and II instar stages of larva. While mortality of III instar larvae was observed only with the treatment of garlic, karanja and neem extracts.

5.3 NEMATOLOGY

5.3.1 Nematicidal potential of plant growth-promoting rhizobacteria against *Meloidogyne incognita* infesting tomato under protected cultivation

Nematicidal potential of three PGPR isolates (*Bacillus subtilis* DTBS 5, *Pantoea agglomerans*, and *Bacillus amyloliquefaciens* DSBA 11) and their consortium against *M. incognita* under laboratory, pots, and field experiments was studied. Under *in vitro* condition, Juvenile mortality of 91.67% was recorded at 100% consortium, followed by 73.33–81.33% by individual isolates. Similarly, hatching inhibition of 84.26% was recorded at 100% PGPR consortium followed by 78.48–83.21% in individual isolates after 96h. of incubation. In the pots' study, soil drenched with PGPR isolates consortium, followed by *B. subtilis* DTBS 5, *P. agglomerans*, and *B. amyloliquefaciens* DSBA 11 recorded significant reduction in the nematode incidence. Whereas in the field study, PGPR isolates applied as soil drenching significantly reduced nematode's incidence in consortium, followed by *B. subtilis* DTBS 5 and *B. amyloliquefaciens* DSBA 11-treated soil in both field experiments. On an average, the plant growth and fruit yield increased compared to untreated control and PGPR isolates applied as soil drenching gave a significantly better result than bare root dip treatment.

5.3.2 Characterization and evaluation *Arthrobotrys* and *Tolypocladium* against *Meloidogyne incognita*

In this collaborative work part of investigation relating to compound and scanning electron microscopic studies relating to characterization and evaluation were carried out. 2D adhesive network, 3D adhesive network, and non-constricting rings were formed by *A. thaumasia* to trap *M. incognita* J2s., The fungal mycelium penetrated the nematode cuticle, developed inside its body, consumed the body contents, then ruptured the cuticle, and subsequently grew out of the body. *T. cylindrosporum* directly parasitized the J2s. In another study the fungus could also parasitize *Paratrichodorus* juveniles.

5.3.3 Comparison of microbial taxa in nematode infected and healthy plants in a protected cultivation

PLFA analysis of roots revealed a significant difference in total viable biomass content between rhizosphere of infected (2213.87 nmol g^{-1} soil) and healthy (1957.22 nmol g^{-1} soil) plants. In general, biomarkers of anaerobes PLFA were more predominant in root samples compared to other microbial groups. The relative abundance of PLFA from anaerobes (t value: 3.75; P=0.019), Gram-negative bacteria (t value: 23.17; P<0.0001), and actinomycetes (t value: 12.48; P=0.0002) was significantly (P<0.05) higher in rhizosphere of healthy than in the rhizosphere of infected plants. In contrast, the relative abundance of Gram-positive bacterial PLFA (t value: 11.88; P=0.0003), Methanotroph PLFA (t value: 10.45; P=0.0005), and fungal PLFA (t value: 8.60; P=0.0010) was substantially higher in rhizosphere of infected than in rhizosphere of infected plants.

5.3.4 Entomopathogenic nematodes and their symbiont bacteria

The genome of entomopathogenic nematode *Heterorhabditis indica*: The draft genome of the *H. indica* Hms1-i20 was sequenced using three genomic libraries of 300 bp, 600 bp and 5 kb sizes by Illumina HiSeq platform. The size of the draft genome assembly was 91.26 Mb, comprising 3,538 scaffolds. 10,494 protein-coding genes were predicted in the present genome. Comparative analysis of *H. indica* genome in comparison to four other nematode genomes revealed that *H. indica* shared 6,574 orthologous groups with *H. bacteriophora*, 6,635 with *C. elegans*, 6,228 with *S. carpocapsae* and 6,669 with *O. tipulae*. A total of 4,824 orthogroups were common between these five nematodes analysed. Protein domain and secretome characterization identified 2,525 transmembrane domain proteins and 370 putative secreted proteins. Subsequent analyses identified 56 GPCRs, 30 peptidases, 31 peptidase inhibitors and 2 Fatty-acid retinol binding proteins in *H. indica* proteome and such proteins may facilitate nematode interactions with insect hosts or bacterial symbionts. Additionally, 2,549 microsatellite loci, 1,548 transposable elements, 631 non-coding RNA loci, 21 likely cases of horizontal gene transfer (HGT) were identified. The mitochondrial genome of *H. indica* was assembled separately which is 17,393 bp in size and 46 genes were detected in mitochondrial genome.

5.3.5 Unravelling the gut-active nature of a *Photorhabdus* toxin in agriculturally-important insects

A functional sub unit of orally active toxin complex (Tc) protein, TcaB (63 kDa), isolated from two strains of *P. akhurstii* namely IARI-SGHR2 and IARI-SGMS1, was tested for biological activity against *Spodoptera frugiperda*, *S. litura* and *Helicoverpa armigera*. The injection LD_{50} values of the toxin was comparable with that of oral LD_{50} values, indicating the toxin's efficacy via oral administration. An oral delivery of 500 ng TcaB caused a continual disintegration of midgut architecture in *S. frugiperda*, *S. litura* and *H. armigera* over 12 to 48 h incubation period putatively leading to escape of TcaB into the hemocoel. Simultaneously, alike of intra-hemocoel injection effect, TcaB oral delivery caused cytotoxicity and immune-stimulatory effect in the hemocoel of all the test insects during 12 to 48 h after inoculation. *In silico* docking analyses suggested that TcaB interacts with several *S. frugiperda*, *S. litura* and *H. armigera* receptor proteins in order to become a gut-active toxin.

5.3.6 Determination of TcaB binding potential with gut receptor proteins *in vivo* in model insect

The role of insect gut receptors in TcaB intoxication process was established. Transcription of candidate gut receptors in TcaB-infected larvae was analyzed, and a cadherin-like gene*GmCAD* was cloned from *Galleria mellonella*. *GmCAD* was highly transcribed in the fourth-instar larval stage and specifically in the midgut tissues. Ligand blot and binding ELISA assays indicated that TcaB bound to the truncated peptides from GmCAD transmembrane-proximal region with greater affinity than that from transmembrane-distal region. Oral administration of bacterially-expressed *GmCAD* dsRNA in *G. mellonella* severely attenuated the expression of target mRNA which in turn alleviated the negative effect of TcaB on insect survival (TcaB-induced mortality in CAD dsRNA pre-treated larvae reduced by 72-83% compared to control), implying the association of GmCAD in TcaB intoxication process.

5.4 AGRICULTURAL CHEMICALS

5.4.1. Development of active molecules for crop protection

5.4.1.1. Synthesis of imidazolyl and pyrazolylchalcone derivatives

A series of title compounds (40 in number) were synthesized by reaction of benzaldehydes with 4'-(imidazol-1-yl) acetophenone and chalcones with phenyl hydrazine respectively. *In vitro* fungicidal bioassay of synthesized compounds against *Rhizoctonia solani* and *Fusarium oxysporum* under laboratory conditions at various concentrations (200, 100, 50, 25, 12.5 ppm) by poisoned food technique revealed that against *R. solani* compound IC-8 (ED_{50} = 0.69 mg L^{-1}) was the most active followed by IC-10 (2.28 mg L^{-1}) & IC-7 (4.35 mg L^{-1}) in imidazolyl series. Pyrazolyl series evaluation revealed that compound P-25 (ED_{50} =5.56) mg L^{-1} showed highest activity followed by P-11 (8.22 mg L^{-1}) & P-2 (8.37 mg L^{-1}). However, in case of *Fusarium oxysporum* bioassay, moderate activity was observed with high ED_{50} values > 119.22 mg L^{-1}. *In vitro* nematicidal evaluation against *Meloidogyne incognita* revealed that among pyrazole series, compound P-21 (ED_{50} = 31.24 mg L^{-1}) was the best and among imidazole series, IC-6 (33.62 mg L^{-1})was most active after 24 h observation.

5.4.1.2 Synthesis and antifungal activity of imines derived from halogen substituted benzenamines

Twenty-seven Schiff bases derived from halogen substituted benzenamines were prepared and characterized using spectral analysis. These compounds were investigated further for their in-vitro antifungal bio-efficacy against *Rhizoctonia solani* and *Macrophomina phaseolina*. Most of the compounds were effective as antifungal agents and their ED_{50} values were ranged from 0.99 to 190.51 μgmL^{-1} against all the test fungi. Structure activity relation studies revealed that substitution of chlorine at the phenyl ring attached to the carbon of imine group resulted in the highest antifungal activity against both the test fungi. The substitution on the ortho position of the phenyl ring attached to the carbon of the imine group with different substituents displayed that the highest antifungal activity was observed against both the fungi with chloro substitution followed by bromo and nitro substitution. The study revealed the fungicidal compounds having the potential for their utilization as templates for developing new antifungal agents.

5.4.1.3. Nematicidal activity of the natural compounds and essential oils

The pot and sick plot experiments showed the promising nematode-controlling activity of citronella oil and citronellal against *M. graminicola* and was at par with carbofuran 3G and velum prime. The number of galls in the roots of rice seedling in citronella oil (0.6 galls/seedling), carbofuran (0.6 galls/seedling) treatment were less as compared to velum prime (1.0 galls/seedling) at 1000 ppm and negative control (3.8 galls/seedling) under sick plot conditions on 30th day after sowing (DAS) in direct seeded rice. Rice seedlings shoot lengthwas at par with carbofuran 3G and velum prime treatments. Further, citronella oil and citronellal were found effective against *M. incognita* in brinjal using the root dip method up to 60 days after in pot culture and results were at par with positive control and better than the negative control.

5.4.1.4 Characterizations of bioactive compounds from *Nigella sativa* seeds for antifungal activity

Optimization of ultrasonic (UAE) and microwave (MAE) technologies for the extraction of bioactive phytochemicals from *Nigella sativa* seeds was undertaken. Both UAE and MAE techniques performed better than conventional solid liquid extraction. Microstructural analysis of extracted samples clearly confirmed the intense influence of ultrasonic cavitation acoustic and microwave energies on the matrix wall, resulting rupture and disintegration to release more phytoconstituents. The optimal extraction conditions were determined as follows: amplitude 32.02 kHz, extraction time 13.12 min, ratio of solvent to solute 35.88 mLg^{-1} for UAE; and microwave power 674.18W, time 168.21s, solvent to solute ratio 70.09 mL g^{-1} for MAE. UPLC-QTOF-ESI-MS/MS analysis of ENS revealed 57 compounds dominated by thymoquinol-*β*-glucopyranoside, kaempferol-3-O-pentoside, nigellimine, nigellimine-N-oxide, nigellamine A_1, thymoquinol, thymoquinone, dithymoquinone and nigellidine-4-O-sulfite. FT-IR based spectral analysis further supported the presence of major functional groups (alkaloids, quinones and flavonoids). ENS exhibited excellent antifungal fungal action against *A. flavus* 2838 (27.6 μgmL^{-1}) followed by *A. flavus* 2547 (34.8 μg mL^{-1}) and *A. flavus* 837 (46.3 μg mL^{-1}). Antifungal action was further confirmed through ergosterol inhibition % and *in silico* docking studies targeting sterol 14-*α*-demethylase of the fungi. Nigellamine A_1, kaempferol-3-O-pentoside, nigellidine-4-O-sulfite were found to be promising and shared favourable binding with the target sites though H-bonds, electrostatic bonds (π-Cation type), hydrophobic bonds (Alkyl, Π-Alkyl, Π-Π Stacked, Π-Π T-shaped, Amide-Π Stacked type) and van der Waals interactions.

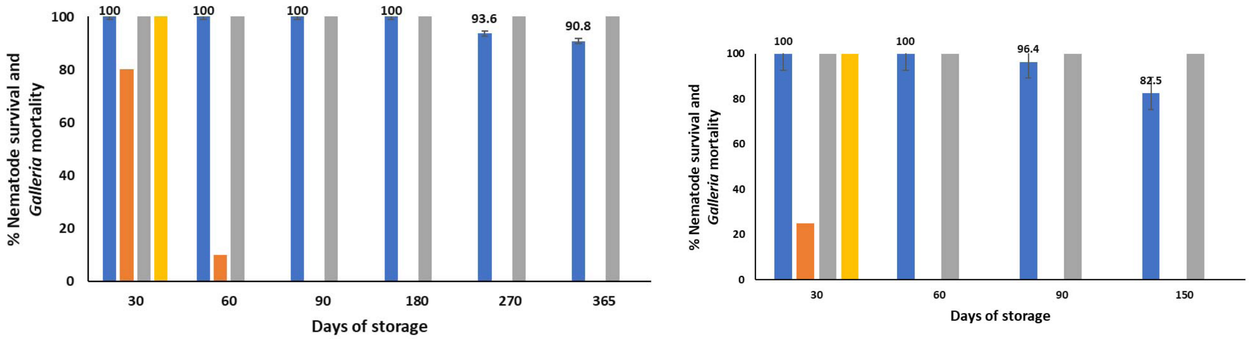
5.4.2. Formulations for delivery of crop protection inputs

5.4.2.1. Design, development, and characterization of controlled release formulation of tropinone

Based on the *in silico* and *in vitro* screening results of 7 alkaloids (atropine, cinchonine, noscapine, piperine, reserpine, strychnine, tropinone) against *Thripspalmi*, tropinone showed maximum activity. It was formulated by encapsulating in cross-linked chitosan matrix using hexamethylenedi isocyanate (HMDI), tolylene-2,4-di isocyanate (TDI) and isophoronedi isocyanate (IPDI) at different stoichiometric ratios. Physico-chemical characterization suggested that structural geometry and concentration of cross-linker were found to have profound effects on encapsulation and release kinetics of tropinone. Maximum encapsulation of tropinone was 80.11% and loading capacity varied from 2.94 to 6.49%. Release from the IPDI and TDI cross-linked formulation showed a monotonically increasing trend while initial lag phase was observed in release from HMDI cross-linked formulations. The release was found to be diffusion controlled and time taken form 50% release ($t_{1/2}$) was found highest at 9.23 days among the formulations. IPDI cross-linked chitosan emerged as best encapsulant for tropinone in terms of encapsulation efficiency and release kinetics.

5.4.2.2. Synthesis of functionalized amphiphilic copolymers for the encapsulation of chlorantraniliprole

Synthesis of amphiphilic polymers using poly(ethylene glycols) (PEGs) of various molecular weights, namely 600, 1000, 1500, and 2000 and dimethyl 5-hydroxyisophthalate in the presence of concentrated



Shelf-life and infectivity of EPNs in the powder formulation stored at 25 and 35°C respectively

H_2SO_4 followed by O-alkylation with bromo hexane and bromo octadecane was undertaken. All synthesized polymers were characterized by ^{1}H and ^{13}C-NMR. When dissolved in water, these polymers aggregate to form micelles of nano size ranging from 43.1 to 66.7 nm as measured by a Dynamic Light Scattering (DLS) instrument. Controlled release (CR) formulations of chlorantraniliprole (CAP) were developed by encapsulating CAP in functionalized amphiphilic polymer. Release kinetics study, of controlled release (CR) formulations (6a-6d) and (7a-7d) showed slower release of CAP in water as compared to commercial formulation (18.5% SC). The $t_{1/2}$ of developed formulations in water ranged from 7.16 to 18.06 days while it was 1.87 days for commercial formulation Coragen 18.5% SC. All the developed CRFs were evaluated for their insecticidal activity against the pest of *Spodoptera frugiperda* (Fall armyworm) and results suggested that CRF 6b formulation showed highest activity (LC_{50}- 0.069 ppm) and performed better than commercial formulation 18.5% SC (LC_{50} = 0.072 ppm).

5.4.2.3. Preparation of controlled release gel formulation of methyl eugenol

A gel formulation of methyl eugenol was prepared to achieve slow release of methyl eugenol. The main advantage of this formulation was that no heat was involved in the gel formation. The formulation was evaluated against fruit fly along with Pusa trap to evaluate the fruit fly attraction potential. Gel formulation trapped 6-4 per trap insects than 7-1 in Pusa trap in 4 weeks. These results revealed that prepared gel formulation was equally effective to Pusa trap till three weeks but showed more whitefly attraction potential in the fourth week.

5.4.2.4. Evaluation of performance and shelf-life of bio-insecticidal EPN formulations

Performance evaluation of lipid metabolism arrestant enriched EPN powder formulation against white grub in sugarcane confirmed biocontrol potential of developed product at par with the synthetic pesticide (bifenthrin). Shelf-life study of the prepared formulation confirmed its stability for at least 1 year at ambient temperature (25°C) and at least 6 months at elevated temperature (35°C). Almost 100% infectivity of formulated IJs against *Galleria mellonella* (*in vitro*) was observed within 72 hours irrespective of storage period.

5.4.3. Analytical methods or extraction protocols

5.4.3.1. Development of LC-MS/MS method for quantification of pesticides

Method for trace level detection and quantification of 100 pesticides were developed and validated in representative crop matrices (cumin seed and cardamom) under crop group 28 (Spices) and their performance were evaluated on member crop (fenugreek seed and tamarind) with special emphasis on sensitivity, recovery and matrix interferences. The instrumental LOQ of 0.005 $\mu g\ g^{-1}$ for most of the pesticides was achieved using LC-MS/MS. Modified

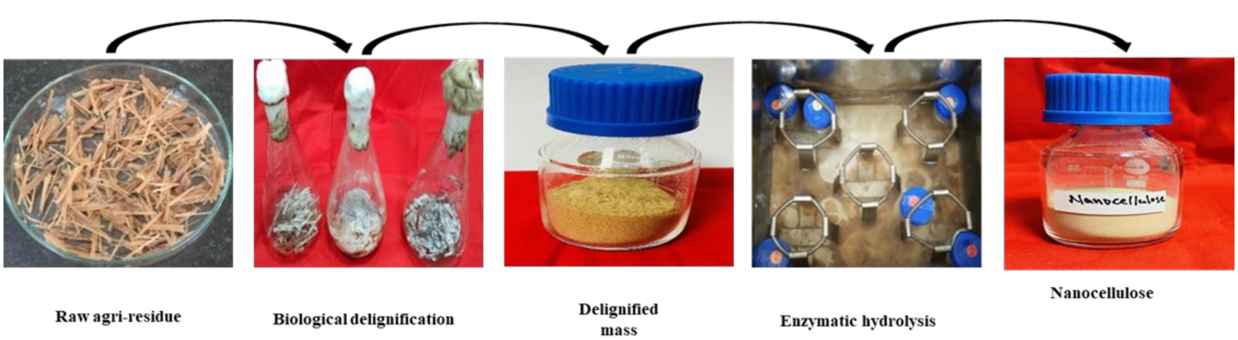
QuEChERS method was optimized, validated, and used for extraction and clean-up for estimation of pesticides. With the optimized method, 76% (cumin) and 73% (cardamom) of the pesticides were recovered in the range 70-120%with the RSD value <20%. The LOQ of 94% of the pesticides ranged from 0.01 to 1 μg g^{-1} forcumin seed and cardamom sample matrix. The global uncertainty for determination of the pesticides at LOQ level for the optimized methods were in the range of 6.81 to 39.86% for cumin and 6.77 to 28.88% for cardamom respectively, at 95% confidence limit. The optimized method for cardamom performed far better in tamarind and thus, can be utilized effectively for member crops. Whereas the optimized method for cumin showed relatively poor performance for fenugreek and thus on residue estimation point of view, reconsideration is required to consider cumin seed as representative crop to decide upon the residue content in fenugreek seeds.

5.4.3.2. Comparative adsorption capacity of adsorbent and ion exchange resins for purification of anthocyanin extract

Six macroporus resins (three adsorbent and three ion-exchange, (XAD-7HP, XAD-16, DIAION HP 20, DOWEX-50X8, IR 120, OPTIPORE-L 493) were screened for adsorption of four anthocyanin (two acylated and two non-acylated) in rose petals (*Rosa rubiginosa*), black rice (*Oryza sativa*), black carrot (*Daucus carota*) and purple cabbage (*Brassica oleracea*) extracts.Adsorption capacity of selected resins ranged between 0.38 to 4.31 mg g^{-1} for acylated anthocyanin and 0.25 to 4.02 mg g^{-1} for non-acylated anthocyanins. Per cent adsorption was more than 65% for all resins except DOWEX-50X8 & IR 120, where adsorption percentage was very low. The adsorption isotherm data were fitted well to the Freundlich isotherm with least χ^2 and AICc (Akaike Information Criterion) values. DIAION HP 20 and OPTIPORE L 493 exhibited the highest multilayer sorption capacities of 98.84% and 95.81%, respectively. Based on these data, OPTIPORE–L 493 ion exchange resin showed best performance in purification of acylated anthocyanin rich extract compared to non-acylated one.

5.4.3.3. Optimization of extraction protocol of xanthophylls from marigold

An ultrasonic assisted extraction (UAE) protocol of xanthophylls from marigold (*Tagetes erecta* L.) African marigold hybrid DAMH-39 was optimized. A Box-Behnken design (BBD) of the response surface methodology (RSM) was employed to optimize the parameters like solid to solvent ratio, ultrasonication amplitude and ultrasonication time for maximum extraction of xanthophylls. Hexane-acetone (1:1 v/v) was used as extraction solvent for the experiment. The optimized model suggested that a ratio of 32.8 solvent to solid (v/w) and 29.4 min ultrasonication at 55% amplitude can extract a maximum of 12.92 mg of xanthophylls per g of florets (dry weight basis). Validation of the model at the optimized conditions resulted a yield of 12.88 mg g^{-1} of total xanthophylls, which was very close to the model predicted value. The total xanthophyll content has been assessed based on lutein equivalent by HPLC.



Agriwaste to nanocellulose flow diagram

5.4.3.4. Optimization of green extraction knowhow of nanocellulose from cellulose rich agri-residues

An extraction protocol based on microbial and enzymatic assisted degradation of cellulose rich agri-wastes has been developed. The two-step process was demonstrated in four agri-residues *viz*. sugarcane bagasse, rice husk, banana pseudo stem and corn cob and compared comprehensively with the help of characterization techniques *viz*. DLS, SEM, TEM, XRD, FT-IR. The nanocellulose microcrystalline fibers has been optimized for their use as filler materials for hydrogel-based composites and as excipients in preparation of powder and tablet formulations.

5.4.4 Management and assessment of contaminants in agricultural commodities and environment

5.4.4.1. Persistence of sulfamethoxy pyridazine in soil and water

Analytical methodology was standardized for sulfamethoxy pyridazine (SMXP) analysis in soil following QuEChERS technique with method LOQ of 0.05 μgg^{-1} and water following solid phase extraction using HLB cartridges with method LOQ of 0.01 μgmL^{-1}. Higher organic carbon in entisol increased microbial activity; therefore, SMXP was more persistent in inceptisol. The optimum moisture percentage at field capacity (FC) aided in microbial degradation, therefore degradation occurred more quickly in FC [DT_{50} was 24.15d (inceptisol) & 8.34 d (entisol)] than in submerged [DT_{50} 40.06d (inceptisol) & 11.12d (entisol)] and half-field capacity [DT_{50} 42.78d (inceptisol) & 14.08d (entisol)]. Organic manure had a positive effect on the degradation of SMXP in inceptisol while it slowed down dissipation in entisol (DT_{50} 7.09 - 7.79 days). In water, SMXP was susceptible to acid hydrolysis (DT_{50} 10.78 - 34.14 days). Dissolved organic carbonincreased SMXP degradation in water. UV irradiation [DT_{50} 5.56d(UV irradiation) & 17.72d (sunlight)] enhanced the dissipation in water due to photodegradation. Higher initial concentration of SMXP reduced the degradation rate (DT_{50}10.98 - 40.76 days). Potential of this antibiotic to move towards ground water was moderate in inceptisol soil (GUS - 2.29) and low in entisol soil (GUS - 1.64).

5.4.4.2. Bio-remediation of petroleum hydrocarbons

Degradation of polyaromatic hydrocarbon (PAHs) was studies using microbes isolated from a contaminated soil. Among 17 bacteria and 3 fungi isolated from a crude oil contaminated soil, *K. rosea* + *A. sydowii* were identified as the best PAH (naphthalene, fluorene, phenanthrene, anthracene and pyrene) degrader in mineral salts medium. Bio-formulations (3 types) of these microbes were in degrading PAHs mixture (naphthalene, fluorene, phenanthrene, anthracene and pyrene, 100 $\mu g\ g^{-1}$ each) in the sandy loam soil. Compared to control, consortium decreased the $t_{1/2}$ by 521-807% (naphthalene), 337-883% (fluorene), 387-533% (phenanthrene), 315% (anthracene) and 220-312% (pyrene). No significant effect of nutrients (ammonium sulfate and compost) was observed on PAHs degradation. Bio-formulations were as effective as free cultures of microbes.

5.4.4.3. Effect of pesticides co-presence on their adsorption in soils

Co-presence of pesticides in mixtures can affect adsorption of individual pesticides in soils. Adsorption of fipronil and imidacloprid was studied in 3 sugarcane soils, individually and in mixture. Individually, imidacloprid adsorption in three sugarcane soils followed order: sandy clay loam > silty clay loam > loam with K_f values of 5.02, 3.20 and 2.58, respectively. Similarly, fipronil adsorption followed order: silty clay loam > loam > sandy clay loam with K_f values of 4.35, 3.09 and 2.08, respectively. Copresence of both pesticides affected their adsorption in soils. Imidacloprid adsorption constant (K_f) in presence of fipronil were 5.21 (sandy clay loam), 3.55 (silty clay loam) and 3.05 (loam). Sorption values (K_f) of fipronil in presence of imidacloprid were 1.33 (silty clay loam), 2.20 (loam) and 2.67 (sandy clay loam). Thus, presence of imidacloprid decreased fipronil adsorption while imidacloprid adsorption increased in presence of fipronil.

5.4.4.4. Removal of pesticides from water using Magnetite-activated charcoal

To remove three most used pesticides namely azoxystrobin (AZX), nitenpyram (NIT), and thiamethoxam (TMX) from water, a magnetite-activated charcoal composite was synthesized and characterized using FT-IR, SEM, and TEM. Linearity range of these pesticides in LCMSMS was between 0.005-1 µg mL^{-1}. The instrument LOD was 0.005 µg mL^{-1} (Signal to noise >3) and LOQ was 0.01 µg mL^{-1} (Signal to noise>10). Maximum sorption was observed for nitenpyram (K_F= 3706.8) followed by azoxystrobin (K_F=3288.51) and thiamethoxam (K_F=3250.87). All the pesticides followed L shaped isotherm suggesting that sorption is concentration dependent and interaction with adsorbent is a stronger for pesticide molecules than the water molecules. The standardized regeneration protocol showed great efficiency as after three reusability cycles only 8-9% decline in sorption was observed. Therefore, such magnetite-activated charcoal composites are highly cost-effective, eco-friendly alternatives for removal of pesticides from wastewater.

5.4.4.5. Evaluation of Metal Organic Framework for removal of tricyclazole residues from water

Twenty-six metal organic frameworks (MOFs) were screened *in-silico* using Grand Canonical Monte-Carlo simulations for tricyclazole removal efficiency. Three metal organic frameworks (MOFs) *viz*., ZIF-8, MIL-53(Al) and Fe-BTC were then chosen to be synthesized and characterized using Raman spectroscopy, XRD, FT-IR, and SEM.MOFs were used to remove tricyclazole (0.01-3 ppm) from fortified samples and sorption capacity varied in range of 74-98% {MIL-53(Al)}, 9-94% (ZIF-8), and 49-94% (Fe-BTC). Adsorption kinetics, isotherm modelling and molecular modelling simulations were carried out to understand mechanism of adsorption.

5.4.4.6. Synthesis and characterization of Graphene Oxide-Zinc Oxide (GO-ZnO) nanoparticles for pesticide sensing and photocatalytic degradation of pesticide residues in water

Hybrid GO-ZnO nanoparticles were synthesized and characterized using various techniques. Further GO-ZnO nano particles were doped with Fe_2O_3 (1, 5 and 10%) and characterized using various techniques. The prepared GO-ZnO nano-probes were found efficient and economical with a glyphosate detection linearity range of 0.1-10 ppm.

5.5 WEED MANAGEMENT

5.5.1 Weed management option in cotton for higher productivity and profitability

Weeds are the one of the most impedances besides insects and diseases for realizing the higher productivity from cotton. Therefore, herbicides such as pendimethalin as pre-emergence (PE), quizalofop and pyrithiobac-sodium as post-emergence (PoE) as sequential and tank mixed or ready mixed application were compared in cotton with weed free control (WFC) and un-weeded control (UWC) in randomized block design with three replications. Results of study revealed that pendimethalin 1.0 kg/ha as PE followed by (fb) tank mixed pyrithiobac-sodium 62.5 g/ha+quizalofop 50 g/ha (W4) as PoE resulted in better weed control of both grassy and broad-leaved weeds than other herbicides treatments except, pendimethalin 1.0 kg/ha PE fb ready mixed (pyrithiobac-sodium 6%+quizalofop 4%) 112.5 g/ha PoE (W7) and tank mixed pyrithiobac-sodium 46.8 g/ha+quizalofop 37.5 g/ha (W5). This herbicide combination also gave higher seed cotton yield and resulted in maximum weed control efficiency except WFC.

5.5.2 Effective weed management in wheat under a CA-based maize-wheat system

Weed management was studied in wheat under zero-till residue-laden conditions in a 12-year-old conservation agriculture (CA) based maize-wheat cropping system. The wheat crop in the experiment was dominated with *Malva parviflora* weeds. To manage this *Malva parviflora* four weed control treatments were planned and adopted in wheat. Results revealed that the tank mix application of carfentrazone 0.020 kg/ha + metsulfuron-methyl 0.004 kg/ha at 30 DAS was highly effective towards reducing weed dry weight of *Malva parviflora* and achieved highest weed control efficiency. This herbicide treatment resulted in ~31% higher wheat yields over un-weeded control.

5.5.3 Weed dynamics and management in CA-based cropping systems

Direct-seeded rice (DSR) witnessed insurgence of weed species such as *Dactyloctenium aegyptium*, *Dinebraretro flexa*, *Leptochloa chinensis*, and *Eleusine indica*, which were not found in PTR, whereas *C. difformis*, *C. iria* were found only in PTR. The application of pyrazosulfuron at 0.025 kg/ha PE *followed by* (*fb*) cyhalofop-butyl at 0.100 kg/ha at 20 DAS *fb* bispyribac-Na at 0.025 kg/ha at 25 DAS could control grassy (by 72%), broad-leaved (by 60%) and sedge (by 43%) weeds and increase rice yield by 125%. *Cyperus esculentus* a perennial sedge gradually superseded/ outwitted perennial sedge *Cyperus rotundus* (which was present from the beginning in CA system) and was most dominant weed in DSR, cotton, maize, and pigeon pea crops in varying intensity. *Medicago denticulata* an annual weed occurred in very high density in mustard under maize-mustard system, and another annual weed, *Malva parviflora* was seen first time in wheat under the maize-wheat-mungbean system in sandy loam soil. *Medicago denticulata* was controlled by pendimethalin @ 1.0 kg/ha and *Malva parviflora* was controlled by pre-mix carfentrazone+metsulfuron.

5.5.4 Integrated weed management options in vegetable peas

The results showed that applying pendimethalin (750g/ha) as pre-emergence (PE) followed by (fb) mulch followed by (fb) pre-mix of (metribuzin + clodinafop) {shagun} (270 g/ha) as post-emergence (PoE) significantly reduced weed growth (density and dry matter) and significantly increased weed control efficiency and weed control index (60.58 and 60.40 percent, respectively). When compared to the unweeded control (2.99 t/ha), this combination increased crop productivity by 1.39 times (39%). Apart from that, mechanical weeding done at 25 and 50 days after sowing (DAS) and sequential application of pendimethalin (750 g/ha) as pre-emergence (PE), followed by (fb) mulch, followed by (fb) quizalofop-p-ethyl (50 g/ha) as post-emergence (PoE) resulted in a lower weed population, increased crop growth, and increased pod yield (4.14 and 4.05 t/ha, respectively). Herbicide residue detected in pea and soil was below the Maximum Residue Limit (MRL), according to the residual analysis of the soil and crop. As a result, it is concluded that these herbicides can be used safely in vegetable peas.

5.5.5 Nano-urea and herbicides effect on weed and wheat productivity

A field experiment was conducted to evaluate the efficacy of nano-urea and herbicides on growth and productivity of wheat. The 16 treatment combinations namely 4 nitrogen management options (control, RDN (120 kg N/ha), 50% RDN + two spray of Nano-urea (40 & 60 DAS) and 75% RDN + one spray of Nano-urea (60 DAS) in main plots while 4 weed management practices (Tank mix of Clodinafop propargyl @ 60g *a.i.*/ha + Carfentrazone-ethyl @ 20g *a.i.*/ha at 30 DAS; Sulfosulfuron + metsulfuron methyl (Ready mix) @ 40 g/ha (product basis) at 30 DAS; Weed free check and Unweeded check) in sub plots were tested in split plot design and replicated thrice. Results indicated that RDN recorded significantly higher yield as compared to both the Nano urea treatments *i.e.*, 50% RDN + two spray of Nano-urea (40 & 60 DAS) and 75% RDN + one spray of Nano-urea (60 DAS). There is 13.3% and 19.4% yield reduction with 75% RDN + one NU spray and 50% RDN + two NU spray in wheat.

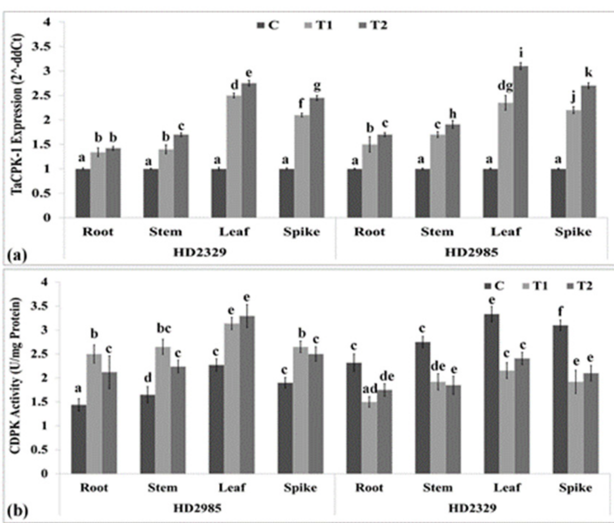
6. BASIC AND STRATEGIC RESEARCH

The basic and strategic research at IARI was focused on high throughput phenotyping for identification of superior donors and breeding lines under normal and abiotic stresses, development of CRISPR-Cas9 genome editing platform in rice, nutritional quality of pearl millet, rice, wheat, soybean, lentil, functional validation of genes and mapping QTLs for biotic and abiotic stress tolerance, 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, development of nanosensors. This section briefly covers some of the significant achievements in these areas.

6.1 PLANT MOLECULAR BIOLOGY

6.1.1 Genome-wide identification of TaCPK-1: Hubs in wheat heat stress signaling

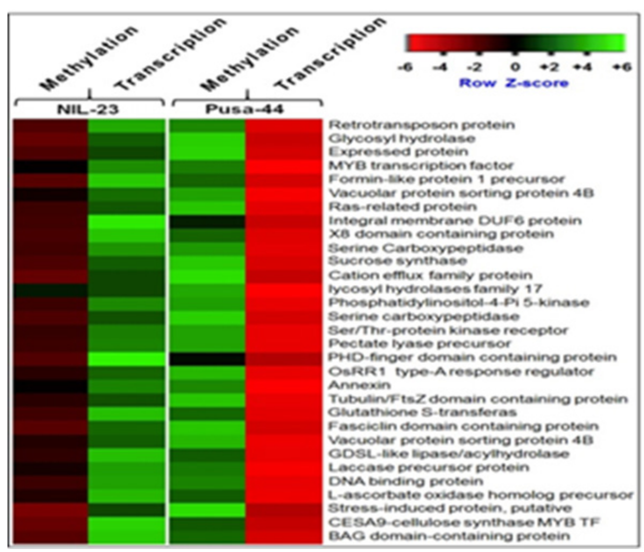
Calcium dependent protein kinase is one of the most important signaling cascades operating inside the plant system due to its peculiar role as thermo-sensor. We identified 493 transcripts showing homology with CDPKs through transcriptome data mining and predicted 28 full length putative CDPKs designated as TaCDPK (1- 28) for their role in high temperature tolerance.



Tissue specific expression analysis of TaC PK-1 and activity assay of native CDPK in contrasting wheat cvs. under differential HS a) Expression analysis of TaCPK-1 in different tissues at transcript level using RT-qPCR b) Activity assay of native CDPK in different tissues of wheat; C-22±3°C, and HS-treated (T1 - 30±3°C, 2 h; T2 - 38±3°C, 2 h); β-Actin gene (acc. no. JQ004803) was used for normalizing the Ct value

6.1.2 Pup1 QTL epigenetically regulates gene expression under P deficiency in rice

Using whole-genome bisulfite sequencing of a pair of rice [Pusa-44 and its near-isogenic line (NIL)-23 harboring Pup1 QTL] genotypes, the molecular functions of Pup1 on DNA (de) methylation-mediated regulation of gene expression under P-starvation stress were deciphered. Many of the P-responsive genes (transporters, TFs, phosphatases, carbohydrate metabolism, hormone-signaling, and chromatin architecture) were hypomethylated/ upregulated in roots of NIL-23 under P stress.



Heat map showing differential methylation in CG context and its effect on gene expression in root of the contrasting rice (NIL-23, P-deficiency-tolerant and Pusa-44, P-deficiency-sensitive) genotypes grown under P-starvation stress

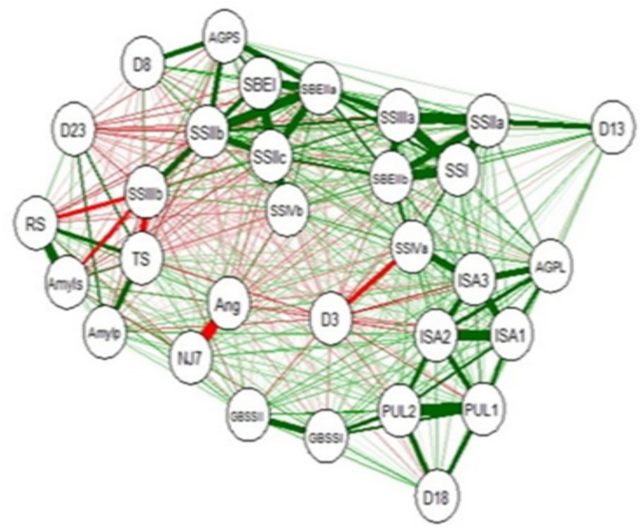
6.2. BIOCHEMISTRY

6.2.1 Phosphoproteome analysis of wheat grown under differential nitrogen treatments along with exposure to elevated CO_2 (eCO_2) and heat stress (HS)

Wheat genotype, HD 2967, grown under N-deficient, -sufficient and -normal conditions along with exposure to eCO_2 and HS (individually and in combination) showed differential expression of various proteins (Nitrite reductase, sHSP, CDPK, etc.) with significant changes in their phosphorylation levels. Nitrate reductase (NR) apoenzyme exhibited significant changes in the level of phosphorylation at two sites.

6.2.2 Starch biosynthesis gene to metabolite correlation in developing endosperm of rice varieties with contrasting levels of resistant starch

A correlation network between 20 starch biosynthesis genes (including their isoforms) and 4 metabolites (total starch content, TSC; amylose content, AC, amylopectin content, APC and resistant starch, RS) was developed using NJ72 (low AC/RS) and Ananga (high AC/RS) rice genotypes during five grain developmental stages i.e. 3,8,13,18 and 23 days after anthesis. RS and AC were positively correlated, and both possessed a strong positive correlation with granule bound starch synthase (GBSS) at all the stages of development.



Correlation network between genes and metabolites using "qgraph" package of R software in developing (3,8,13,18 and 23 DAA) rice endosperm. Positive and negative correlations are highlighted with green and red color edges. Color intensity is proportional to the correlation coefficient values

Differentially expressed proteins in wheat in response to eCO2 and HS under differential nitrogen treatment

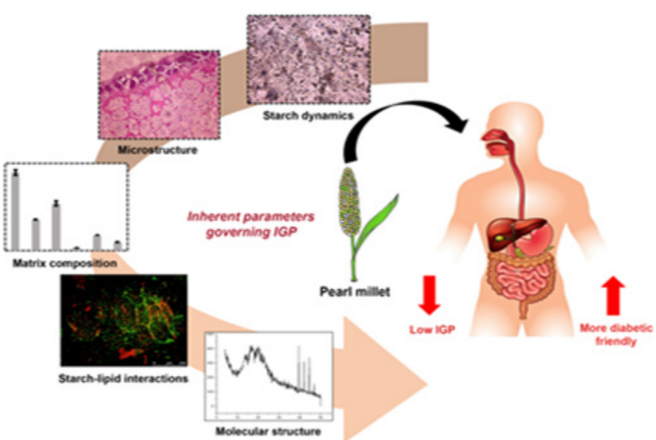
Protein Group	Name	Sequence	Changes in Phosphorylation Level		
			eCO_2	HS	eCO_2+ HS
K7UTP6	Nitrate reductase apoenzyme	aQIAtVR sLscAER	0.61 0.57	0.24 0.98	0.19 0.78
K7V1I2	Arginine serine-rich protein 45-like	gsPSPR gRsPsPPPk	2.72 2.44	1.32 1.96	1.21 0.98
P12810	HSP 16.9	sIQIsG tSsETAAFAGAR	2.12 1.52	3.14 4.45	12.25 8.92
B4FJG1	Chlorophyll a-b binding protein chloro-plastic-like	AGGIIGtRFESSDVk nEAGGIIGtR	2.7 1.2	4.5 2.5	3.2 1.9
B4FUV7	Uncharacterized protein	sLscAER sGsVTNWTSANR	0.61 0.85	0.99 0.56	0.85 0.91
C0PE12	Hypothetical protein	aQAEEEtLASER	0.55	0.96	0.45
C4J038	Calcium-dependent protein kinase	gRsPsPPPk	2.45	4.68	5.15

6.2.3. Effect of different thermal treatments on pearl millet flour shelf life, nutrient digestibility and its bio-accessibility

Amongst the different thermal treatments, like microwave (MW), infra-red (IR) and hydrothermal (HT), HT was found to be most effective in inhibiting the activity of rancidity causing enzymes (lipase, lipoxygenase, peroxidase and polyphenol oxidase) and improving the flour shelf life of pearl millet. It also reduced the starch digestibility by decreasing rapidly digestible starch and increasing slowly digestible starch and resistant starch fractions. On the contrary, HT treatment slightly reduced the bio-accessibility of phenolics and micro elements (Fe and Zn).

6.2.4 Pearl millet flour has inherently low glycemic potential (IGP)

In-vitro oro-gastro intestinal simulation revealed that pearl millet possessed low IGP (63.71%) compared to rice (65.9%). The synergistic effect of short- and long-range molecular patterns (R1047/1022: 0.80 & CD%: 21.73%) of starch were explored using FTIR and XRD which revealed that superior crystalline compactness was vital for low IGP.



Comprehensive characterization of food matrix variables affecting the IGP of pearl millet (*Pennisetum glaucum*)

6.2.5 Carotenoid profiling of processed orange carrot products

Retention of carotenoids in differentially processed carrot products showed highest β-carotene levels in citrate buffer-probiotic fermented (10.18 mg/g DW) followed by 1.5% sorbitol dipped samples (8.28 mg/g DW), while α-carotene was found to be higher in 1.5% sorbitol dipped (1.28 mg/g DW) compared to citrate buffer-probiotic fermented samples (0.85 mg/g DW). The highest lutein content was found in 2% NaCl-saline fermented (0.34 mg/g DW) followed by 2x 108 probiotic dipped samples (0.29 mg/g DW).

6.2.6 Nutritional and phytochemical profiling of microgreens at different stages of growth

The comparative nutritional (Fe and Zn content) and phytochemical (antioxidant potential, total phenolic, ascorbic acid, tocopherol, total dietary fibre content and phytic acid content) profiling of six microgreens (mungbean, lentil, pearl millet, mustard, red radish and red cabbage) at different stages of growth indicated that mungbean and lentil have maximum nutrient density on 7th, pearl millet on 11th day and mustard, red radish and red cabbage on 5th day after planting.

6.2.7 Development of soymilk-based synbiotics using fructo-oligosaccharides (FOS), raffinose family oligosaccharides (RFOs) and anthocyanins as prebiotics

Comparative prebiotic potential of RFOs and FOS at two concentrations (2 and 3%) was studied in soymilk matrix subjected to probiotic fermentation for 24 h with *Lactobacillus rhamnosus* and *Weissella confusa* 30082b. The results revealed highest viable probiotic cell count in the synbiotic soymilk supplemented with 3% RFOs as a prebiotic source along with high production of butyrate. Soymilk fermented with 2% RFOS + 2% FOS + 2% sucrose + 1% vanillin showed overall maximum consumer acceptability.

6.2.8 Arresting the rancidity of rice bran by regulation of lipase and lipoxygenase

Rice bran is a rich source of bioactive compounds, but is under-utilized as it is susceptible to hydrolytic and oxidative rancidity. The inhibition of deterioration during storage was evaluated by prior treatments like autoclave, infrared, low temperature and dry heat. Autoclave treatment proved to be best in reducing lipase and lipoxygenase activities, thereby, helping to retain the bioactive compounds.

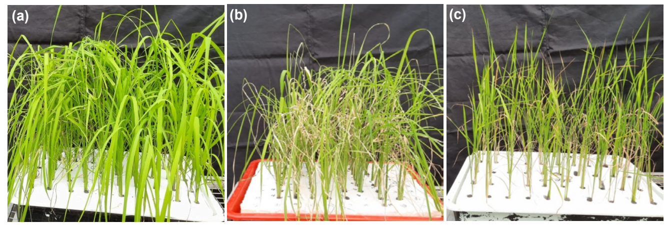
6.3 PLANT PHYSIOLOGY

6.3.1 Staygreen trait for yield stability in wheat under combined heat and drought stress

Wheat growing regions of the world often encounter simultaneous drought and heat stress at anthesis and grain filling stage causing severe yield loss. Ten recombinant inbred lines (RILs) of wheat, along with their parents (HI 1500/DBW 43) were evaluated under timely sown with irrigation (control) and without irrigation (drought stress) and late sown with irrigation (heat stress) and without irrigation (combined heat and drought stress). The genotypes were grouped into three clusters using multivariate analysis based on various physiological traits like relative water content, membrane stability index, total chlorophyll, net rate of photosynthesis, leaf area duration, yield and thousand grain weight at anthesis and post-anthesis stage. The RILs, GCP 6 and GCP 33 were identified as high staygreen based on the above mentioned traits under combined stress while GCP 23 and GCP 30 were low staygreen RILs. The staygreen RILs showed up-regulation of the gene involved in chlorophyll biosynthesis (*TaCHLD)* and down-regulation of the chlorophyll degradation genes (*TaPaO*, *TaPPH* and *TaSGR1*).

6.3.2 Identification of rice germplasm tolerant to iron toxicity and low phosphorus stress grown in northeast India

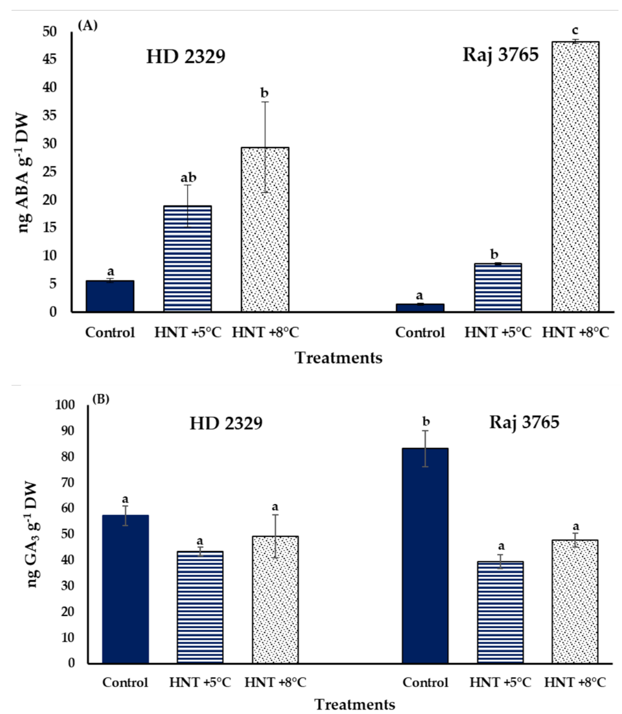
Iron (Fe) toxicity is among the major factors contributing to low rice productivity in North-east India because of low soil pH (4.0 to 5.5) which creates nutrient deficiencies, especially phosphorus (P). Indigenous rice germplasm of 85 lines was phenotyped under controlled condition for root traits, acid phosphatase, organic acid in root exudate, and Fe-toxicity symptoms under Fe toxic+low P, Fe toxic+control P, and control treatments. Leaf bronzing was used to score the genotypes visually on a scale of 1-4. The shoot biomass was reduced by >60% in FeT+low P followed by 35% reduction under FeT compared to control. Both FeT+low P and FeT treatments showed a 65 and 17% increase in acid phosphatase activity, respectively, in comparison to control.



Growth of rice seedlings (25 days old) under (a) control, (b) Fe toxic, and (c) Fe toxic + low P conditions

6.3.3 Antioxidant and hormonal control of tolerance to high night temperature in pistil of wheat genotypes

High night temperature (HNT) impairs crop productivity through reproductive failure of gametes (pollen and pistil). A study was conducted to determine the antioxidant mechanism for homeostatic control of



Effect of HNT on (A) ABA and (B) GA_3 concentration in the pistils of wheat genotypes HD 2329 (sensitive) and Raj 3765 (tolerant) under control, HNT (+5°C) and HNT (+8°C) conditions

free radicals and involvement of abscisic acid (ABA) and gibberellic acid (GA_3) in HNT stress protection in the pistils of contrasting wheat genotypes. The ears of two contrasting wheat genotypes – HD 2329 (susceptible) and Raj 3765 (tolerant) were subjected to two HNTs (+5°C and +8°C) over ambient. HNT significantly increased ROS in pistils of HD 2329 and relatively to greater extent compared to Raj 3765. The ROS levels were balanced by increased activity of peroxidase under HNT in tolerant genotype. The hormonal status showed increased ABA and decreased GA_3 contents with increasing temperature suggesting their role in the tolerance mechanism.

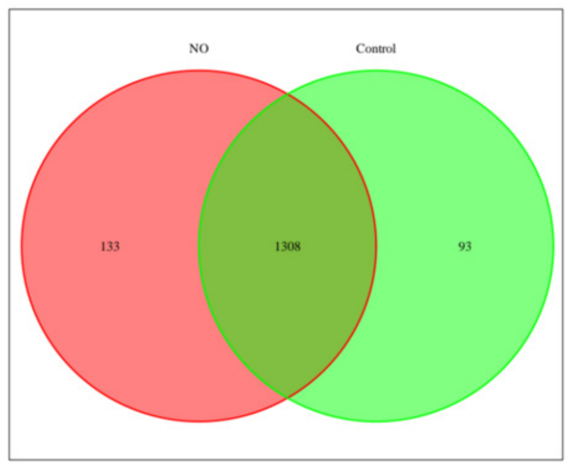
6.3.4 Comparison of ear and flag leaf photosynthesis in wheat

Non-availability of chambers for measurement of photosynthesis of wheat ear led to the designing and fabrication of a prototype of chamber. The chamber consisted of an assembly of transparent acrylic tube with provision for illumination and cooling inside a box. The chamber tubing was connected to a Portable Photosynthesis System (Li 6400). Provision was made to adjust the height of the chamber by sliding along a vertical iron stand. Photosynthetic measurement of flag leaf and wheat ear at grain filling stage was based on one sided leaf and two-sided ear projected area, respectively.

Photosynthesis chamber for measurement of wheat ear photosynthesis

6.3.5 Identification of nitrogen remobilization associated miRNAs in rice

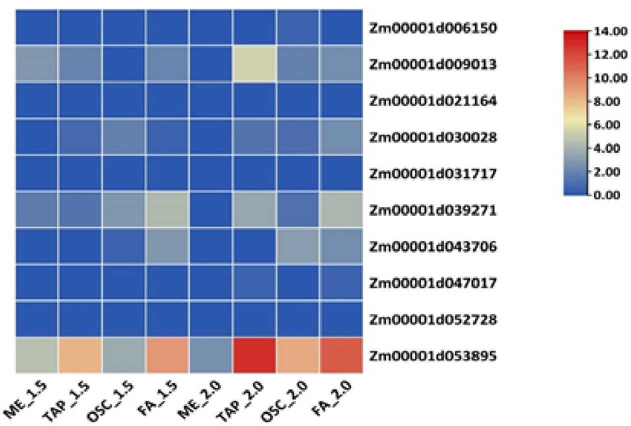
Small RNA was extracted from panicle, flag leaf and second leaf of high NUE rice genotype grown under nitrogen deficient (N0) and sufficient (N120) conditions. Based on miRNAseq analysis, 26 differentially expressing miRNAs were identified. Among the differentially expressing novel miRNAs, 11 were down-regulated and 14 were up-regulated. Based on the sequences of differentially expressed known and novel miRNAs, the putative target genes were predicted by the tool psRNA Target with default parameters. Expression pattern of differentially expressed novel and known miRNAs associated with NUE showed that miR397 was significantly up-regulated by N120 in panicle and flag leaf while miR5384, miR9776 and miR159 were up-regulated by N deficiency.



Venn diagram of showing distribution of known and novel miRNAS in N0 vs Control (N120) treatments

6.3.6 Genome-wide identification and characterization of bHLH transcription factor family genes related to anther development in maize (*Zea mays* L.)

bHLH transcription factors, like MS23, MS32, bHLH122, and bHLH51 sequentially take part in somatic development of the anther lobe. The role of bHLH genes in tapetal cell differentiation in maize was analysed from genomic databases of *Zea mays.* The genome-wide analysis identified 67 putative bHLH family proteins (ZmbHLH proteins) in maize, which were, classified into 22 subfamilies by comparative phylogenetic analysis with *Arabidopsis* bHLH proteins. Subcellular localization and genome distribution analysis showed that the loci were located non-randomly on the ten maize chromosomes. Further, analysis of conserved cis-elements in the promoter regions, protein interaction networks, suggested that bHLH family proteins are probably involved in multiple physiological processes in plant growth and development in maize.



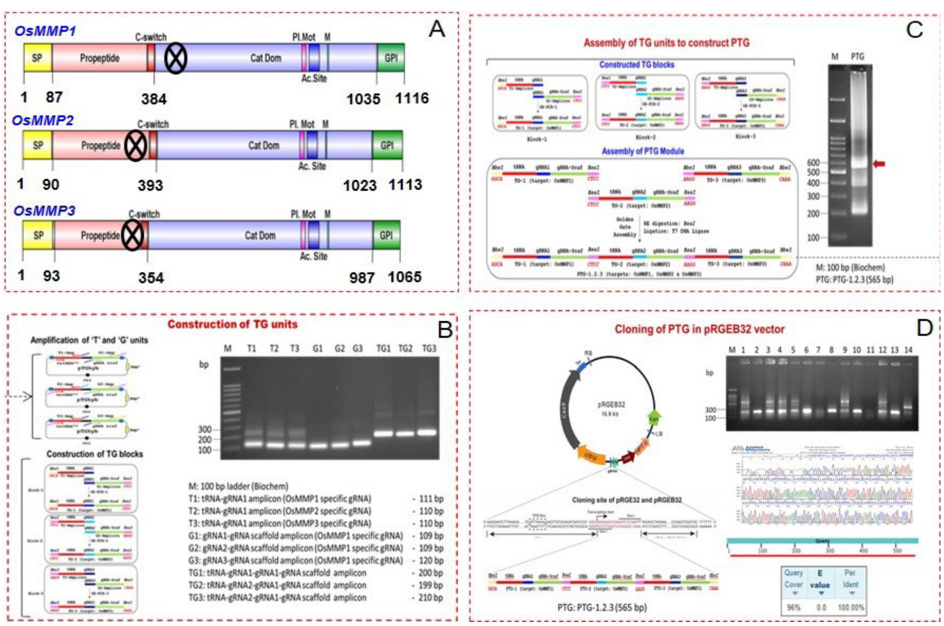
Heatmap showing the RNA profiling of three different cell types (i.e., ME, meiocytes; TAP, tapetum; OSC, other somatic cells) plus fixed anthers (FA) at two stages in maize anthers. Data taken from GSE182588 to identify our 67 identified genes from ZmbHLH gene families

6.3.7 CRISPR/Cas genome editing for the improvement of abiotic stress tolerance in rice

Clade A PP2Cs family genes negatively regulate rice's ABA signalling pathway and abiotic stress tolerance. CRISPR–Cas9-mediated genome editing was used to create mutations in *OsPP2C* clade A family genes to improve abiotic stress tolerance. Gene-edited mutant lines were generated for *OsPP2C10* (5 new alleles), *OsPP2C12* (2 new alleles), *OsPP2C48* (12 new alleles), *OsPP2C81* (1 new allele) in mega rice variety, *i.e.* MTU1010 for the given genes. Also, homozygous mutant lines have been identified for genes such as *OsPP2C10*, *OsPP2C12*, and *OsPP2C48*. Preliminary results of experiments showed reduced excised leaf water loss and early leaf rolling in homozygous *OsPP2C10* mutant plants. In future, the mutant will be characterized for abiotic stress tolerance ability. All these mutant lines will be used to generate double mutants.

6.3.8 Construction of expression cassette for multiplex editing of matrix metalloproteinase genes in rice

Matrix metalloproteinases (MMPs) are calcium- and zinc-dependent endopeptidases well-known for



Construction of 3X-PTG and cloning into pRGEB32(A) Different domains of *OsMMP* genes (cross marks representing gRNA target sites). (B) TG assembly through overlap extension PCR. (C) PTG assembly through golden gate assay. (D) Cloning of PTG in pRGEB32 vector and confirmation of legitimate cloning through Sanger's sequencing

their role as extracellular matrix (ECM) modifier in animal system. Plants also contain MMPs, albeit less in number and their striking structural homology with vertebrate MMPs envisages similar cellular localization and molecular function. We targeted to knockout three classical candidates *OsMMP* genes (*viz. OsMMP1, OsMM2* and *OsMMP3*) which were identified from rice genome. We identified one guide RNA each for knocking-out the *OsMMP* genes through CRISPR/Cas9 mediated gene-knockout approach. We followed a polycistronic tRNA-gRNA (PTG) mediated sgRNA multiplexing (3X-PTG) to facilitate simultaneous knockout of all the three *OsMMP*genes. The 3X-PTG was cloned in Cas9 containing rice transformation vector pRGEB32. *Agrobacterium tumefaciens* mediated transformation of *japonica* rice cultivar 'Kettaki' using the recombinant pRGEB32 vector was performed to obtain genome edited plants which are in T_0 stage.

6.4 GENETICS

6.4.1 Wheat

Marker-assisted transfer of genes for seedling and adult rust resistance in wheat: NILs carrying seedling resistance genes *Lr19*, *Lr24*, *LrTrk*, *Sr26*, *Yr5*, *Yr10* and *Yr15* were developed in wheat varieties HD 2967, HD 2733 and HD 2932. For adult plant rust resistance, genes *Lr34*/*Yr18*, *Lr46*/*Yr29*, *Lr67*/*Yr46* and *Lr68* were developed in wheat varieties HD 2733 and HD 3059 and characterized for rust resistance. The NILs with three APR genes (*Lr34*/*Yr18*+*Lr46*/*Yr29*+ *Lr67*/*Yr46* and *Lr34*/*Yr18*+*Lr46*/*Yr29*+*Lr68*) showed near immunity to both leaf and stripe rusts at adult plant stages.

Pyramiding of rust resistance genes in wheat at IARI-RS, Wellington: Pyramiding of stem and yellow rust resistance genes *Sr26*, *Sr27*,*Yr10* and *Yr15* in 6 elite cultivars carrying *Lr24*/*Sr24*, *Lr19*/*Sr25*, *Lr45*, *Lr47* targeting NWPZ and NEPZ is in BC2F4 stage. Pyramiding of stem and leaf rust resistance genes, *Sr24*/*Lr24*, *Sr25*/*Lr19* and *Sr26*, in stepwise and simultaneous manner was attempted with recipient parents *viz*., Lok1 using donor parents *viz*., Darfkite (*Sr24*/*Lr24 and Sr26*) and Wheatear (*Sr25*/*Lr19*)). The presence of the rust resistance genes was carried out at each generation using molecular markers *Gb*(*Sr25*/*Lr19*), *Sr24#12* (*Sr24*/*Lr24*), and *Sr26#43* (*Sr26*) in the backcross derivatives and also in the donor parents.

GWAS on SRT and APR of leaf rust resistance in bread wheat: Multilocus genome-wide association studies (ML-GWAS) were performed on a panel of 400 diverse wheat genotypes using 35K SNP genotyping assays and trait data of leaf rust resistance. Six ML-GWAS models revealed a set of 201 significantly associated QTNs for seedlings and 65 QTNs for adult plant resistance (APR), explaining 1.98-31.72% of the phenotypic variation for leaf rust.

Identification and characterization of candidate genes *TaZHD1* and *TaZHD10* controlling leaf rolling in wheat: Two new leaf rolling TFs genes, *TaZHD1* and *TaZHD10*, were uncovered in wheat using comparative genomic analysis of the target region that housed a major QTL for leaf rolling. The extreme RILs and parental lines displayed significant variance in leaf rolling during the booting and heading stages. The relative expression of these genes was validated by qRT-PCR analysis, which yielded consistent findings across all genotypes tested at the booting and anthesis stages.

Characterization of mutant lines for glaucousness in wheat: Mutant lines (M5) in HD 3086 background were screened for the presence of genes for glaucousness, awnless and adaptation to moisture stress. The non-glaucous lines showed the presence of a null allele for the three major genes at the *W1* cluster (Ta-DMH, Ta-DMP, Ta-DMC), known for glaucousness in wheat.

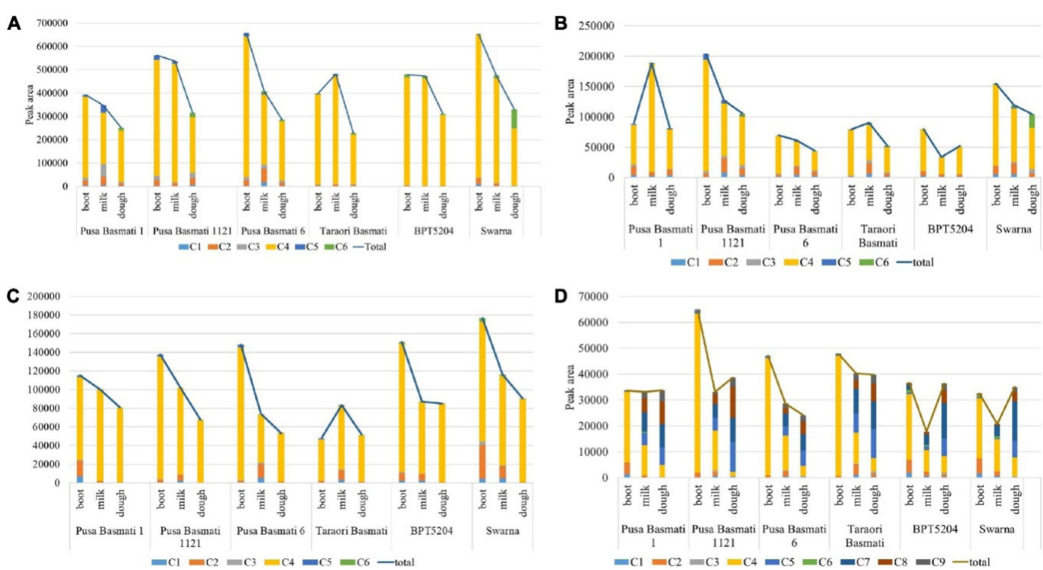
Genetic gain in grain yield (GY) in wheat: Grain yield was estimated in mega wheat varieties released between 1900 and 2016 for the north-western plain zone (NWPZ) of India by sowing under timely sown, tilled, and early sown conservation agriculture (CA) conditions for four consecutive years under irrigated conditions. The average annual genetic gain in GY since 1905 under timely sown irrigated conditions was found to be 0.544% yr^{-1} over the average of all varieties and 0.822% yr^{-1} (24.27 kg ha^{-1} yr^{-1}) over the first released variety, NP4. The realized mean yield increased from 2,950 kg ha^{-1} of the variety NP4 released in 1905 and 5,649 kg ha^{-1} of HD 3086 released in 2014. Regression analysis revealed a linear reduction in height and peduncle length (PL) over the years with a simultaneous and linear increase in biomass at the rate of 43.9 kg ha^{-1} yr^{-1} or relatively at 0.368% yr^{-1} mainly because of delayed heading and increased crop duration. Interestingly, genetic gain evaluation under early sown CA conditions for 4 years showed similar relative gain (RG) (0.544% yr^{-1}) but with a higher absolute value (29.28 kg ha^{-1} yr^{-1}).

GWAS and structure analysis in Indian dwarf wheat: The genomic regions associated with the grain yield, iron, and zinc content and physiological traits like canopy temperature, NDVI were identified through association mapping of a panel comprising 117 Indian dwarf wheat accessions using 35k genotypic data information. Association mapping revealed significant QTNs for important traits. Population structure revealed the presence of 7 sub-populations.

GWAS to identify loci and candidate genes for grain micronutrients and quality traits in wheat: Genomic regions governing grain zinc concentration (GZnC), grain iron concentration (GFeC), grain protein content (GPC), test weight (TW), and thousand kernel weight (TKW) were investigated in a set of 184 diverse bread wheat genotypes through GWAS. The highest number of MTAs were identified for GPC (23), followed by TKW (15), TW (11), GFeC (4), and GZnC (2). In silico analysis revealed important putative candidate genes such as F-box-like domain superfamily, Zinc finger CCCH-type proteins, Serine-threonine/tyrosine-protein kinase, Histone deacetylase domain superfamily, and SANT/Myb domain superfamily proteins.

6.4.2 Rice

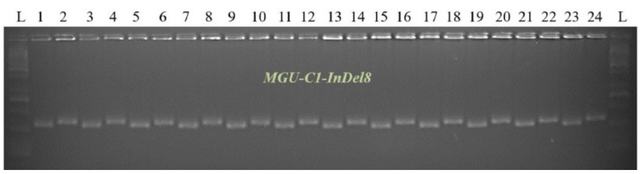
Spatio-temporal characterization of γ-oryzanol in developing rice grain: A significant antioxidant, γ-oryzanol, found in rice grains is a category of sterylferulates and caffeates. Six rice varieties (four Basmati and two non-Basmati) were evaluated for the distribution and dynamics of γ-oryzanol and its components in spatial and temporal scales. Cycloartenyl caffeate was predominant in all the non-seed tissues during the three developmental stages that reduced with maturity while, 24-methylenecycloartanyl ferulate, campesterylferulate and β-sitosteryl ferulate increased significantly towards maturity. Milling led to a significant reduction in γ-oryzanol content.



Cultivar-specific variation for total γ-oryzanol and its components in (A) leaf blade, (B) leaf sheath, (C) peduncle and (D) spikelet; C1: 24-methylenecycloartanyl-p-coumarate; C2: Δ7-stigmastenyl ferulate; C3: stigmasterylferulate; C4: cycloartenylcaffeate; C5: cycloartenylferulate; C6: campesterylcaffeate; C7: 24- methylenecycloartanylferulate; C8: campesterylferulate; C9: β-sitosterylferulate

6.4.3 Maize

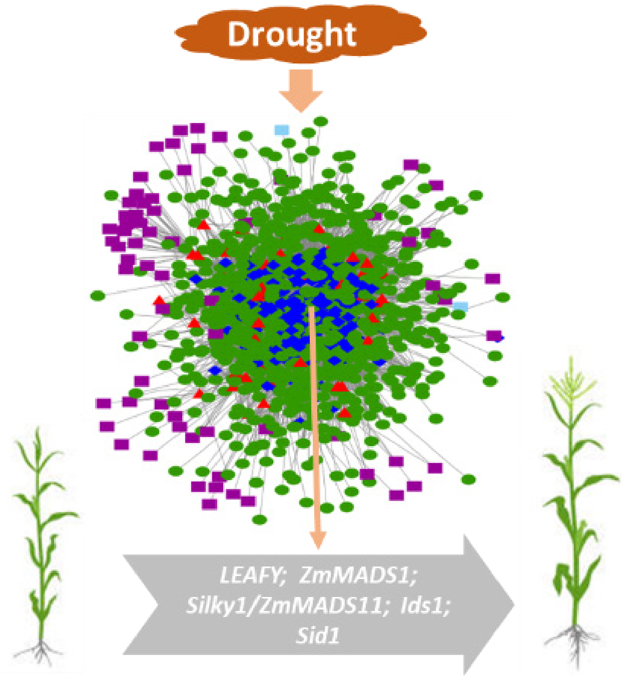
Development and validation of markers for *C1-Inhibitor* (*C1-I*) locus in maize: The presence of *C1-I* gene in the maize germplasm makes the anthocyanin-based identification of haploid seeds difficult. Two *C1-I* specific breeder-friendly markers (MGU-CI-InDel8 and MGU-C1-SNP1) covering (i) 8 bpInDel and (ii) A to G SNP were developed, respectively, that predicted the presence of *C1-I* allele with 92.9 and 84.7% accuracy, respectively



DNA profile of inbreds using MGU-CI-InDel8 marker

Nucleotide variation in *fea4* conferring variation in kernel row number (KRN): Two genotypes each for 10, 12, 14, and >14 KRN were sequenced for the *fea4* gene (Gene ID: GRMZM2. G133331). Nucleotide positions at 1188 bp, 1214 bp and 2442 bp showed SNPs among high and low KRN genotypes *viz*., A>T, G>C, and T>C, respectively. The transversion at 1188 caused change in amino acid (serine to threonine) and the other two positions contained synonymous changes.

Dissection of drought stress-regulatory network in maize: The network theoretic approach illustrated the existence of complex adaptive behaviour for drought stress-responsive regulatory network with 1129 nodes (genes: 766; miRNAs: 56; TF: 307), 9247 edges (TF-TF: 2105; TF-gene: 6148; TF-miRNA: 431; Target mimic-miRNA: 151 and miRNA-gene: 412). The drought-responsive regulatory network is dense and scale-free with a small world and hierarchical backbone of interactions. The centrality measure calculation showed the transcription factor family (ERF, C2H2, MIKC_MADS and GRAS) members were ranked on top in drought stress-responsive regulatory network and candidates such as *LEAFY*, ZmMADS1, Silky1/ZmMADS11, *Ids1* and *Sid1* play a major role in the transition of vegetative to the reproductive stage of maize.



Drought-responsive regulatory network during transition from vegetative to reproductive phase

***Agrobacterium*-mediated transformation using immature embryos in maize:** Immature embryos of three inbred lines *viz*. V390, HK193-2 and HK1-163 were used for *in vitro* regeneration and transformation studies. *Agrobacterium tumefaciens* (LB4404) and the binary vector (pCAMBIA3301) were used for the transformation. Following infection, the embryos were

Multiple shoots on development media

co-cultivated for 16-18 hours in dark and subsequently sub-cultured on a regeneration media containing 5μM Dicamba and 3μM 2,4-dichlolorophenoxy acetic acid (2,4-D) in MS media. The callus was transferred to shooting media, MS media containing 2μM kinetin and 4μM thidiazuron and kept in dark for 2 weeks for regeneration of shoots. For rooting, the regenerated shoots were placed on rooting media MS containing 2μM NAA for 2 weeks in the light.

6.4.4 Pearl millet

Identification of low rancid genotypes: Pearl millet inbred germplasm association panel comprising 257 genotypes was used to estimate rancidity in the flour using relevant biochemical indicators. The fresh and stored flour (10^{th} day) were analyzed for rancidity parameters like comprehensive acid value, peroxide value and activity assay of rancidity causing enzymes such as lipase and lipoxygenase. Based on the extent of rancidity genotypes, five low rancid (IP 19334, IP 13520, IP 18168, IP 10379, IP 18246), five medium (IP 9406, IP 6869, IP 7762, IP 11311, 81B-P6) and five high (IP 7470, IP 10085, IP 17690, IP 10811 and IP 8949) rancid genotypes were identified.

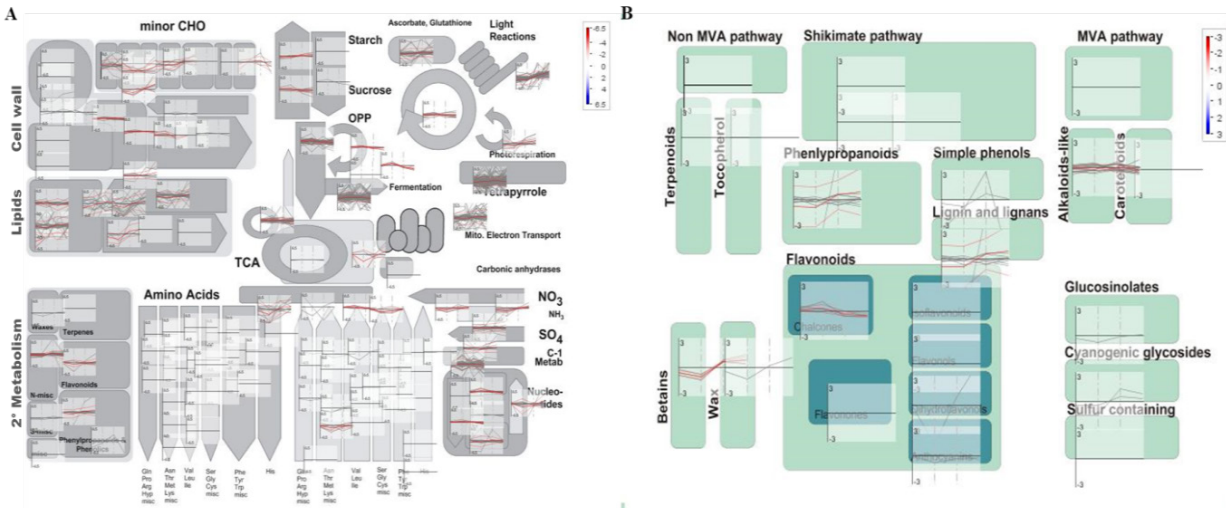
Inheritance of cream grain colour in pearl millet: Two inbreds of cream grain colour and three inbreds of grey grain colour were used for generating six F_1s and their reciprocal crosses. The segregation pattern of F_2 and backcross generations revealed that the inheritance of cream grain colour is governed by a single dominant gene with no maternal inheritance.

Grain colour variation in pearl millet genotypes

Estimation of iron, zinc, phytic acid, protein and total phenols in pearl millet: For nutritional parameters, three thousand plants from six generations of all crosses were assessed. Iron and zinc content was evaluated using XRF-spectrometer while total proteins, total phenols, and phytic acid were estimated using Near-infrared reflectance spectroscopy (NIRS). A prediction model for nutritional profiling based on the whole grain of pearl millet was developed. The iron content ranged from 17.6 to 151.4 ppm and the zinc content from 10.7 to 135.1 ppm. Similarly, protein content ranged from 5.94 to 15.57%, phytic acid 0.87 to 1.15%, and total phenol from 0.052 to 0.205%.

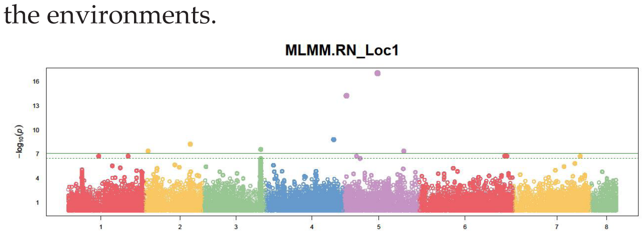
6.4.5 Chickpea

Genome-wide transcriptome analysis and physiological variations in chickpea to salinity: Comparative transcriptome analysis of tolerant (ICCV 10, JG 11) and sensitive (DCP 92-3, Pusa 256) chickpea genotypes in control and salt-stressed environments generated 530 million reads from root samples using Illumina HiSeq-2500. A total of 21,698 differentially expressed genes (DEGs) were identified of which 11,456 and 10,242 were up- and down-regulated, respectively. The DEGs were associated with hormone signalling, photosynthesis, lipid and carbohydrate metabolism and cell wall biogenesis. A total of 4257 differentially expressed GO terms were categorized into 64 functional groups of which GO terms like an integral component of membrane, organelle, and cellular anatomical entity were highly represented in tolerant genotypes under salt stress. Significant up-regulation of transcripts encoding potassium transporter family HAK/KUP proteins, MIP/aquaporin protein family, NADH dehydrogenase, pectin esterase, and PP2C family proteins occurred under salt stress. The tolerant lines (ICCV 10 and JG 11) engaged highly efficient machinery in response to elevated salt stress, especially for signal transduction, transport and the influx of K+ ions and osmotic homeostasis.



Interactions of metabolic pathways under salinity stress

Genome-wide association studies for root nodulation traits in chickpea: Evaluation of 300 chickpea genotypes in four different environments showed maximum genotypic and phenotypic coefficient of variation for traits like higher nodule number, nodule fresh weight, shoot fresh weight, and seeds per plant. ICC 6995, ICC 111 and ICC 506 were identified with high number of nodules and high mean yield over locations. GWAS led to the identification of 7 SNPs, a significant number of nodules explaining more than 15% phenotypic variation with 5 of them stable across the environments.



Significant SNPs associated with nodulation in chickpea

6.4.6 Lentil

Transcriptomic analysis of tolerant (PDL-1) and sensitive (L-4076) lentil cultivars at the seedling stage showed up-regulation of abscisic acid (ABA) signalling and secondary metabolites synthesis. The ABA-responsive genes *viz.* dehydrin 1, 9-cis-epoxycarotenoid dioxygenase, ABA-responsive protein 18 and BEL1-like homeodomain protein 1 recorded more than 4.0 log2 fold change in the tolerant genotype. Also, A total of 12,836 simple sequence repeats and 4,438 single nucleotide polymorphisms were identified which can be utilized in molecular studies. PDL-1 performed better under high alkalinity stress which was attributed to its higher mitotic index, more accumulation of K+ in roots and shoots and less aberrantly dividing cells. Also, antioxidant enzyme activities, osmolytes' accumulation, relative water content, membrane stability index and abscisic acid were higher in the tolerant cultivar.

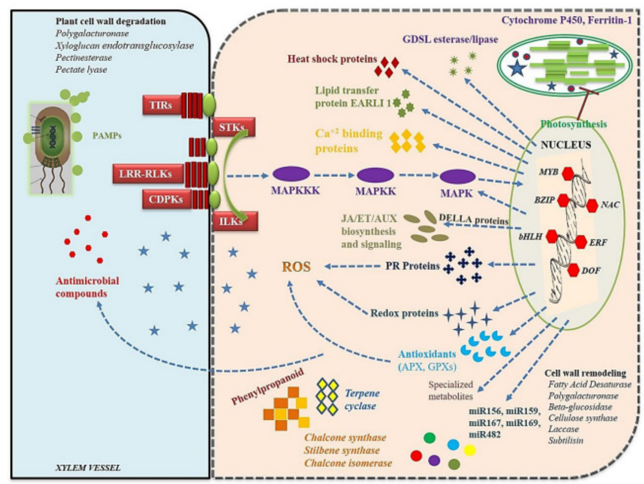
Characterization of unique lentil (*Lens culinaris* Medik.) genotype with seed-coat color anomalies: A unique lentil genotype, L4717-NM was identified as a natural mutant (NM) derived from a variety L4717, producing brown, black, and spotted seed-coat coloured seeds in a single plant. The genetic similarity of L4717 with NM was established using 54 SSR markers. Seeds with black seed coat showed better nutraceutical values for most of the studied traits. A highly significant ($p \leq 0.01$) and positive correlation was observed between antioxidant capacity measured by 2,2-diphenyl-1-picrylhydrazyl (DPPH) activity and total phenolic content (TPC), total ascorbic acid (TAA), total flavonoid content (TFC) whereas protein content recorded a negative correlation.

Genotypic variation in root architectural traits under contrasting phosphorus levels in Mediterranean and

Indian-origin lentil genotypes: Root architectural traits of 110 diverse lentil genotypes of Indian and Mediterranean origin were assessed under hydroponics setup at the seedling stage under two conditions: adequate P supply and deficient P supply. Total root length (TRL) and primary root length (PRL) showed strong positive association with all other characteristics excluding root average diameter (RAD) in both P treatments. In both P treatments, the RAD revealed a significant negative association with total root tips (TRT), as well as total root volume (TRV) and total root forks (TRF) in the deficit conditions of P. Total root volume (TRV), total surface area (TSA), and total root tips had higher coefficient variance values. According to the comprehensive phosphorus efficiency measure (CPEM), PLL 18-09, PLS 18-01, PLL 18-25, PLS 18-23 and PLL 18-07 were identified as the efficient, while IG112131, P560206, IG334, L11-231 and PLS18-67 were inefficient genotypes.

Transcriptome analysis for seed-size trait in cultivated lentil (*Lens culinaris* Medik.): A transcriptomic analysis of large-seeded (L4602) and small-seeded (L830) genotypes generated nearly 375 million high-quality reads, of which 98.70% were properly aligned to the reference genome. Various differentially expressed genes associated mainly with the hormone signalling and cell division pathways, transcription factors, kinases, etc. were identified as having a role in cell expansion and seed growth. String analysis identified various modules having certain key proteins like Ser/Thr protein kinase, seed storage protein, DNA-binding protein, a microtubule-associated protein, etc. In addition, some growth and cell division–related micro-RNAs like miR3457 (cell wall formation), miR1440 (cell proliferation and cell cycles), and miR1533 (biosynthesis of plant hormones) were siphoned for their role in seed size determination. Using RNA-seq data, 5254 EST-SSR primers were generated as a source for future studies aiming for the identification of linked markers.

Host-pathogen interaction pathways in response to *Rhizoctonia bataticola* infection in *Lens culinaris* Medik.: RNA-seq analysis in lentils following inoculation with *R. bataticola* generated >450 million high-quality reads with 96.97% aligned to the reference genome. Differentially expressed genes were associated with changes in phenolic compounds, transcription factors (TFs), antioxidants, receptor kinases, hormone signals which corresponded to the cell wall modification enzymes, defence-related metabolites, and jasmonic acid (JA)/ethylene (ET) pathways. String analysis revealed the role of various disease-responsive proteins *viz*., LRR family proteins, LRR-RLKs, protein kinases, etc. in the host-pathogen interaction. Some key miRNA targets *viz*. miR156, miR159, miR167, miR169, and miR482 were identified which may have a vital role in *Rhizoctonia*-based response in lentils.



Metabolic pathways involved in resistance to *Rhizoctonia bataticola*

6.4.7 Mungbean

Assessment of mungbean (*Vigna radiata* L.) cultivars in relation to phosphorus utilization efficiency under phosphorus stress environment: Phosphorus utilization efficiency was evaluated in 24 diverse mungbean cultivars under the hydroponic system. Cultivars MH 521, MH 805 and PM 5 were identified as efficient and responsive under low phosphorus conditions.

6.4.8 Indian mustard

Wide hybridization for broadening genetic base in *Brassica juncea:* Four crosses were attempted between *B. oxyrrhina*/*B. rapa*//*B. juncea* by using four genotypes of *B. juncea viz*., NPJ 253, NPJ 176, SEJ 8 and Pusa

Tarak to create genetic variability. Three crosses were attempted between *B. tournifortii* and *B. juncea* (SEJ 8, NPJ 176 & NPJ 253) for incorporation of drought tolerance. For incorporation of *Alternaria* resistance, *S. alba+B. juncea* (RLM 198) cybrid and *B. juncea* Acc. NPJ 176, SEJ 8 and NPJ 253 were crossed.

Introgression of resistance to white rust and powdery mildew in Indian mustard

A set of 37 F_2s by crossing five white rust-resistant mustard accessions (WRW 28, WRW 29, WRW 41, WRW 206 and Ooty collection) with known donors (Heera, Donskaja and Pusa mustard 31) was obtained. The segregation for white rust resistance was observed in F_2 s for conducting a test of allelism. Another set of 33 fresh F_1 crosses was attempted among 10 white rust-resistant accessions (WRW 28, WRW 34, WRW 38, WRW 41, WRW 71, WRW 142, WRW 151, WRW 206, Ooty collection 1 and PMW 18) and known donors (Heera, Donskaja, Pusa mustard 31, RLC 3 and Leafy 56) to identify novel genes.

Nineteen F_3 progenies (from six crosses involving PMW 18, WRW 4, WRW 28, WRW 29, WRW 41 and PM 31) were advanced to F_4 (15 SPS) during *rabi* 2021-22 which will be subjected to selection for both white rust and powdery mildew resistance under hot spot conditions at Wellington.

Marker-assisted improvement of popular varieties for white rust and/or quality traits: Screening of 82 backcross populations led to identification of one line with white rust resistance in PM22 background and six lines with both low erucic acid content and white rust resistance and one double low line in Pusa Jagannath background.

Introgression of high oleic acid content: In the screened *Brassica juncea* germplasm, oleic acid was observed upto 49% compared to 65% in *B. napus* genotypes. Further, F_2 population was generated to introgress high oleic content in *B. juncea*.

6.4.9 Soybean

Inheritance of seed size and its mapping in soybean: F_2 population from cross between AGS457 with large seed (average 100-seed weight-30 g) and small-seeded soybean genotype SKAF148 (average 100-seed weight 7 g) showed the involvement of polygene in the control of seed size. The mapping studies showed that thirteen of the 42 QTLs were at known loci of which five were major QTLs, namely *qSL-10-1*, *qSW-4-1*, *qSV-4-1*, *qSLW-10-1*, and *qSLH-10-1*

6.5. SOIL PHYSICS

6.5.1 Effect of tillage, residue, irrigation and nitrogen management on soil physical properties and root growth dynamics in wheat in an Inceptisol

Long-term tillage experiments from 2014 onwards were continued during 2021-22 *rabi* season with wheat (cv HD 2967) on a sandy loam soil at ICAR-IARI farm to study the effect of different tillage, residue, irrigation and nitrogen management practices on soil physical properties and root growth dynamics in wheat. The treatments comprising of two levels of tillage. Conventional tillage (CT) and No tillage (NT); two levels of mulching (with maize crop residue mulch @ 5 t ha^{-1} (R+) and without residue (R0) as main plot factors and three nitrogen doses (50, 100 and 150% of the recommended dose of N) and two levels of irrigation [full irrigation (I_F) and deficit irrigation (I_D)] and as subplot factors were evaluated in a split-factorial plot design. Results showed an increase in Mean Weight Diameter (MWD) at 0-5, 5-15 and 15-30 cm soil depths under NT and crop residue mulching than CT and no mulch. With the increase in nitrogen, the MWD of soil increased in all these depths. There was decrease in bulk density (BD) and increase in soil hydraulic conductivity (SHC) of soil under NT and crop residue mulching. The root length density (RLD), root mass density (RMD) and root diameter (RD) of wheat also increased under NT than under CT. The correlation studies showed that root length density of wheat was significantly positively correlated with MWD and water stable aggregates (WSA) but negatively correlated with the BD of soil at 0-15 cm soil depth. Thus, farmers can successfully adopt NT system in irrigated wheat with maize residue mulch

Correlation matrix between root length density of wheat and soil physical properties at 0-15 cm soil depth

	MWD	WSA	BD	SHC	CRI RLD	Jointing RLD	Flowering RLD	Milking RLD
MWD	1.00							
WSA	0.93**	1.00						
BD	-0.61*	-0.51	1.00					
SHC	0.67*	0.55	-0.36	1.00				
CRI RLD	0.60*	0.70*	-0.32	-0.01	1.00			
Jointing RLD	0.75**	0.72**	-0.70*	0.60*	0.29	1.00		
Flowering RLD	0.60*	0.43	-0.85**	0.55	0.22	0.78**	1.00	
Milking RLD	0.79**	0.77**	-0.60*	0.70*	0.45	0.74**	0.69*	1.00

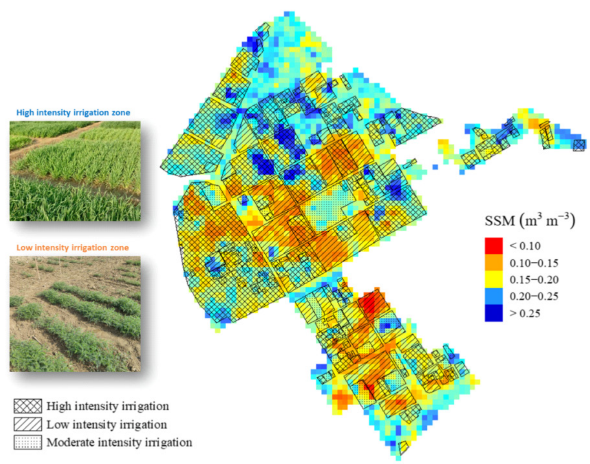
application to improve long-term soil physical health for a better root morphological development.

6.5.2 Prediction of soil mean weight diameter through machine learning technique

For prediction of the soil aggregate stability parameter of aggregate mean weight diameter (MWD) using easy to measurable parameters, a total 121 soil samples were collected from 0-15 and 15-30 cm of soil depths from eighteen villages of Nilokheri, Nissang and Assandh block of Karnal district, Haryana. MWD was successfully predicted by ANN, SVM and RF machine learning approaches. Inclusion of bulk density improved prediction capability of the models. The MLR and CART showed lower predictive capability than other three approaches. SVM models predicted the MWD with more satisfactory performance as compared to the other models owing to its higher flexibility and capability to model non-linear relationships.

6.5.3 Regional root zone soil moisture mapping from near-surface measurements

Surface soil moisture (SSM) maps at a spatial resolution of 30 m were generated for the IARI farm area during the *rabi* season using the ensemble machine learning method. Ensemble modelling had better accuracy as compared to individual models with RMSE at 0.056 $m^3 m^{-3}$, with lower mean biased error (-2.3e-03 $m^3 m^{-3}$). The SSM maps were successfully validated with the field irrigation zone map in which areas occupied by crops of high- and low-intensive irrigation were clearly delineated. The approach is aimed at reducing the uncertainties associated with individual models and undertaking a systemic integration of microwave, thermal, and optical techniques for SSM retrieval.



Areas occupied by high- and low-intensive irrigated crops over the range of soil moisture as mapped through the satellite data and ensemble approach

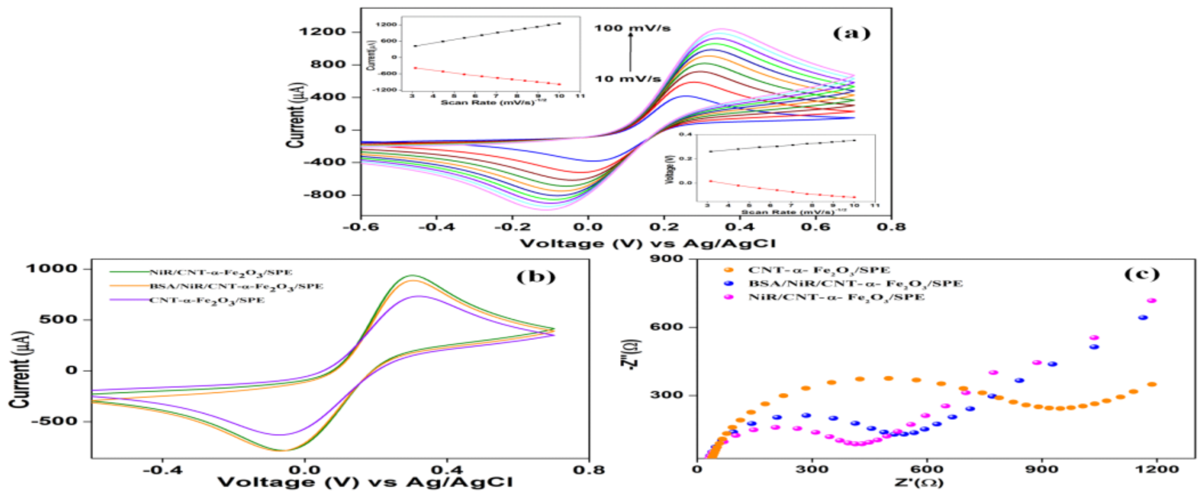
6.5.4 Biophysics

6.5.4.1 Fabrication and validation studies of soil nitrate nanosensor

Secondary nitrate products such as nitrite, nitric acid and nitrosamine compounds are responsible for adverse health effects. Thus, the increasing level of nitrate in soil, water, food and feed may prove

Performance indicators of the fabricated nanosensors

S.No	Nanosensor	Surface ionic concentration (i_s) (mol/cm^2)	Diffusion coefficient (D) (cm^2/s)	Charge transfer resistance (R_{CT}) (Ω)	Heterogeneous electron transfer rate constant (K_e) (cm/s)
1	CNT-α-Fe_2O_3/SPE	15.50×10^{-9}	5.90×10^{-8}	948.20	0.6×10^{-5}
2	NiR/CNT-α-Fe_2O_3/SPE	20.10×10^{-9}	9.80×10^{-8}	413.05	1.31×10^{-5}
3	BSA/NiR/CNT-α-Fe_2O_3/SPE	18.90×10^{-9}	8.76×10^{-8}	515.08	1.01×10^{-5}



Current response and charge transfer resistance of the fabricated nanosensors

Comparison of the nitrate nanosensor with the colorimetric method

S No.	Performance indicator Parameter	Technique	Nitrate added (ppm)		
			0.05	0.2	0.4
1	Measured value (ppm)	Electrochemical	0.048	0.197	0.391
		Colorimetric	0.042	0.176	0.348
2	Recovery (%)	Electrochemical	96	98.5	97.8
		Colorimetric	84.4	88	87
3	RSD (%)	Electrochemical	0.54	0.66	1.33
		Colorimetric	1.67	2.49	3.54

hazardous for plant, human and animals' health. The fabrication of nanosensor was accomplished using prepared nanocomposite (CNT-α-Fe_2O_3) and nitrate reductase for specific detection of nitrate in soil extract. The sensitivity and limit of detection obtained using the nanosensor were 63.87 µA/log (mg/L)/cm^2 and 0.09 mg/L, respectively. The high correlation (r^2 = 0.998) with the colorimetric method implied futuristic scope of practical utility of the fabricated nanosensor for fast, accurate, and in-field detection of nitrate content in soils during crop cultivation.

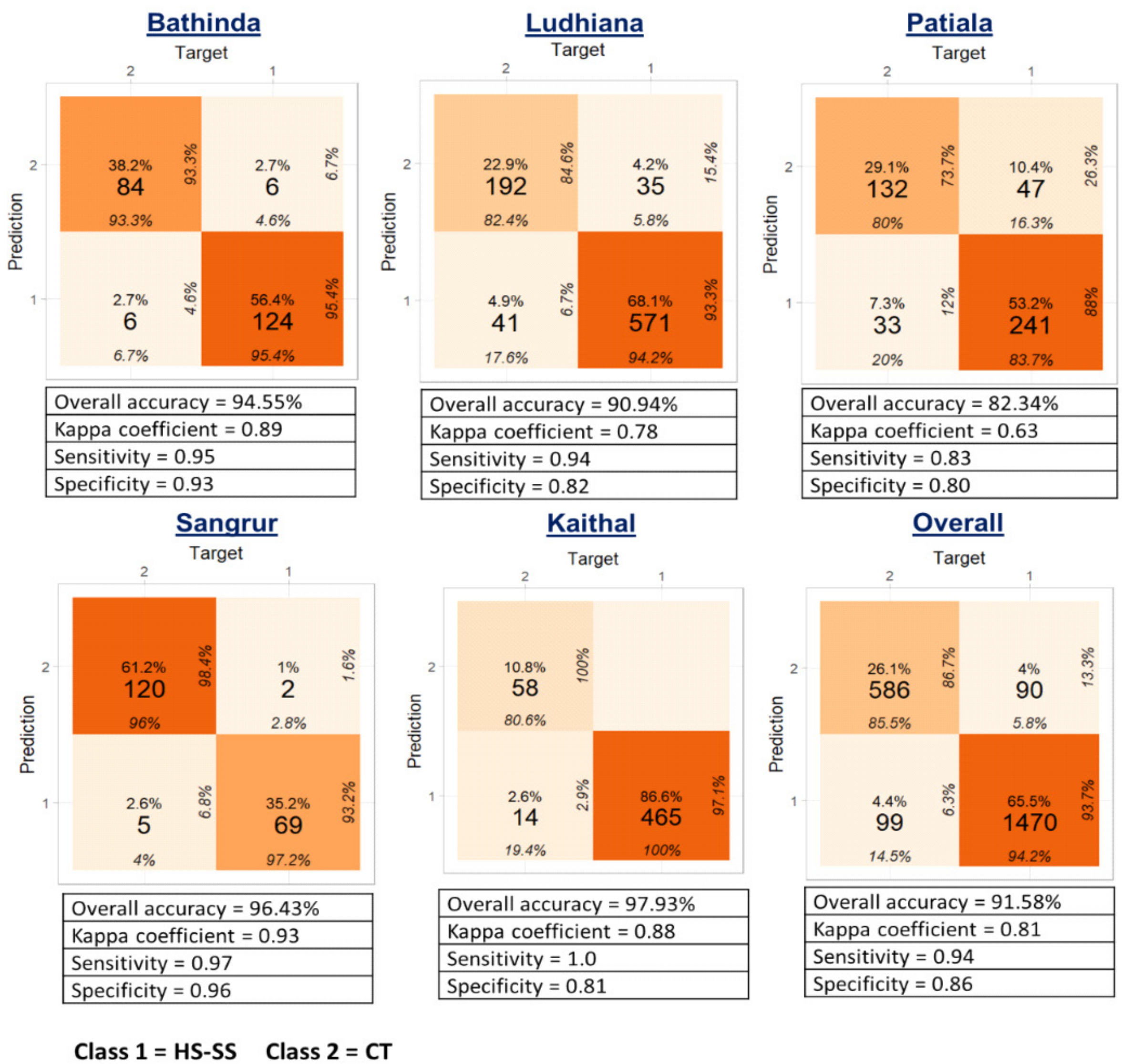
6.5.5 Remote Sensing and GIS

6.5.5.1 Operational monitoring of crop residue burning in india by satellites

The work on monitoring of burning of crop residue in North-West India on daily basis using thermal satellite remote sensing was operationalized during 2021-22. Daily bulletins on burning events of rice and wheat were disseminated to central and state government stakeholders. The bulletins and burning events maps were hosted on CREAMS Geoportal (http://creams.iari.res.in). A total 92047 rice burning events were detected in the six states between 15-Sept, 2021 and 30-Nov, 2021, which are distributed as 71304, 6987, 4242, 4, 1350 and 8160 in Punjab, Haryana, UP, Delhi, Rajasthan and MP, respectively. Total 56157 wheat burning events were detected in the five states between April 01, 2022 and May 31, 2022, which are distributed as 14511, 2878, 10981, 28, and 27759 in Punjab, Haryana, UP, Delhi, and MP, respectively.

6.5.5.2 Discrimination of conservation tillage practices in wheat using Sentinel-2 satellite

We developed a robust methodology for distinguishing Happy seeder and Super seeder (HS-SS) sown wheat from the conventional tillage (CT) during the early season using Sentinel-2 satellite data. The temporal profile of different spectral indices *viz.*, CARI, NDTI, NPV-NSSI, NDVI, BI, STI and NDSVI over sowing window were calculated. The combination of CARI to NDTI was identified as a suitable index

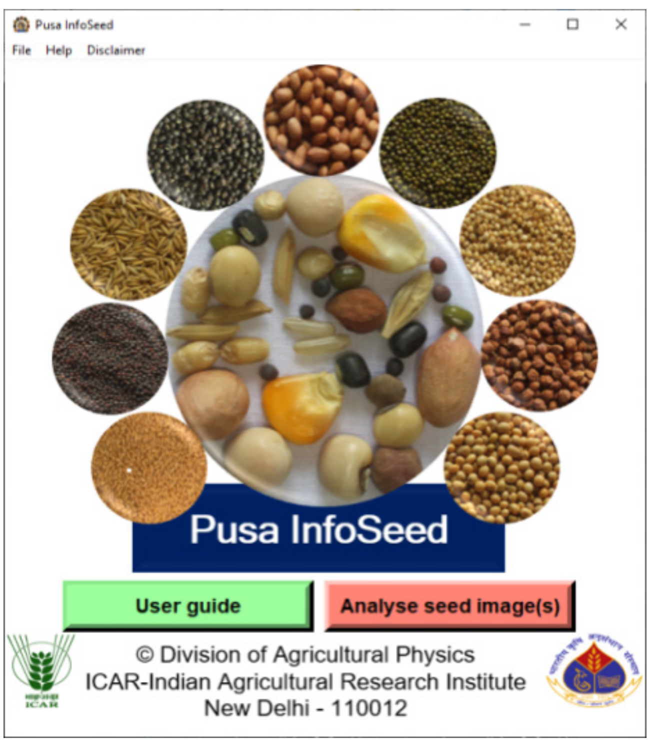


Confusion matrix and accuracy measures of tillage classification. In each confusion matrix, counts and overall percentage are represented in the middle, column percentage at the bottom and row percentage at the right side of the tile. Orange palette color intensity is based on the counts

for distinguishing between the two methods. The methodology was validated using ground truth collected in different districts of Punjab and Haryana. The algorithm used for classification of CT versus HS-SS performed well with an overall accuracy of 92% across the different districts of Punjab and Haryana. The overall Kappa coefficient was 0.81 indicating the robustness of algorithm in providing class agreements that were greater than chance occurrence.

6.5.5.3 Development of Pusa InfoSeed Ver. 1

Manual assessment of seed parameters (number of seeds per ear, seed size and shape) is laborious, time consuming and subject to sizeable human error and biases. An image-based software named "Pusa InfoSeed" was developed for assessing seed morphometry and phenotyping using machine learning algorithms. The "Pusa InfoSeed" software is a Windows-based desktop application which can work with the images of seeds for different crops. The software calculates the parameters like seed count, average seed length, test weight, specific seed weight, average seed width, one-sided seed surface area, roundness, hull area, solidity, equivalent diameter, eccentricity and frequency distribution of seed surface area from RGB images which can be captured by any ordinary smart phone or a digital camera.



Front end of 'Pusa Infoseed' software

6.5.5.4 Assessment of leaf nitrogen content using spectral data

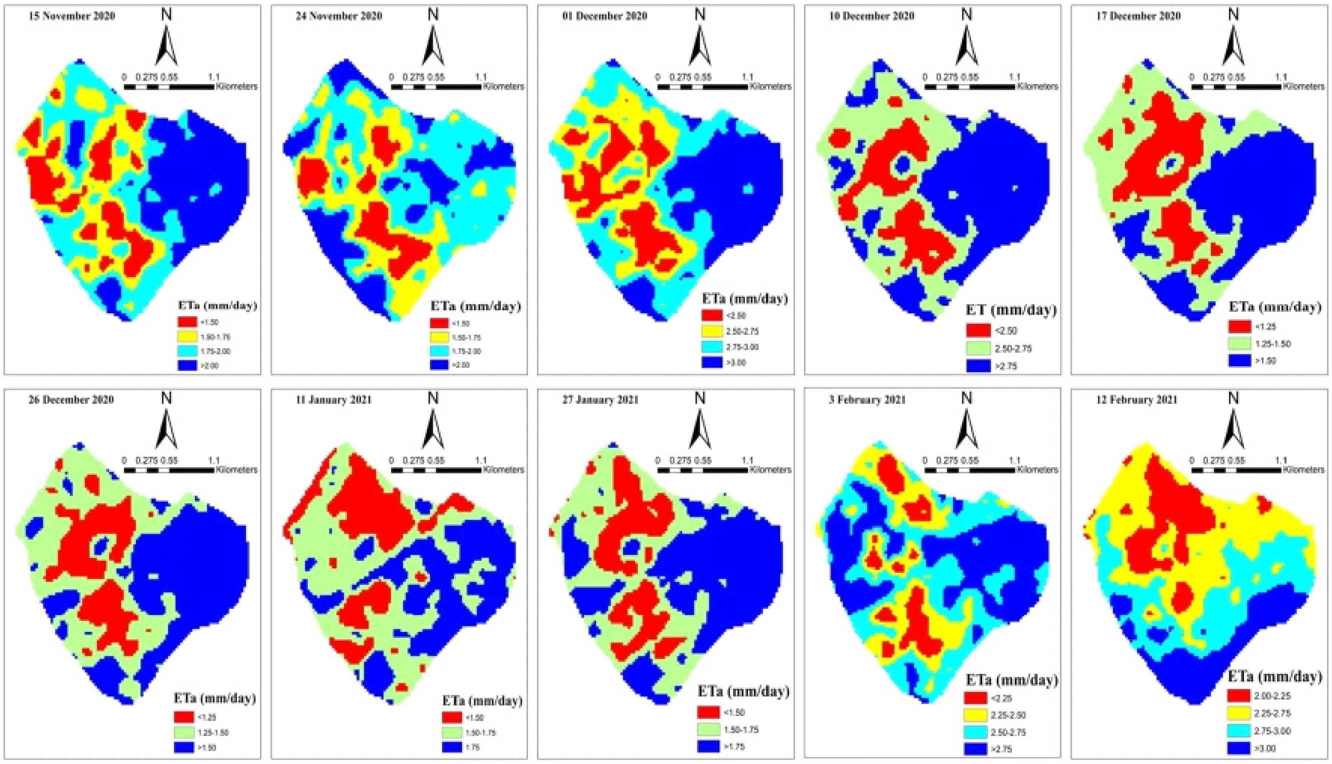
Collection of spectral signatures of wheat crop under varying levels of nitrogen application at different growth stages was undertaken using ASD spectroradiometric data and UAV acquired hyperspectral data. Synchronizing with spectral signature of leaf chlorophyll and leaf nitrogen content (LNC) was done. Four machine learning models (ANN, ELM, LASSO, SVR) were evaluated and implemented to predict and estimate leaf nitrogen content. The ANN performed well with R^2 values of 0.99 and 0.97 for calibration and validation phases, respectively. Stepwise MLR model was developed based on the following sensitive wavelengths, 399, 520, 668, 691,767, 774, 803, 827, 830, 848, 904, and 922 nm with R^2 value 0.967.

6.5.6 Agricultural Meteorology

6.5.6.1 Spatial estimation of evapotranspiration in wheat using remote sensing through surface energy balance approach

The operational simplified surface energy balance (SSEBop) model was used to estimate evapotranspiration of ICAR – IARI farm using Landsat – 8 (OLI) data. Field experiment on wheat (variety: HD 2967) was undertaken in experimental farm of ICAR - IARI during *rabi*, 2019-20 & 2020-21. In both seasons, homogeneous crop was grown and micrometeorological data were collected in which temperature, humidity, and wind speed sensors were installed at five different heights (0.5,1, 2 4 and 8 m) and net radiation and PAR sensors at 2 m height.

During active growing seasons, a rapid increase in crop height increased aerodynamic roughness. At the early stage, soil evaporation contributed of the latent



Estimated evapotranspiration loss by SSEBop model at different dates of cropping season of *rabi* wheat

heat flux due to less vegetation at sowing time. Rn and LE reached the highest value at midday with a 2 h time lag between the highest Rn of the day and the highest sensible and ground heat flux in the afternoon. The actual ET estimated using the SSEBop model could account for 82 to 83% of the variation of ET calculated by BREB method.

6.5.6.2 Machine learning for estimating reference evapotranspiration using meteorological data

Reference Evapotranspiration (ET_o) is a measure of evaporative demand of the atmosphere and helps in irrigation scheduling at critical stages of crop for hydrological and water resource planning and maximizing productivity. Daily weather data during wheat growing period (46^{th} to 15^{th} SMW) were collected for the period 1984 to 2022 for IARI, New Delhi and for the period of 1985 to 2018 for Hisar, and 1971-2017 for Amritsar, Patiala and Ludhiana. A model was developed for ETo estimation during wheat growing period by random forest (RF), support vector machine (SVR) and Artificial neural network (ANN) using different weather parameter combination. Based on evaluation of model's performance using standard statistical criteria during calibration and validation, RF performed best followed by SVM and ANN for all five stations. Based on ranking done using various standard statistical criteria, model developed by (Tmax, Tmin, RHM, RHE, Ws, Rs) weather input combination was ranked first for IARI, New Delhi and model developed by (Tmax, Tmin, RHM, RHE, Rs) weather input combination was ranked first for Hisar, Patiala, Ludhiana and Amritsar. Performance of the model developed for ET_o estimation by all three machine learning techniques using (RHM, RHE) and (Tmin, RHM) weather input combination was poorest as compared to other combination for all the five station. The ETo estimated by machine learning techniques using two weather input combination (Tmax, Rs) and (Tmin, Rs) performed excellent by RF and SVM and (Tmax, Tmin) by ANN for all the five stations.

6.5.6.3 Weather based agromet advisory

Weather based bilingual agromet advisory bulletin based on past weather, real time weather and weather forecast for forthcoming five days are prepared on two days (Tuesday and Friday) a week. These bulletins along with daily weather data and medium range weather forecast are uploaded on the Institute website (www.iari.res.in) and are also being sent through electronic media for wider dissemination among farmers and stake holders. The bulletin contains summary of previous week's weather along with normal weather data, value added medium range weather forecast information (for the next 5 days) and crop management which is based on decision tools and weather forecast. It gives a warning to the farmers regarding rainfall variation, its amount and other weather variables including pest/disease problems etc. so that farmers can make decisions about crop management, application of nutrients, irrigation scheduling, sowing, harvesting etc. During 2022, 105 bilingual agromet advisory bulletins were prepared and SMS regarding agromet advisory were sent through the m-Kisan portal.

6.5.6.4 Analysis of climatic conditions for desert locust (*Schistocerca gregaria*) invasion in India

Desert locust *Schistocerca gregaria* is an occasional, polyphagous, trans-border migratory pest. The role of extreme weather and cyclonic storm at Arabian Sea was studied for outbreak of desert locust by collecting data for last 50 years. Back-to-back cyclones in 2018 and 2019 led to development of low-pressure system in Mediterranean Sea facilitating breeding of locust in the Iranian desert followed by their migration to NW India during November to April. The amount of *rabi* season rainfall (306.5 mm in 2019-2020) and number of rainy days (18 days) also acted as a favourable factor for locust invasion.

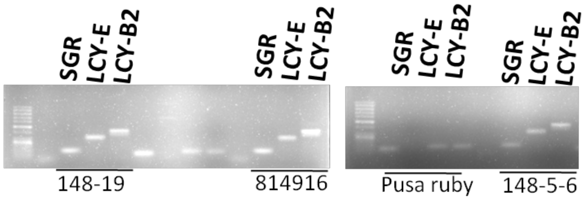
6.6 NATIONAL PHYTOTRON FACILITY (NPF)

The National Phytotron Facility facilitates experiments under controlled environmental facilities for scientists and scholars from various ICAR institutes and Universities. During 2022, 180 new experiments were accommodated along with a few on-going experiments. The NPF was visited by a number of domestic visitors along with delegation from National Commission for Scheduled Tribes, Govt. of India and foreign delegations from Nepal and Ethiopia.

Herbicide tolerant soybean plants in BC_1F_1 generation inside glass house of the Phytotron

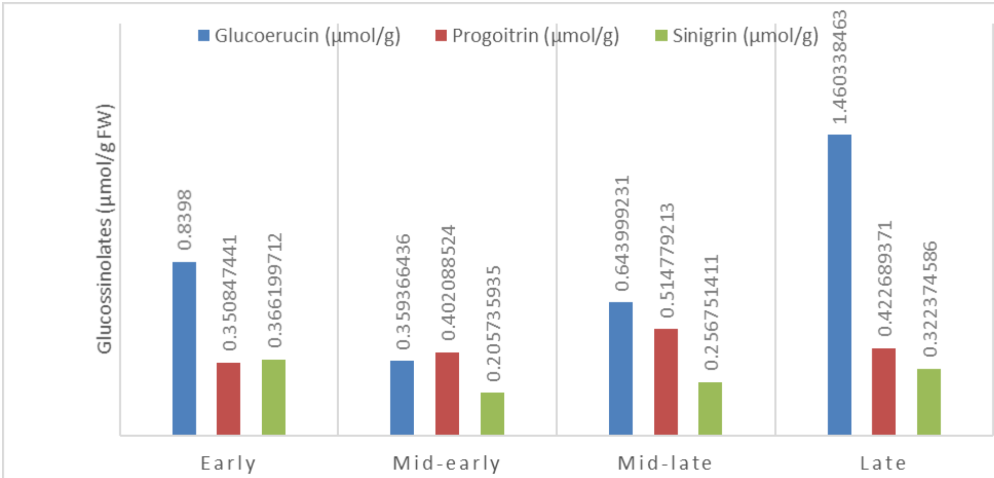
6.7 VEGETABLE SCIENCE

Characterization of carotenoid biosynthesis pathway genes in tomato and carrot genotypes: HRM analysis revealed variation in the sequences of LCYE, CCS, CRISTO and GGPS2 genes in the carrot genotypes with varying root color. The expression pattern of carotenoid biosynthesis genes like *lycopene ε-cyclase* (*LCY-E*), and *lycopene β-cyclase 2* (*LCY-B2*) was changed in different genotypes of both crops.



Gel picture showing amplicons of genes like *Stay Green (SGR)*, *lycopene ε-cyclase (LCY-E)* and *lycopene β-cyclase 2 (LCY-B2)* in tomato genotypes. (L: 1 kb)

Determination of glucosinolates in cauliflower: The UPLC-QToF-ESI-MS analysis of glucosinolates was performed in ten varieties of four maturity groups of cauliflower. Glucoerucin was found to be a prominent



Glucosinolate content in different maturity groups of cauliflower analysed using LC-MS

glucosinolate than sinigrin and progoitrin and was highest in Pusa Deepali (2.214 µmol/g FW).

Tropicalization of cabbage & broccoli: Evaluation of five $F_{2:3}$ progenies from Pusa Ageti (no chill type) × Golden Acre (chill type) showed head bursting phenotype. Biparental mating between F_2 plants recorded that two combinations (P10/P22; P4/P3) formed proper compact heads.

Characterization of Can CMS lines: Newly developed *Can* sterile cytoplasm carrying CMS lines was studied for heterosis and combining ability in early group of Indian cauliflower using line × tester design (6 CMS lines, 8 testers and 48 F_1 hybrids). CMS lines *Can* (DC-121), *Can* (DC-67) and *Can* (DC-63) were good combiners for curd yield and *Can* (DC-94-2), *Can* (DC-23) and *Can* (DC-8) for earliness.

***Genetics of Alternaria leaf spot (ALS) resistance in cauliflower and Brassica vegetables*:** Two populations (F14/DC-309, F14/C10) and [(Cauliflower-DC 351 × *Diplotaxisgomez-campoi* -WS-14)] × Cauliflower DC-351] were developed and used for screening for ALS. Plants having disease resistant and cauliflower-matching morphotypes were advanced to BC_2.

***Or* gene associated changes in PGRs and morphometrics in orange cauliflower:** Gibberellin content was found to be highest in white type plants while abscisic acid was the maximum in heterozygous type. The *Or* gene increased petiole length, reduced leaf size (44.7%), scar size (25.5%), curd size (89%), increased compaction in curd knobs, reduced knob length and overall plant frame.

Molecular characterization of different *Brassica species* and *Brassica napus* derived recombinant inbred lines for Black rot resistance and introgression of 'A' genome specific black rot resistance in cauliflower

Evaluation of *Brassica* species and *Brassica napus* derived recombinant inbred lines showed that 32 lines possessed resistance to black rot disease. Characterization using DNA markers linked to *Xcc* resistance revealed that SSR Na14-G02 present in B-7 genome could validate between parental lines of RILs (GSL-1 (S) and BN-2-1 (R) *Brassica napus*). The F_4 population carried a single dominant gene for *Xcc* resistance. Polymorphic survey was conducted between susceptible and resistant line using 'A' genome specific SSR markers. Inter-specific BC_1 hybrids between cauliflower (susceptible) variety (Pusa Meghna, Pusa Sharad) × *Brassica napus* (resistance- BN-2-1, BRS04, BRS08, BRS09) were raised and inoculated artificially with *Xcc* race 1, 4 and 6. Resistant BC_1 interspecific hybrids were backcrossed with cauliflower (Recovery parent, Pusa Meghna, Pusa Sharad, Broccoli) and BC_2 seed harvested and raised in field. DA, DB and DC sub-genome specific primers were used to detect sub-genomic fragments (A, B C) in alien introgression lines.

Mapping of genes for anthocyanin in brinjal: QTL-seq approach was used to select three putative genes namely *SMEL_003g186740.1, SMEL_009g333280.1 and SMEL_010g353630.1* for anthocyanin production in brinjal. Inheritance pattern of Phomopsis fruit rot resistance in the F_2 progeny derived from cross between Pusa Kranti and BR 40-7 was governed by two independent recessive genes with complementary epistasis and one major QTL associated with phomosis blight was identified.

Mapping of downy mildew resistance in cucumber and identification of genomic regions associated with resistance: Segregation of the F_2 and BC progenies of resistant (DC-70) and susceptible (DC-773) genotype for downy mildew revealed a major single recessive gene with modifiers or minor QTLs governed resistance to downy mildew. QTL-seq analysis established two major QTLs each in Chr. 3 and Chr. 6.

Molecular mapping of parthenopcarpy in cucumber: QTL-seq comprising of the early parthenocarpy and non-parthenocarpic bulks of cucumber along with the parental lines identified two major genomic regions, one each in chromosome 3 and chromosome 6 spanning over a region of 2.7 and 7.8 Mb, respectively. Conventional mapping using $F_{2:3}$ population also identified two QTLs, Parth6.1 and Parth6.2 in chromosome 6 which indicated the presence of a major effect QTL in chromosome 6 determining parthenocarpy in Pusa Parthenocarpic Cucumber-6 (PPC-6). The flanking markers, SSR01148 and SSR 01012 for Parth6.1 locus and SSR10476 and SSR 19174 for Parth6.2 locus were identified and can be used for introgression of parthenocarpy through the marker-assisted back-crossing programme. Functional annotation of the QTL-region identified two major genes, Csa_6G396640 and Csa_6G405890 designated as probable indole-3-pyruvate monooxygenase YUCCA11 and Auxin response factor 16, respectively, associated with auxin biosynthesis as potential candidate genes.

Marker assisted backcross introgression of gynoecious and parthenocarpic traits into elite lines of cucumber: BC_2F_1 and BC_3F_1 population were developed through foreground and back-ground selection for introgression of gynoecious traits into the elite cucumber genotypes, DC-48, DC-43 and Pusa Long Green. PPC-6 was used as donor and Pusa Uday and Pusa Long Green as recipient for introgression of parthenocarpy.

Molecular diversity and population structure analysis in vegetables: Diverse genotypes of bottle gourd, bitter gourd, garden pea were studied for their diversity and population structure. Out of the different SSR markers 16, 33 and 38 were found to be polymorphic in the three crops, respectively. Population structure analysis revealed six populations in both the gourds and four in garden pea.

Physiological and biochemical characterization for reproductive heat stress tolerance in garden pea: The average relative water content and greenness index was found to be 27.6 and 26.0% lower under heat stress compared to control in garden pea. Membrane stability (MSI) was positively correlated with yield parameters like NPP (0.52), PL (0.48), NSP (0.38), APW (0.38) and YPP (0.42). Plants responded to high temperature by increase in H_2O_2 and malondialdehyde (MDA) content compared to control.

Development and validation of EST-SSR markers using transcriptome data in okra: A total of 1,06,224 SSR loci were identified from the transcriptome assembly data of okra. The mononucleotide repeats were dominant with a frequency of 72.20% followed by trinucleotides 15% and dinucleotide 10.68%. In total, 183 primer pairs (156 di and 27 trinucleotides) were randomly selected for PCR validation. Overall, 23 pairs showed polymorphism among the 12 *Abelomoschus* samples accounting for 14.1% polymorphism percentage. Twelve okra accessions were used to assess the molecular diversity using these 23 EST SSR primers. The PIC values for 23 SSR markers ranged from 0.077 for (OSSR 60) to 0.649 for (OSSR138).

Development of goat web-genomic resource: Transcriptome based species-specific web resource of goat, CsE × SLDb (http://backlin.cabgrid.res.in/oyvmvtdb/index.php/) was developed with information related to assembled transcripts along with length, their putative function, locations on reference chromosome, BLAST details and the pathways associated. In addition to these, for DEGs, log_2FC (Log_2Fold Change) and FDR (False Discovery Rate) were also provided. The database contains 1,86,184 Transcripts, 1988 DEGs (distributed in 4 comparisons), 1278 Transcription Factors, 21,524 SSR and 1,58,301 variants and the database occupies ~102 Mb space.

Development of genomic resources in Onion and Garlic: In onion, 137 new genomic SSR markers mined from whole genome sequence were synthesized and used for diversity assessment. Out of these 45 SSRs markers amplified, 34 were monomorphic and 11 were polymorphic. In garlic, 9 SSRs out of 228 SSRs were identified and used for diversity assessment.

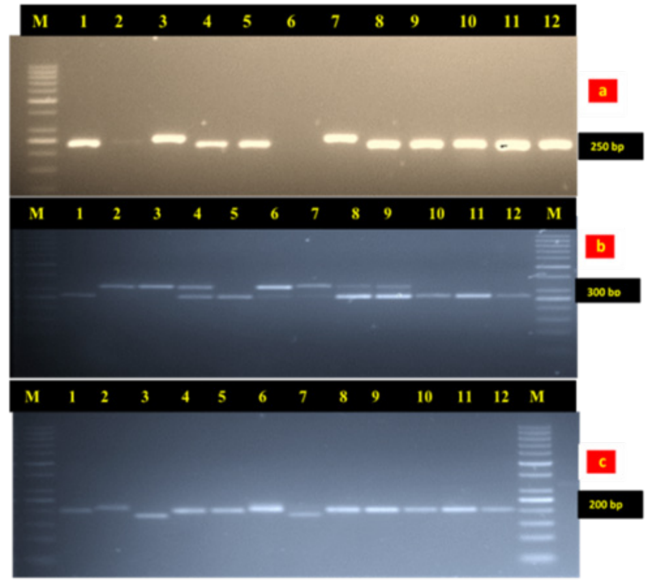


Figure: Representative gel photograph showing amplicons obtained from three okra SSR primers a) OSSR23 b) OSSR150 c) OSSR121 in 12 okra accessions.

7. SOCIAL SCIENCE AND TECHNOLOGY TRANSFER

The support of government programmes and schemes, technological interventions and capacity building have been crucial in socio-economic upliftment of rural poor. The School of Social Sciences carried out studies on assessment of e-NAM, KCC and ecosystem services support; initiated and evaluated Pusa Samachar as an innovative means of technology dissemination; undertook technological interventions for climate resilience and nutritional security; and mobilized groups for agripreneurship. The performance of improved varieties and technologies in OFTs and FLDs were assessed.

7.1 AGRICULTURAL ECONOMICS

7.1.1 Innovations in Agricultural Marketing and Institutional Arrangements for Enhancing Farmers' Income in India

- A study on e-NAM, an innovative approach to agricultural marketing, showed that only about 15 per cent of the APMC markets were linked with this platform and farmers' participation rate was around 13 per cent. The major commodities traded are cereals, which account for nearly 40 per cent of total volume and 25 per cent of the value of trade in 2020-21. The trade concentration analysis also indicated that selected states only were actively participating in e-NAM. It was found that the e-NAM prices were significantly lower than the Agmark.net prices in most commodities in the majority of the states. Only a very few states recorded the higher prices in some commodities. A very little amount of total production is being traded through e-NAM (1.6% of total food grain production and 2.3% of paddy production). The inter-marketing trade is almost negligible, which could be one of the reasons for not increasing the competition and achieving better price realization under e-NAM.
- The factors determining farmers' choice of market was analyzed by the multinomial logit model. The local market received the highest share in selected crops, except sugarcane. A detailed analysis of the market choice of paddy farmers showed that, out of 24355 farmers who reported production of paddy, 46 per cent farmers preferred selling to local traders. Contrastingly, the price realized in the local market is less than the MSP. Further, it was found that the small and marginal farmers and farmers belonging to the disadvantaged section of the society like SC/ST farmers prefer local traders over APMCs. MSP awareness is a critical factor that encourages farmers to sell to APMCs. The parameter estimates multinomial treatment effects of choosing a value chain on the price realized. The analysis indicated that the farmers selling to APMC realized 27 per cent more sale value in comparison to the farmers selling to local traders.
- India is considered as one of the important destinations of foreign direct investment (FDI) among developing economies. The spillover effect of FDI on the Indian food processing industry was studied using random effect panel regression model, which indicated a positive relationship between the productivity and FDI spillovers in the Indian FPI. The effect was significant within industry and is also known as the horizontal spillover effect. There is also an indication of the positive vertical spillover effect through the backward linkages, but such effects were absent in forward vertical spillover. The pattern of FDI inflow into the FPI in recent times indicated increased contribution through the automatic route, largely from the developing countries.

- Fresh and processed fruits constitute around four per cent of the India's total agricultural export during TE 2019-20. Export of fresh and processed food has registered a growth rate of nine per cent and five per cent, respectively, for the period 2009-10 to 2020-21. India has higher relative rejection rate (RRR) of fruits in Australia compared to China, while China has higher RRR of fruits in EU and USA as compared to India.

7.1.2 Exploring linkages of agricultural production systems and ecosystem services for sustainability

Crop residue management using Happy Seeder: A primary survey in Karnal, Haryana indicated that 49 per cent of the sampled farmer adopted Happy seeder. The happy seeder adopter farmers incurred lower input costs and total cost in cultivation (Cost C3) in wheat than that of non-adopters and realized more yield of about four q/ha. Income over Cost A2+family labour was also found to be more in all categories of happy seeder adopter farms in comparison to non-adopter farms. A partial budgeting analysis also showed that happy seeder adopters gained additional average net revenue amounting to ₹ 12,210/-, which can be attributed to yield gains and expenditure reduction. The technical efficiency in wheat cultivation was also obtained using double bootstrapped DEA, and found that the average technical efficiency score of adopters (0.987) was higher than that of non-adopters.

Assessment of risk in the cultivation of millets in major states: In India, the area of millets is on the decline, and this decline is not compensated by the rise in productivity except in bajra. In this context, a study was undertaken to examine the risk in millet production using all India-level data on yield. The study considered all the millets such as bajra, jowar, ragi, and small millets. Expected yield loss and monetary value of expected yield loss were estimated to represent the risk in physical and monetary terms. Major millet-producing states were categorized into high, medium, and low-level risk categories so that state-specific programs may be framed to stabilize the yield.

Role of WUA in technical efficiency of farmers in Andhra Pradesh: In this study, a bootstrapping DEA model with an input orientation was employed across 216 observations. The level of technical efficiency of the rice production activities tended to increase in the study area, while optimal scale efficiency was only achieved by a small number of farms. Scale efficiency scores changed approximately by 90%, and the proportion of those achieving increasing returns to scale was high. Using a truncated regression, the main inefficiency factors could be linked to the demographic characteristics of the households, as well as the proportion of income from rice as a proportion of total household income.

The linkage between electricity consumption and agriculture growth: The long-run co-movement and the causal relationship between electricity consumption and real gross state domestic product (GSDP) from agriculture and its allied sectors was examined empirically. When the heterogeneous states effect is taken into account, the empirical results fully support a positive long-run co-integrated connection between GSDP and electricity consumption. It could detect both long-run and short-run unidirectional causality running from electricity consumption to agricultural growth. Further electricity consumption was also found to augment the use of technology factors in agriculture. This calls for implementing policies and strategies for achieving higher electricity use in agriculture and improved efficiency in its utilization simultaneously.

Major drivers of chemical fertilizer usage: The determinants of chemical fertilizer expenditure in rice and wheat crops in India using 77th round of NSS data on "Land and Livestock Holdings of Households and Situation Assessment of Agricultural Households" were identified. A censored regression model, Tobit, was used to estimate the determinants since not all farmers used chemical fertilizers. The data collected from 14921 paddy farmers from January-August 2019 and 7294 wheat farmers from September-December 2019 are used in the analysis. While the fertilizer expenditure for paddy is determined by the socio-economic variables and paid-out expenditures on the inputs and services, in the case of wheat and the farmers growing both paddy and wheat, the socio-economic variables did not significantly affect it. Further, climatic variables like rainfall, maximum and minimum temperatures are crucial determinants in wheat cultivation.

Impact of public intervention efforts for conservation of paddy ecosystems in Wayanad district of Kerala: A study was undertaken to examine the dynamics of shifting cropping patterns in the state of Kerala, India, and evaluate the role of public interventions in conserving paddy ecosystems in the state. The cropping pattern of Kerala witnessed a shift from paddy to cash crops. Owing to the low profitability of paddy farming in the state, paddy ecosystems were converted on a large scale. The resultant twin issues of falling agricultural growth and ecological disturbance thus prompted the Government of Kerala to enact the 'Kerala Conservation of Paddy Land and Wetland Act' in 2008. Structural break analysis revealed that the Act could significantly arrest reduction in paddy land area in Kerala to an extent of 11, 253 ha annually. Hence, the findings reflect on the scope of public interventions in conserving important agro ecosystems.

Ecosystem services delivered by Eastern Yamuna canal in Western Uttar Pradesh: With the existence of Eastern Yamuna canal, farmers drafted nearly 85 million cubic meter (MCM) lesser groundwater compared to without the canal existence. Total value of reduced irrigation hours due to lesser pumping hours with electric and diesel (average), estimated to ₹158 million with existence of canal. Canal water added 598 MCM of water to aquifer with its recharging capacity, which is worth ₹108-299 million. A comprehensive accounting of all the benefits delivered by EYC to the ecosystem in its command area shows that canal generates minimum monetary worth more than its working expenses. Anchoring on average statistics, EYC renders ecosystem services of monetary value ₹1122.86 million, which is nearly 48.27 per cent higher than its working expenses.

Child & Adult malnutrition landscape & linkages between malnutrition and agriculture: Based on district-level National Family Health Survey (NFHS, 2015-16 & 2019-20) data, the prevalence of malnutrition among children and adults in rural India was investigated. The child malnutrition index was constructed by taking into account the prevalence of stunting, wasting and underweight among children under-five whereas two indicators i.e. thin men and thin women were used to construct adult malnutrition index. The determinants of malnutrition revealed that improved food grains productivity along with diversity in food consumption basket as measured by increased pulses in the diet showed a reduction in the incidence of malnutrition (stunting and wasting) in the children.

Meta-analysis of impact of bio-fortification on health and nutritional outcome: A systematic review and meta-analysis were conducted to analyze the impact of bio-fortification on health and nutritional outcome. A structured literature search was conducted in databases like Web of Science, Google Scholar, AgEcon Search and CeRA -J gate for the period 2000-2021. Out of 1404 studies identified, 28 studies were selected for systematic review, out of which 12 studies were found desirable for meta-analysis. The meta-analysis suggested that consumption of iron bio-fortified crops would increase the iron content on an average of 0.09 g/dl in women and children. Consumption of Vitamin A and Zinc bio-fortified crops will increase the serum retinol and plasma zinc level on an average by 0.66 µg/dl in women and children. These results reiterate the importance of bio-fortification programs and help to determine the future course of action.

7.2. AGRICULTURAL EXTENSION

7.2.1 Evaluation of Farmer-centric Government Schemes and Programmes for Agricultural Extension Policy Advocacy

PUSA SAMACHAR: Multimedia based innovative extension model: Video based extension initiative in form of 'Pusa Samachar' was launched on August

15, 2020 to disseminate and educate the farmers and other stakeholders about the latest technologies and seasonal cultural practices. Every Saturday at 7 PM a new episode is uploaded at IARI official YouTube channel. A total of 230 episodes of Pusa Samachar in Hindi, Telugu, Kannada, Tamil, Bangla and Oriya were broadcasted among the farmers through You Tube channels as well as whatsapp groups. One dedicated Pusa WhatsApp number (9560297502) has been launched, in which farmers send their farm problems with pictures and scientists reply promptly. There are 29,300 subscribers of IARI YouTube Channel with total viewership of more than 9 lakhs. In every episode time specific crop management practices, successful farmers' stories, Pusa WhatsApp salah and weather broadcast are given. Content Analysis of 93 episodes of Pusa Samachar (Hindi) was done. A total of 274 topics were covered in 17 different disciplines/areas including farmers' success stories. Disciplines wise topic coverage included: Agronomy (21.15%), Genetics (16.60%), Plant Pathology (10.90%), Vegetable Sciences (25.34%), Horticulture (7.15%), Entomology (4.16) Protected Cultivation (2.33%), Agricultural Engineering (3.12%), Microbiology (2.77%), Soil Science (1.06%), Economics (1.15%), Floriculture (1.01%), Student based Topic/ Career (0.28%), Biochemistry (2.07%), Agricultural Chemicals (0.16%) and Success stories of Farmers (0.75%).

Devising Extension Approaches for Climate Change Adaptation

Social learning approach helped the farmers to adopt climate resilient technologies like direct seeded rice, zero-till wheat, summer moong and IPM in cotton in Mewat, Haryana. About 32 demonstrtaions of DSR and 108 demonstrations of zero till wheat were laid out in Bihar (Gaya) and Haryana (Mewat and Gurugram). Though the farmers secured 2.64 per cent higher yield under transplanted system of paddy cultivation, the benefit: cost ratio was 18.6 per cent higher in case of direct seeded system as there was 22.24 per cent saving in cost of cultivation. IARI wheat variety HD 2967 performed better in zero-till system and the farmers secured higher benefit cost ratio in zero-tillage wheat (2.71) in comparison to conventional system (1.25). Convergence based extension approach helped to construct one additional check bund in adopted village-Dohari in Gaya (Bihar) with people's collective contribution of 10 per cent cost of the bund in terms of labour. It led to availability of one irrigation in 15 acres of additional land. Pusa *Kisan Vikas Samiti* has been formed with 35 farmers to manage the interventions. The impact of climate smart village was assessed in Jalpaiguri, West Bengal. The adoption of different climate resilient cropping system like pulse based cropping system has increased from 11.25 per cent in 2015 to 52.50 per cent in 2020. The number of farmers who changed their planting or sowing time of crops to adapt with changing climate increased from 24.50 per cent to 53.75 per cent. Earlier only 19.75 per cent farmers were cultivating any climate smart crops as an adaptive measure. But now almost half of the farming communities (46.50%) adopted different climate smart crops to cope up with changing climate. The intervention of land shaping (20%) i.e. the low land converted into medium land by using the soil excavated from the pond, gave 4.3 q/ha more yield of paddy over farmer's practice in Kaikhali and Bongheri villages of Sunderbans in West Bengal. Availing the opportunity to grow vegetables and pulse crops by using the water stored in the pond, the farmers could secure higher net income (₹ 49449 ha^{-1}) as compared to the farmers' practice with traditional rice-fallow system under low land (₹ 4884 ha^{-1}).

Magel Tyala Shet Tale **–'Farm Pond on Demand" scheme of Maharashtra:** *Magel Tyala Shet Tale* –'Farm Pond on Demand" scheme was launched in February 2016 by the State Agriculture Department in Maharashtra with the objective of assuring each and every farmer, a permanent source of water. Socio-economic assessment of the scheme was carried out in Vidharbha and Marathawada regions of Maharashtra with a sample size of 320 farmers. It was found that the cultivated land utilization index of major crops increased after the adoption of farm ponds from 0.22 to 0.67. The benefit- cost effectiveness increased from 17.27 to 48.83 per cent. The main reasons to discontinue the farm pond were identified as draining of bore well/ well to store water in farm pond; lesser life span of farm pond due to low quality material used for construction and maintenance of farm pond after taking subsidy being non- mandatory.

7.2.2 Converging Agripreneurship, Farmers' Innovations and Modern Technologies

More returns from farms by utilizing farmers' innovativeness, practical wisdom in combination with modern technologies and effective marketing is visualized to result in profits for farmers. Promotion of agri-entrepreneurship in rural areas and inculcating skills to efficiently market their produce has emerged as the key for transforming agricultural sector and enhance farmers' profits. Keeping this in view, an action research study was taken up to develop a business model for small farm holders to make farming remunerative.

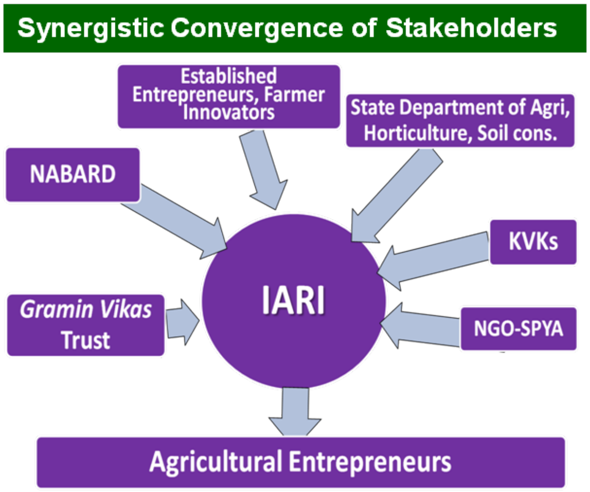
Farmer Led Innovations: Lessons learnt: Case studies of Farmer Led Innovations (FLIs) were conducted to draw lessons for developing agripreneurship. Based on learnings derived from case studies of innovator farmers; testing of agripreneurship process model was developed and tested in project villages of NCR Delhi. Agriprenurship process was found to be a dynamic function of personal entrepreneurial competencies (PECs) of individuals and entrepreneurial climate to establish and attain entrepreneurial success. PECs like innovativeness, business orientation, moderate risk bearing, opportunity recognition, drive for excellence and effective networking were found to be in dynamic interplay with entrepreneurial climate like government schemes, availability of technical guidance, availability of credit and infrastructural ease to reach successful agripreneurship development.

Action Research on Agripreneurship: Prioritisation and implementation of IARI technologies for Agrienterprise ventures uptake based on location and farmers' needs in a participatory mode were taken up. Technological innovations of IARI and few other ICAR institutes were promoted in project villages for enterprise uptake based on microscreening and training need assessment. Mentoring and handholding of nascent entrepreneurs in project villages was done. Linking the trained farmers and farm women was done with marketing agencies. Ten trainings on durum wheat processing and entrepreneurship development were conducted in Indore regional station, eighteen short trainings on wheat seed production were conducted and six villages were developed as wheat seed villages. Developed 25 wheat farmers of six villages from Dewas, Indore and Dhar districts as wheat seed entrepreneurs during 2021-22.

Mobilization for collectivisation of farmers: Two Farmer Producer Companies (FPCs) were established with 100 members each and four women SHGs were formed in project villages in collaboration with NABARD. One farmer already linked with IARI for commercial seed production through participatory seed production programme has been facilitated to continue the programme. Factors facilitating establishment of FPCs were documented.

Convergence model

Synergistic collaborations of strengths of each stakeholder resulted in agri-enterprise uptake in project village.



Infrastructure and location were found to have a substantial influence on the creation of linkages for smooth functioning of nascent agri-ventures launched in project villages. Credit availability limitations were found to be hindering forward linkages whereas poor infrastructure limited the opportunities for establishing linkages. Rural areas close to towns were found to have greater farm/ non-farm linkages. Most of the agri-entrepreneurs were found to be utilizing their non-formal or social linkages for establishing business networks. Formal networks were not utilized usually.

7.2.3 Agricultural Extension for Nutrition and Health (AE4NH)-Strategies and Models

Household level food consumption data from NSS 68th round survey and key nutritional indicators from NFHS 2019-20 data of 71 districts of Uttar Pradesh state have been compiled to examine the empirical connection between dietary diversity and nutritional outcomes. In terms of underweight among children, Sant Ravidas Nagar, Jaunpur & Bijnor districts performed better and districts Deoria, Banda & Ballia performed worst. In women underweight nutrition incidence, Maharajganj, Sonbhadra & Bareilly were better performing districts and worst performing districts were Saharanpur, Chandauli & Mahoba. Linkages between Dietary Diversity and Nutritional Outcomes were empirically studied by employing panel regression analysis random effect model. A negative relationship between the degree of variety in food consumption and under nutrition was observed. A negative and significant relationship was observed between under nutrition incidence, women literacy and health insurance. Further, the results revealed that households' access to drinking water, sanitation facilities significantly improved the nutrition security. The results of impact study on nutri sensitive agricultural (NSA) interventions on households' (HHs) nutrition security with a sample size of 350 randomly selected rural HHs from Baghpat and Sonipat districts revealed that HHs with participation (treated) in NSA interventions had higher Household Food Consumption Score (HFCS) than the non-participated (control) HHs. The difference in HFCS between treated and control households were 70.77 and 56.96 for nearest neighbour matching methods and it was statistically significant at five per cent level.

7.2.4 RS Pusa Bihar

7.2.4.1 Field demonstration

FLDs of chickpea were organized in Samastipur district of Bihar to popularize the Conservation Agriculture technologies and pulse integrations in cereal based cropping system. Different varieties of wheat and paddy have been distributed to the farmers of different districts of Bihar.

7.2.4.2 Achievement of *Rabi* 2021-22 wheat demonstration under IARI outreach programme

In *rabi* 2021-22, with a goal to popularize IARI wheat varieties among farmers under the IARI Outreach Programme, a total of 520 minikits demonstrations of five timely sown wheat varieties (HD 2967, HD 3226, HD 2733, HD 3249, CSW-18) and five late sown wheat varieties HD 2985, HD 3118, HI 1563, HD 3171 and HD 1621 were laid out in 13 districts of Bihar and Jharkhand through KVKs. The results were very encouraging and farmers showed interest to grow new wheat varieties. All the varieties performed well in all the districts of the two States. Among all the varieties tested, HD 2967 performed well and yielded on par with other varieties. HD 1621 performed well among late sown varieties of wheat. In some villages and part of Jharkhand and West Bengal, HI 1563 and HD 2985 performed well and are becoming popular. Although, HD 2733 is 20 years old variety, it is popular and preferred by the farmers due to high yield, good chapatti making quality and low water requirement.

Even today there are several villages in the remote corners of Eastern India where improved agricultural technologies have not reached. It is true that the improved high yielding varieties i.e. timely sown wheat varieties *viz*. HD 2967, HD 3226, HD 2733, HD 3249, CSW-18 and late sown wheat varieties *viz*. HD 2985, HD 3118, HI 1563, HD 3171 and HD 1621 are suitable to the specific agro-climatic condition and produce higher than other traditional varieties.

7.2.4.3 Exhibition and Participation in *Kisan Mela*

IARI actively participated in three days *Kisan Mela* on March 12-14, 2022 at Dr. Rajendra Prasad Central Agricultural University, Pusa Bihar. The varieties of wheat, paddy, moong and papaya were demonstrated at the IARI stall. More than 1000 farmers and visitors paid visit to the stalls and got agricultural advisory services and benefitted with IARI technologies.

- A field day was organized at 'Borlaug Institute for South Asia' during March 05, 2022 at farm Harpur, Pusa Samastipur district, Bihar.
- Actively participated in three days *Kisan Mela* on February 25-27, 2022, Bagvani Mahotasav -2022, Horticulture Department, Bihar Government, Patna.
- Actively participated in one day *Kisan Mela* on March 15, 2022 at Parivartan Non Government Organization, Ziradei, Shiwan , Bihar.
- Detail information about agriculture was given to the farmers during scientists-farmers interactions at our station as well as in any other events related to farmers.
- Day to day farm advisory services were given to farmers over mobile phone about package of practices of different crops.

7.2.5 RS Indore

7.2.5.1 Institute wheat demonstrations of latest varieties *rabi* 2021-22

Sixteen demonstrations of seven new wheat varieties (HI 8802, HI 8805, HI 8823, HI 1605, HI 8759, HI 1634 and HI 1636) with recommended package of practices were conducted in 4 villages i.e. Donta Jagir, Sakri, Bhatoni and Naru Kheri of Maksi Block, District Dewas, M.P., on 7.7 hectares area (0.48 ha average demonstration). Average yield recorded was 49.13 q/ha in these demonstrations against 37.81 q/ha in check varieties. Increase in yield was 11.3 q/ha or 30.04% in these demonstrations compared with 4 check varieties grown with farmers' own practices.

7.2.5.2 Wheat, soybean and maize demonstrations in Tribal Area (TSP)

A total of 31 demonstrations of nine new wheat varieties (HI 8802, HI 8805, HI 8823, HI 1605, HI 1544, HI 8663, HI 8737, HI 8759 and HI 1634) with recommended package of practices were conducted in four tribal villages i.e. Sherkund, Sejgarh and Gokalyakund of block Manpur, Distt. Indore and village Kagdipura of Nalcha block, district Dhar M.P. on 11.95 hectares area (0.38 ha average demonstration). The average yield of test varieties was 39.94 q/ha against 21.81 q/ha in check varieties.

During *kharif*, 2021 soybean demonstrations of latest soybean varieties (JS 2034 and JS 2069) on 5.25 hectares area (0.25 ha average demonstration) and 25 maize demonstrations of two hybrid varieties (Super-82, and Kanak) on 6.25 hectares area (0.25 ha average demonstration) were conducted in above villages. Average yield of soybean was 10.40 q/ha in these demonstrations against 7.50 q/ha check yield. Increase in yield was 2.87 q/ha or 41.6% in these demonstrations compared with three check varieties i.e. JS 335, JS 9305, JS 9560 grown with farmers' practices. The average yield of maize was 26.20 q/ha in these demonstrations against 12.20 q/ha check yield. Increase in yield was 14 q/ha or 117% in the demonstrations compared with local check varieties grown with farmers' own practices.

7.2.5.3 Vegetables Minikit (Okra, Brinjal, Sponge Gourd, Tomato, Spinach, Bottle Gourd, Bitter Gourd) Demonstrations under TSP

A total of 60 vegetables minikit demonstrations for (40 females and 20 males) were conducted in five tribal villages *i.e.* Sherkund, Sejgadh, Gokliyakund, of Manpur block, District Indore and Jirapura & Kagdipura of Nalcha block District Dhar, M.P. on 7.2 hectare area (0.12 ha. average demonstration). Average number of pickings per family was 12.5 with average monetary value in local market equivalent to ₹ 376/- during the season.

7.2.6 RS Kalimpong

7.2.6.1 Development of innovative agricultural extension models project

Institutionalization and out-scaling of IARI-Post Office Linkage Extension Model

- The improved IARI technologies of rice (PS-5, Dhiren, MTU 7029), mustard (PM-26, PM 30 and Pusa vijay) were promoted in Darjeeling, Kalimpong and Jalpaiguri district of West Bengal. The average yield ranged between 42-48 q/ha for PS-5 variety of paddy.
- The impact of IARI-Post office linkage extension model was assessed in three districts using PSM method with a sample of 1000 farmers (500 treated and 500 control). The finding revealed that the treatment i.e. participation in IARI-Post office model had significant impact $p<.01$ on enhancing yield of rice and mustard crop in the region.

Devising Extension Approaches for Climate Change Adaptation and Livelihoods Security

- The impact of climate smart village was assessed. The adoption of different climate resilient cropping system like pulse based cropping system has increased from 13% in 2015 to 38% in 2021. The number of farmers who changed their planting or sowing time of crops to adapt with changing climate increased from 24.50 to 53.75%. Earlier only 23.50% farmers cultivated climate smart crops as an adaptive measure. Presently more than half of the farming communities (57.50%) adopted different climate smart crops to cope up with changing climate. Similarly, the adoption of other climate smart technologies like climate smart varieties (PS-5, Swarna sub-I of paddy; cultivation of pulses (Arhar, Moong), Pusa Vishal of green gram; PM 26, PM28, and PM 30 of Mustard), line sowing (62.50%), zero tillage (52.50%), DSR (45%), intercropping (67.50%), mulching (56.25%), IPM (58.75%) , INM (47.50%) were also adopted.

Analysis of ICT based extension approaches

One android based mobile app namely Darjeeling mandarin was developed using react native language for providing digital agro-advisory services. Google fire data base was used in the backend.

Mobile App on Darjeeling Mandarin

7.2.6.2 Nutrition education for enhancing nutrition security and gender empowerment

- The nutritious vegetable varieties like red cabbage (Red Jewel), carrot (Sahiba, Sachi), cucumber (ADV 268, Nalini-F1), bottle gourd (Meghdoot, Vinayak F1), bitter gourd (Palee F1, Harithwa, NHBI-2009 F1), fenugreek (Methi, PEB), cow pea (Pusa Sukamal), leafy vegetables kale (Pusa kale 64), lettuce (Great lakes), spinach (OP) were promoted in Darjeeling district and Jalpaiguri district of West Bengal.
- Off-season nutritious red cabbage cultivation became highly popular in Lava hills of Kalimpong. The farmer namely Gyanendra Rai reported that he earned ₹1.80 lakh from 0.5 acre land as against ₹0.70 lakh from normal green cabbage cultivation.

7.3. TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Outscaling Agricultural Innovations for Enhancing Farm Income and Employment

***Rabi* 2021-22:** The performance of location-specific improved varieties of wheat, mustard, chickpea, lentil, carrot, and palak was assessed through 349 trials over an area of 119.37 ha during *Rabi* 2021-22. The feedback on IARI varieties from the various locations is as follows:

- At Nidana (Rohtak, Haryana), the yield of wheat varieties in timely sown condition, HD 2967 (4.65 t/ha), HD 3086 (4.53 t/ha) and HD 3226 (4.46 t/ha) was higher than local cultivar (WH 711, 4.0 t/ha).
- The average yield of late-sown wheat varieties HD 3298 and HD 3271 was 4.70 t/ha and 4.75 t/ha, respectively in Maholi, Palwal (Haryana).
- At Bhagwanpur Chittawan (U.P.), among four timely sown wheat varieties, the highest average yield was recorded in HD 3237 (5.1 t/ha), followed by HD 3086 (4.88 t/ha), HD 3226 (4.65 t/ha) and HD 2967 (4.47 t/ha) as compared to local check DBW 303 (3.8 t/ha).
- At Basoli, Baraut (U.P.), among four timely sown wheat varieties, the highest average yield was recorded in HD 3226 (4.86 t/ha), followed by HD 2967 (4.84 t/ha), HD 3237 (4.65 t/ha) and HD 3086 (4.53 t/ha) compared to local check DBW 303 (4.0 t/ha).

***Kharif* 2021:** During *Kharif* 2021, a total of 303 assessment trials were conducted at villages Nidana (Rohtak), Maholi (Palwal, Haryana) and Bhagwanpur (Meerut, UP). Eleven paddy varieties, four pulse crops, including one of moong Bean (Pusa Vishal) and three arhar varieties (Pusa 991, Pusa 992, Pusa 16) and vegetable varieties covered an area of 104.48 ha. The results are presented as under

- The highest average yield of PB-1692 (6.0 t/ha), followed by PB-1718 (5.11 t/ha), was recorded at Nidana, Rohtak, followed by Pusa 2511 (4.96 t/ha) at Maholi, Palwal and PB-1509 (4.96 t/ha) and Pusa-1121 (4.86 t/ha) at Nidana, Rohtak.
- Pusa 1431 yielded 0.65 tonnes per ha at Nidana, Rohtak, whereas, at Maholi Pusa Vishal, P-1431and Pusa-9531 yielded 1.35, 1.57 and 1.47 tonnes per ha, respectively, which was observed as an increase of 8, 26 and 17.52 per cent over the yield of the local check.
- For PB-1509, the increased net return was ₹17912 and ₹ 36482 at Maholi and Bhagwanpur Chittawan, respectively; for PB-1692, the increased net return was ₹35905 at Nidana and ₹ 39150 at Maholi.
- Pusa 1431 yielded 0.65 tonnes per ha at Nidana, Rohtak, whereas, at Maholi, Pusa Vishal, P-1431 and Pusa-9531 yielded 1.35, 1.57 and 1.47 tonnes per ha, respectively, which was an increase of 8, 26 and 17.52 per cent over the local check.
- For PB-1509, the increased net return was ₹17912 and ₹36482 at Maholi and Bhagwanpur Chittawan, respectively; for PB-1692, the increased net return was ₹35905 at Nidana and ₹ 39150 at Maholi.
- The paddy varieties Pusa 2521 and PB-1401 fetched an extra net return of ₹ 4350 and ₹11200, respectively, over a local check at Maholi (Palwal, Haryana). Moong varieties Pusa Vishal and Pusa -1431 recorded extra net returns of ₹ 7000, ₹ 9576, ₹ 22750 and ₹ 6120, respectively, at Maholi, Palwal and Bhagwanpur Chittawan, Meerut, respectively. For Pusa 9531, it was recorded to be ₹15330 at Maholi.
- The okra variety Pusa Bhindi 5 recorded the highest yield of 13.25 t/ha at Bhagwanpur, 11.8 t/ha at Nidana and 12.5 t/ha at Maholi. Bottle gourd Pusa Naveen yielded 24.2 t/ha, 22.5 t/ha and 22.0 t/ha at Bhagwanpur, Nidana and Maholi, respectively. Sponge gourd, Pusa Sneha yielded 17.2 t/ha and 155 q at Bhagwanpur, and Maholi and brinjal Pusa Uttam yielded 31.5 t/ha and 26.5 t/ha at Maholi and Nidana of Haryana, respectively.

7.3.2: Technology integration and transfer to strengthen the farming system in partnership mode

The partnership project is being implemented with selected ICAR Institutes/ SAUs/V.O.s in different parts of the country. The sharing of results and their feedback on the crop trials of IARI varieties was carried out through joint workshops with partner institutions. Suitable farm production, plant protection and post-harvest technologies and farm enterprises were discussed based on participatory analysis and joint consultations for the profitable farming system during workshops held at Institute. Partner organizations assessed and promoted the technologies through demonstrations, training, field days etc.

***Rabi* 2021-22:** During *rabi* 2021-22 under NEP collaborative program with ICAR institutes and SAUs, 248 demonstrations involving 26 varieties of 10 crops in nine states were conducted, covering an area of 42.18 ha at 12 locations. In collaboration with voluntary organizations, 452 demonstrations covering 23 varieties of 10 crops in an area of 105.96 ha were conducted during *rabi* 2021-22. The feedback on IARI varieties from the various institutions is as under.

- The newly released variety of IARI wheat HI-1633 has shown good performance in late sown condition with an average yield of 4.15 t/ha which was 18.14% higher than the local check GD-496 was suitable for irrigated late sown condition of South Gujarat's paddy-wheat cropping system due to early flowering & resistance to different insect pests of wheat (NAU, Navasari).
- All the IARI wheat varieties HD 3086, HD 2967, HD 3226 and HD 3271 and the mustard variety Pusa Vijay performed better than the local check. (Farmers at Ghaziabad, Uttar Pradesh, CRD, Gorakhpur and MGKVK, Gorakhpur).
- HD 3298 recorded a 1.85 q/acre yield, HI 1620 yielded a whopping 22 q/acre (YFA, Rakhra, Patiala, Punjab).
- The per cent increase of yield of demonstrated wheat varieties HD 3249 and HD 2967 was 10.04 and 9.29%, respectively, over of the local check (ISHARA, Deoria).
- Palak variety Pusa All Green has a high demand due to high acceptance at CIAR, Port Blair (Andaman and Nicobar Island).
- Farmers liked Palak (All Green variety) for its high yield *i.e.* 13.0 t/ha (yield increase of 35.4%) and variety Pusa Bharti, 11.70 t/ha (yield increase of 21.8 per cent, B: C ratio of 3.66) compared to local Kiran variety (9.6 t/ha) (ICAR-NRRI, Cuttack).
- Mustard variety Pusa Tarak was preferred due to less branching and yield. The oil per cent was very good and suited for late sown condition. PM-30 was preferred due to better yield. It was also suited for the late sown conditions (ICAR-IIVR, Varanasi).
- SHDA, Gorakhpur has Lord Buddha Vegetable Producer Co. Ltd, an FPO encompassing 1350 farmers and has been active in producing seeds, including that of HD 2967. Also a women farmers' group *'Mahila Sahbhagita Jaivik Utpadak Samooh"* has been formed at village Sirrora, Salempur, Ghaziabad for small scale value addition enterprises by VO partner FARMER, Ghaziabad. Five FPOs developed by NRRI, Cuttack also have started paddy seed production.

***Kharif* 2021:** During *Kharif* 2021, under NEP, 281 demonstrations on nine crops with 18 varieties covering an area of 43.30 ha were conducted at 12 ICAR Institutes/ SAUs. In collaboration with voluntary organizations, 528 demonstrations on 12 crops with 23 varieties covering an area of 81.55 ha were conducted at 19 locations of voluntary organizations. The summary of results and feedback on IARI varieties from the various institutions are as below:

- The increase in yield of newly released paddy varieties of IARI, e.g. Pusa Sambha-1850 and Pusa Sugandha-5, over that of the local check (Indryani) was 22.83 and 20.25%, respectively (NAU, Navasari).

- Demonstrations of paddy varieties Pusa Sugandha 5 and Pusa Sambha (P-1850) yielded ~10 to 13.5% and ~14.00 to 21.5%, respectively, higher compared to the local check (ICAR-IIVR, Varanasi, Shamayita Math, Bankura, West Bengal, Mahayogi Gorakhnath KVK, Gorakhpur).
- Demonstrations with PB-1718, PB- 1509, PB-1121, PB 1637 and PB- 1401 gave an ~12 to 24.23% yield increase over the local check (PB 1509, yield 4.20 t/ha) (KVK, Saharanpur, HESCO, Dehradoon).
- Good performance of paddy P-2511 (5.80 t/ha) and P-1850 (5.20 t/ha) with 13.72 and 1.96% yield increase, respectively, over the local check (5.10 t/ha, BPT 5204, Sambha mansoori) (SHDA, Gorakhpur).
- Sponge Gourd, Pusa Sneha gave 40% more yield than local check Kerilo. The farmers liked the fleshy fruit with attractive colour and aroma, and its cultivation can be scaled up in medium and upland situations (ICAR-NRRI, Cuttack).
- Higher yields of green gram Pusa Vishal (18.81 %), Pusa 9531 (29.09%) and Pusa 1431 (21.82%) were obtained as compared to the local check IPM2-3, SML-668, and farmers' seed (KVK Kangra, HP).
- Good performance of sponge gourd, Pusa Sneha and other crop varieties, *i.e.* Bhindi (Pusa 5), Amaranthus (Pusa Kiran and Pusa Lal Chaulai) than the local varieties, *i.e.* Susthira, CO_2 and Arun, respectively was recorded (KAU, Thrissur, Kerala).
- Sponge Gourd (Pusa Sneha) and Bottle Gourd (Pusa Santushti) were promoted in the tribal area for Nutri-garden and were liked by the consumers (MPUAT, Udaipur, Rajasthan).
- Okra Pusa Bhindi 5 was taken in January and its performance was very good, giving 50% more yield and a higher B: C ratio than the local check (ICAR-CIARI, A&N Islands).
- The variety was preferred by farmers as it was resistant to yellow mosaic virus and has uniform fruit size (CRD, Gorakhpur)
- Farmers appreciated BGA for saving on fertilizer costs and reducing the cost of cultivation (PRDF, Gorakhpur).
- Farmers liked brinjal for its oval-shaped fruit, spinelessness, medium size 200 to 250 gm, fewer incidences of the shoot and fruit borer infestation, and resistance to little leaf and blight disease (Vidya Bhavan KVK, Udaipur, Rajasthan).

7.3.3. Participatory Seed production of improved varieties of IARI at seed-hub

Under Participatory Seed production of improved varieties during *kharif* 2021, 12.2 t of PB-1509, 32.2 t of Pusa-44, 3.4 t of PB-1121, 9.4 t of PB 1401 and 5.0 t of PB-1718 seed were produced at Rakhra.

7.3.4. Pusa *Krishi Vigyan Mela* 2022

Pusa *Krishi Vigyan Mela* 2022, themed "*Takniki Gyan Se Aatmnirbhar Kisan*" was organized at the IARI *mela* ground from March 9-11, 2022. IARI Fellow and IARI Innovative Farmers Awards were bestowed on 5 and 36 farmers, respectively. Farm technologies developed by the Institute for sustainable agricultural development were displayed in the thematic pandal. Two hundred twenty stalls of ICAR Institutes/SAUs, KVKs, Govt./PSUs, agri-startups, NGOs, SHGs, FPOs, innovative farmers and other private entrepreneurs were set up. More than 70,000 visitors from different parts of the country, including farmers, farm women, extension workers, entrepreneurs, students and others visited the *mela*. Also, for the first time, many stakeholders could benefit from the live webcasting of the *mela* in different parts of the country. Five technical sessions were organized on different themes of agricultural importance.

7.3.5 Off-campus Exhibitions

CATAT participated in the following exhibitions to display Institute's technologies and products

- Diamond Jubilee Year Celebration and Farmer Fair organized by Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, on January 4, 2022.

- Kisan *Mela* and Agri exhibition at Morena, MP, from November 11-13, 2022.

7.3.6. Farmers' Outreach Programme

Farmers from different villages of NCR were mobilized to participate virtually in the following events and attend the PM's address during

- Release of the 10th Instalment under PM-Kisan and Release of Equity Grant to FPOs January 1, 2022 at B.P. Pal Auditorium, IARI.
- Nation-wide virtual interaction of the Hon'ble PM of India with farmers on May 31, 2022 at NASC Complex.

7.3.7 Off-campus Trainings/ Field Days

- One-day training on 'Nutri-gardens' for 30 farmers of Kanvi Village, Hapur (UP) under the SCSP Scheme on November 11, 2022.
- Organised *Kisan Diwas and Swachhta Abhiyan* at village Sujanpur Akhara, Ghaziabad, UP on December 23, 2022.

7.3.8. Agro-Advisories to farmers

Provided agricultural advisories for *rabi* crop harvesting & threshing, sowing of summer vegetables *kharif* crops and managing agricultural activities during Covid-19 through AIR, DD, newspapers and mobile phone.

7.4 AGRICULTURAL TECHNOLOGY INFORMATION CENTRE (ATIC)

Agricultural Technology Information Centre (ATIC) was established in 1999 at ICAR-IARI to serve as a 'Single Window Delivery System' for the Institutes' products, services and technologies to the farmers/ entrepreneurs etc. IARI being a premier institute in the agricultural sector and located in the capital city, is frequently visited by a large number of farmers, extension workers, entrepreneurs, etc. from different parts of the country every year for inputs, services and advice. There is a lot of demand from farming community and urban visitors for Pusa seed of different seasonal crops varieties including vegetables kits. It is important that products, technologies and services are delivered directly from single window of the Institute to the ultimate users, so that there is no distortion of information. Thus, ATIC is playing a crucial role of single window delivery of technology, information, advisory services over Pusa helpline, exposure visit of farmer, sale of Pusa seed, biofertilizers, farm literature etc. for the benefit of the farming community.

Pusa Helpline: Besides farm advisory services, farmers are given farm advice through Pusa Helpline (011-25841670, 25846233, 25841039 and 25803600-PRI line), 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 farmer's of Delhi and Rajasthan. A total number of 11,650 farmers calls from 17 states were received through Pusa *Agricom* (A toll free Helpline Number-1800-11-8989), Pusa Help-line (011-25841670, 25841039, 25846233, 25803600) and *Kisan Call Centre* 1800-180-1551 (IInd level) on various aspects of agriculture.

Advisory Services: Farm advisory services to 14,665 farmers and other stakeholders were provided at ATIC during the year. Visitors (farmers/ farm women/ entrepreneurs/ officials) visited ATIC for seeking advisory services, purchase of Pusa seed, farm publications, biofertilizers and enquiry about training programme and also contacted over Pusa Helpline. Information & advisory needs of the visitors are also being catered through LED display boards, farm literature, information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples and bio-fertilizers displayed at the centre.

Pusa Seed and Publication sale: Pusa seeds of worth ₹26,84,388/- and farm publication for ₹24,030/- have been sold to the farmers during the year.

Publication of *Prasar Doot*: Four issues of Hindi farm magazine "***Prasar Doot***" were published by the centre during the reporting period. About 500 farmers and others got farm advisory services through e-mails during the period. ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators.

Feedback and linkages: The feedback of farmers on different technologies are collected at ATIC, which provides a ground for need based technologies. The ATIC has also developed functional linkages with various agencies working for the farming community to effectively cater the information needs of the different stake holders. Linkages with KVK, State Line departments, SAUs, ICAR Institutes and Farmers Producer Organizations have been established.

7.5 KRISHI VIGYAN KENDRA

7.5.1 On Farm Trials (OFT)

Pink ball worm management in cotton: Pink ball worm insect is a serious problem in cotton, especially in Pataudi block of district Gurugram of Haryana. The KVK Gurugram surveyed the areas, interacted with farmers and selected the cotton growing farmers of village Maujabad. Ten OFTs were laid out on the farmer's field for the management of the pest. Pheromone traps, Spinosad 45% SC, @ 1ml/L and Profenophos 40% + Cypermethrin 4% @ 1 ml/L were applied after 45 DAS and 2nd spray was applied after 15 days of 1st spray. Result showed that the intervention increased the cotton yield by 24.09% over the farmer's practice (one spray of 25% Cypermethrin @ time of flowering) with the net profit of ₹ 1,26,520/-per ha.

Weed management in pearl millet: Krishi Vigyan Kendra, Gurugram conducted OFT on weed management in pearl millet. The results indicated that the use of Atrazine @ 0.75 kg *a.i.* + 2,4-D ethyl ester 0.5 kg *a.i.* per ha @ 25-30 DAS gave 17.6% increase in grain yield over no use of weedicides by farmers. The weed population was reduced by 66.25% and grain yield was recorded as 29.5 q/ha with straw yield 68.50 q/ha under technical intervention, whereas under farmer's practice it was 24.6 q/ha and straw yield 57.7 q/ha.

Integrated nutrient management in mustard: KVK, Gurugram observed low productivity and profitability of mustard in Gurugram district (19.5-22.50 q/ha) due to low level of organic carbon & imbalanced application of nutrients by farmers, therefore, an OFT was organized on integrated nutrient management in mustard. Farmers applied fertilizers NPK as 60:46:0 kg/ha whereas recommendations are FYM five ton/ha + NPK liquid bio fertilizer @ 10 ml/kg seed treatment+ Sulphur bentonite 20 kg/ha + 75% NPK of RDF (N-60, P-40, K-40 Kg /ha) based on soil test results and 1 spray of 0.5% K_2SO4 at 60 days after sowing. The grain yield of 25.92 q/ha was recorded under technical intervention where as in farmers' practice it was 22.51 q/ha. The results revealed that grain yield increased by 15.14% over farmers' practice and net profit increased by 17.36%.

OFT on integrated nutrient management on mustard

7.5.2 Training and other activities

Training Programme on Motor Rewinding: Krishi Vigyan Kendra, Shikohpur organized one vocational training course on motor rewinding during February 22, 2022 to March 4, 2022 at KVK campus in which nine rural youths from Gurugram district participated. The trainees learnt the complete process opening and winding the defective motors. A set of tools was also provided to the participants for smooth functioning of training and to start the vocation.

Vocational Trainings on Dress Designing and Tailoring: KVK, Gurugram organized 45 days training programme for rural youth on dress designing and tailoring w.e.f. December 14, 2022 to January 27, 2022 at village Uncha Majra. A Total number of 25 rural girls including farm women participated.

Trainings under ARYA Project: The Krishi Vigyan Kendra, Shikohpur organized one training programmes on Protected Cultivation in two phases, phase I during December 8-22, 2022 and phase II [rd] December 23-January 5, 2023 in which ten rural youths from district Gurugram participated. Under these training programmes, the youths were given hands on training along with practical details related to these vocations to make them efficient in these skills and take it up as entrepreneurial activity.

One-day Capacity building programme on Processed Food for FPO/ FPC & farmers for Exports: One-day capacity building programme on Processed Food for FPO/ FPC & farmers for Exports was organized by KVK Gurugram on March 3, 2022 at KVK Gurugram, funded by APEDA, New Delhi wherein 104 farmers and farm women participated physically during the training programme. Smt. Rekha Mehta, Assistant General Manager, APEDA, New Delhi, advised the farmers to minimize the use of pesticide and chemical for exporting the produce.

Training programme on Scientific Bee Keeping: Krishi Vigyan Kendra, Shikohpur organized four trainings on scientific bee keeping during January 24-February 01, 2022; February 7-15, 2022; February 18-25, 2022 and March 2-9, 2022 in which a total of 106 farmers including youth from Nuh and Gurugram district participated. During the training, the scientific rearing and management of apiaries, management of bee boxes

Training on scientific bee keeping

during different seasons, extraction and processing of honey, packaging labelling and marketing of honey were covered.

***Kisan gosthi* on Catch the Rain Water:** One gosthi for mobilization of farmers on "Catch the Rain Water" under Jal Shakti Abhiyan was organized at Bissar village, in which 20 farmers participated. Two trainings of two days each were organised for farmers on "Catch the rain water and water use efficiency" at village Sadhrana on April 25–26, 2022 wherein 58 farmers participated and another on August 26-27, 2022 at village Bar Gujjar wherein 51 farmers had participated. One-day farmers' fair cum exhibition was organized at KVK Shikohpur, Gurugram under Jal Shakti Abhiyan-2022 on July 27, 2022. Dr. B.S. Tomar, Joint Director (Extension), IARI, New Delhi, was the chief guest and he urged the farmers to minimize the wastage of water. A total of 265 farmers, farm women, students and extension workers participated in the *Mela*.

Training under Jal Shakti Abhiyan

Awareness campaign on efficient and balanced use of fertilizers including Nano-Urea: One-day farmers' awareness campaign on 'Efficient and Balanced Use of Fertilizers (including Nano-Fertilizers) was organized at KVK Gurugram on June 21, 2022. The farmers were advised to use the optimum dose of fertilizers based on the soil test results and grow agro-forestry plants such as neem, sheesham, drum stick, acacia, kachnaar, etc. in panchayat land in the villages.

Awareness on Natural Farming- Fifteen awareness programmes on natural farming were conducted by KVK Gurugram. During the programmes, various methods which are included in the Natural Farming were discussed. A total of 1232 farmers and farm women participated in the programme. Preparation of vermi-compost, vermin-wash, Jeevamrut, GhanJeevamrut, Panchgavya, Bhamastta, Beejamrut, etc were discussed by KVK experts.

Awareness programmes on natural farming

Field day under OFT and FLD: Four field days were organized on various aspects *viz*: INM in Mustard on February 9, 2022 at Tajnagar village, block Farukhnagar for CFLDs under NFSM, pearl millet on September 29, 2022 at Tripadi village, summer moong package and practices on July 07, 2022 at Maujabad village and Pigeonpea package and practices on November 23, 2022 at Raiseena village of Gurugram district. A total of 109 farmers and farm women participated in the programme.

Swacchata Campaign 2.0: KVK, Gurugram organized Swacchta campaign 2.0 from October 2-31, 2022. During the programme, various activities like swacchata oath, weeding out of old records, swacchata drive in KVK campus and adopted and non-adopted villages, goshthi on importance of swacchta, awareness to school students were created. During the swacchta month, more than 700 farmers, farm women, students and other stakeholders participated in the programme.

7.5.3 Celebration of Important Days

Sl. no.	Important day celebration	Date	Participants	Venue
1	National Girl Child Day	January 24, 2022	44 girl student	KVK Gurugram
2	World Pulse Day	February 10, 2022	74 farmers and farm women	Tirpadi village
3	International Women's Day	March 8, 2022	79 farm women	Ooncha Majra
4	World Environment Day	June 6, 2022	21 staff	KVK Gurugram
5	World Soil Day	December 5, 2022	53 farmers and farm women	Maujabad
6	National Kisan Diwas	December 23, 2022	92 farmers and farm women	Farrukhnagar

8. EMPOWERMENT OF WOMEN IN AGRICULTURE AND MAINSTREAMING OF GENDER ISSUES

Though women make significant contribution in agricultural development and household livelihood security, they continue to be a vulnerable group in social system mainly due to lack of access to resources as well as opportunities for capacity building. Realizing the need of women empowerment for promotion of inclusive development, several initiatives were taken towards capacity building of women in areas of value-addition, nutritional security and collective action.

8.1 Skill Building in Nutrition Sensitive Agriculture (NSA) for Empowerment of Rural Women

Four training programmes (of three days duration) were organized to develop skills in preparing value added products of sorghum, pearl millet, barnyard millet through Nutrition Sensitive Agriculture Centres (NSACs) established in Harsanakala and Jagdishpur villages of Sonipat district of Haryana and Sunehra and Bassi villages of Baghpat District of U.P. under the DBT funded project "Skill building in Nutrition Sensitive Agriculture for Empowerment of Rural Women". The purpose of establishing this centre was to create awareness about nutritional benefits of nutri-cereals, nutri rich crops and varieties, kitchen gardening and achieving a healthy living with little creativity and effort and extending it for commercialization to earn a livelihood. Rural women were trained in preparing value added products of nutri cereals. The trainees were also made aware about IARI PUSA Samachar YouTube channel. The videos on nutritional importance and successful entrepreneurs of Pusa Samachar were streamed to educate the rural women.

8.2. Enhancing Nutritional Security And Gender Empowerment

KVK, Gurugram celebrated *Poshan Maah* from September 1-30, 2022 during which a total of six awareness programmes, three trainings and one poster competition for school students on the theme "Health & Nutrition" were organized, which benefitted 390 farm women, Anganwadi workers and school students. The details of the various activities organized during the Poshan Maah are given below:

Glimpses of capacity building activities undertaken under Nutri Sensitive Agriculture (NSA) Centre

Date	Name of activity	Location	Number of beneficia-ries
1.09.2022	Training on "Preservation of seasonal fruits and vegetables"	Dadupur village	16
2.09.2022	In-service training on "Importance of fruits and vegetables in our daily diet and establishment of nutri-garden" at Anganwadi Centers"	Anganwadi Center, Uncha Majra	30
3.09.2022	Awareness camp on "Nutrients, their role in human body and food sources"	Shankar ki Dhani village	42
5.09.2022	Awareness camp on "Health benefits and processing of nutri-cereals"	Pukharpur village	24
7.09.2022	Awareness camp on "Balanced diet, Nutri-thali and Nutri-garden"	Khwaspur village	18
15.09.2022	Poster competition on "Health and Nutrition" for school students	KVK, Shikohpur	24
17.09.2022	National campaign on "Poshan Abhiyan and Tree Plantation"	KVK, Shikohpur	152
20.09.2022	Awareness camp on "Balanced diet, Nutri-thali and Nutri-garden"	Iqbalpur village	28
22.09.2022	Awareness camp on "Nutrients, their role in human body and food sources"	Pataudi	30
26.09.2022 -30.09.2022	Training on "Establishment of nutri-garden to achieve nutrition security at household level"	Tajnagar village	26

During the programme, participants were given knowledge about nutrients, their requirement and role in human health, their food sources. They were also made aware about health benefits of nutri-cereals and were motivated to make nutri-cereals like jwar, bajra, ragi etc. part of their daily diet. During September 26-30, 2022 training on "Establishment of nutri-garden to achieve nutritional security at household level" was organized in which 26 women participated.

National campaign on "Poshan Abhiyan and Tree Plantation" was organized on September 17, 2022, at KVK campus in which 152 beneficiaries participated. KVK distributed a total of 550 plants of guava, drumstick, lemon, aonla, tamarind, neem and 1500 seedlings of tomato, chilli and brinjal to the participants to motivate them to establish a nutri-garden in their backyard. IFFCO also distributed 100 vegetable seed kits to the participants on this occasion.

8.3 Effectiveness of SHGs for Gender Empowerment

One vocational training was organized on "Food processing, preservation and value addition" in two phases (Phase I: 26.11.2021 to 11.12.2021 and Phase II: 13.12.2021 to 20.12.2021), in which 9 women participated from two villages *viz*. Uncha Majra and Mushedpur. In the year 2022, a total of two SHGs named Saheli SHG from Uncha Majra village and Sakhi SHG from Mushedpur village started their enterprise with aonla products. These SHGs were supported with utensils, processing and packaging machines. They made different products like aonla pickle, candy, juice, murrabba and powder etc. Both the SHGs started their value addition enterprise with aonla products and started earning as per the following details:

Indicators	Saheli SHG, Uncha Majra	Sakhi SHG, Mushedpur
Size of entrepreneurial unit	05 women	04 women
Total produce/annum (kg)	Aonla products & other pickles	Aonla products & other pick-les
Sale value of the produce in the market: ₹/Kg	200-400/kg.	100-250/kg.
Cost of production/annum (₹)	95,000/-	62,000/-
Gross Returns/ annum (₹)	2,40,000/-	1,10,000/-
Net Returns / annum (₹)	1,45,000/-	48,000/-
C: B Ratio	1:2.53	1:1.77

A total of 10 women SHGs trained under ARYA project are running their value addition enterprise in a sustainable manner and creating their own identity in the society. Out of these, 10 women SHGs were recognized for their work:

- Smt. Pooja Sharma, President of Kshitiz SHG received Nari Shakti Puruskar-2021 by Hon'ble President of India on March 8, 2022 on the occasion of International Women's Day.
- SHG "Prajapat" was given first prize with a cash prize of ₹ 1,00,000/- by the Hon'ble Chief Minister of Haryana, Sh. Manohar Lal Khattar during SARAS mela in April, 2022.
- SHG "Pragati" was given second prize with a cash prize of ₹ 50,000/- by the Hon'ble Chief Minister of Haryana, Sh. Manohar Lal Khattar during SARAS mela in April, 2022.
- SHG "Dev" was given third prize with a cash prize of ₹ 25,000/- by the Hon'ble Chief Minister of Haryana, Sh. Manohar Lal Khattar during SARAS *mela* in April, 2022.

9. POST GRADUATE EDUCATION AND INFORMATION MANAGEMENT

The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence for more than 115 years in research, teaching and extension. The Post Graduate School of ICAR-IARI continues to provide national and international leadership in Human Resource Development by awarding Post Graduate degrees in 26 disciplines. So far, 4617 M.Sc., 84 M. Tech. and 5179 Ph. D. students including 495 international students have been awarded degrees. The Institute has received accreditation from National Agricultural Education Accreditation Board of ICAR (2020-2025 with A grade). The Institute has also submitted the Self Study Report (SSR) of IARI for NAAC Accreditation (2nd cycle) on November 30, 2022. As per the requirement of NAAC-SSR submission process, IARI has also registered for the Electoral Literacy Club (ELC) at the office of the Electoral Registration Officer, Assembly Constituency-39 (Rajinder Nagar), New Delhi-110012.

9.1 POST GRADUATE EDUCATION

9.1.1 Admission during the Academic Session 2022-2023

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 M.Sc./M.Tech./Ph.D. programme are based on an 'All-India Entrance Test' conducted by the NTA/ICAR. The foreign students are admitted through DARE and are exempted from the written test. During the academic year 2022-23, 257 students (including 11 physically challenged) were admitted to M.Sc./M.Tech. and 285 students (including 10 physically challenged; 3 ICAR in-service; 7 under faculty upgradation scheme and 2 under departmental technical, 1 in Departmental Scientific scheme and 2 under CWSF) were admitted to Ph.D. courses. Besides, 76 students (10 students at CIAE, Bhopal; 15 students at IIHR, Bengaluru; 16 students at NIBSM, Raipur; 10 students at NIASM, Baramati and 09 students at IIAB, Ranchi) were admitted at PG Outreach programmes at our sister institutes. In addition, 5 international students (2 M.Sc. & 3 Ph.D.) from, Nepal, Syria, Myanmar and Kenya were also admitted. At present, the total number of students on roll is 1435 (297 M.Sc., 25 M. Tech. and 1113 Ph.D.), which includes 19 international students (4 M.Sc. & 15 Ph.D.).

9.1.2. Convocation

The 60th Convocation of the Post Graduate School of the Indian Agricultural Research Institute (IARI) was held on February 11, 2022 (both in virtual and physical mode). Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt. of India, Shri Narendra Singh Tomar was the Chief Guest and delivered the Convocation Address. Shri Kailash Choudhary, Hon'ble Union Minister of State for Agriculture and Farmers Welfare, Govt. of India, was the Guest of Honour on the occasion. Dr. T. Mohapatra, Secretary, DARE & Director-General, ICAR, presided over the function. The Chief Guest and Guest of Honour presented the medals, awards and degrees to the students and faculty.

The Chief Guest dedicated six varieties of fruits and vegetables to the nation *viz.*, two varieties of mango Pusa Lalima, Pusa Shresth; brinjal variety Pusa Vaibhav; palak variety Pusa Vilayati Palak; cucumber variety Pusa Gynoecious Cucumber Hybrid-18 and Pusa Alpana variety of rose. In his convocation address, the Chief Guest exhorted the students for entrepreneurship development and appealed for taking up farming as a profession. He also appreciated the efforts of Institute for the development of new varieties and technologies in the field of agriculture. He highlighted the priorities of the government in the field of agricultural research and farmers' welfare. Dr. A.K. Singh, Director, ICAR-IARI presented the Director's Report on the significant achievements of the Institute during 2021, and informed that wheat varieties developed by this institute contribute nearly 60 million tons to nation's granary worth ₹ 80,000 crores annually. Similarly, the Basmati varieties developed by the institute predominate basmati cultivation in India accounting for 90% of the total foreign exchange (₹29524 crores) earned through export of Basmati rice amounting to ₹ 32,804 crores. About 48% of mustard grown area in the country is cultivated with IARI varieties. The total economic surplus generated from Pusa Mustard 25 is estimated at ₹ 14323 crores (at 2018 prices) during the last 9 years. Dr. Rashmi Aggarwal, Dean & Joint Director (Education), IARI presented the Dean's Report.

During this Convocation, 285 candidates (173 M.Sc., 12 M. Tech. and 100 Ph.D.) including 8 international students (4 M.Sc. and 4 Ph.D.) were awarded degrees. Prof. R.B. Singh, Former Director, ICAR-IARI, New Delhi was conferred upon D.Sc. *honoris causa*. NABARD-Professor VL Chopra Gold Medal & Best Student of the Year award for M.Sc. and Ph.D. were presented to Ms. Debarati Mondal, Division of Biochemistry and Dr. Siddharood Maragal, Division of Vegetable Science, respectively. Five students each in M.Sc. and Ph.D. received IARI Merit Medals.

Degree distribution during convocation by Hon'ble Minister

VI Dr. A.B. Joshi Memorial Award for the biennium 2020-21 was presented to Dr. D.K. Yadava, ADG (Seeds), ICAR, New Delhi. Second Best Agricultural Extension Scientist Award for the biennium 2021-2022 was presented to Dr. R.N. Padaria, Head & Professor, Division of Agricultural Extension, IARI, New Delhi. XXII Shri Hari Krishna Shastri Memorial Award-2021 was presented to Dr. A.D. Munshi, Principal Scientist, Division of Vegetable Science, IARI, New Delhi. XXII Sukumar Basu Memorial Award for the biennium 2019-20 was presented to Dr. Rajan Sharma, Principal Scientist, Dairy Chemistry Division, ICAR-NDRI, Karnal. XVIII Dr. B.P. Pal Medal for the Year-2021was presented to Dr. Firoz Hossain, Principal Scientist, Division of Genetics, IARI, New Delhi. Dr. C.M. Parihar, Senior Scientist, Division of Agronomy, IARI, New Delhi received the Best Teacher Award in Agricultural Higher Education-2021.

Convocation address by the Chief Guest

9.1.3 Special Lectures

Lal Bahadur Shastri Memorial Lecture: As a part of the convocation week, Dr. K.V. Prabhu delivered the 52nd Lal Bahadur Shastri Memorial Lecture on "Living in Symphony with Rights of Farmers and Plant Breeders" on February 10, 2022 (Virtual Mode). Dr. Prabhu highlighted the role of PPV&FRA in varietal registration, maintenance and characterization. Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR, New Delhi chaired the session. Dr. Rashmi Aggarwal, Dean & Joint Director (Education), ICAR-IARI, proposed a formal word of thanks.

Celebration of National Girl Child Day 2022: ICAR-Indian Agricultural Research Institute celebrated

National Girl Child Day 2022 on January 24, 2022 through virtual mode. This programme was sponsored by Gender Advancement for Transforming Institutions (GATI), WISE-KIRAN-DST, Govt. of India. Dr. Surya Rathor, Principal Scientist, Extension Management System, ICAR-NAARM delivered a lecture on “Motivating Girls for Higher Participation in STEMM” (STEMM-Science, Technology, Engineering, Mathematic, Medicine) and her presentation touched all the important issues of equality, equity and opportunities for the girl child. The program was chaired by Dr. A.K. Singh, Director, ICAR-IARI.

The number of activities comprising of the presentations by Dr. Rashmi Aggarwal, Dean & Joint Director (Education), IARI on “Status and achievements of IARI- PG girls students”, recitation competition of poem on topic “Daughters are blessings” / “बेटिया है दुआए´´, by PG students. Ms. Simar Deep Kaur, Ph.D. Student of Biochemistry won the 1^{st}prize, Ms. Arti Kumari won 2^{nd} prize and 3^{rd} prize were shared by Ms. Deepti Tiwari and Balaji B.. Ms. Shivani Singh, Ph.D. Student from London expressed her views on girl’s issues at global level and more specific to Indian context. The selfies of daughter with father/parent were invited from all categories of staff through a Goggle link which were compiled and presented by Dr. R.R. Burman, Principal Scientist, Division of Agricultural Extension, IARI, New Delhi.

Dr. A.K. Singh, Director, ICAR-IARI and chief guest of the function appreciated the efforts made by PG students for their hidden talents and thanked Dr. Surya Rathor for a motivating lecture. The program ended with the words of thanks by Dr. Rashmi Aggarwal.

International Women’s Day: ICAR-Indian Agricultural Research Institute, New Delhi celebrated the International Women’s Day through virtual mode on March 8, 2022. The theme of the event was “Gender equality today for a sustainable tomorrow”. Dr. Rashmi Aggarwal, Dean & Joint Director (Education), IARI was the Chief Guest of this function. Dr. Alka Singh, Head & Professor, Division of Agricultural Economics, IARI & Nodal Officer, Gender Advancement for Transforming Institutions (GATI), WISE-KIRAN-DST, Govt. of India, welcomed the audience. On this occasion, Dr. Renuka Karandikar, CEO, BioPrime AgriSolutions Pvt. Ltd., delivered the International Women’s Day Lecture on the topic “Women Transforming Indian Agriculture”.

International Women’s Day lecture

IARI Foundation Day: ICAR-Indian Agricultural Research Institute celebrated its 117^{th} Foundation Day on April 1, 2022. Dr. T. Mohapatra, Secretary (DARE) & DG (ICAR) delivered the Foundation Day Lecture. The occasion was presided over by *Padma Bhushan* Professor R.B. Singh. Dr. T.R. Sharma, DDG (Crop Science), ICAR was the Guest of Honour.

Dr. B.P. Pal Memorial Lecture: The 29^{th} Dr. B.P. Pal Memorial Lecture was delivered by Dr. Ravi P. Singh, Distinguished Scientist & Head-Wheat Improvement, Global Wheat Program, CIMMYT, México on the topic “Wheat breeding for global food and nutrition security under climate change” on May 26, 2022. Dr. Trilochan Mohapatra, Secretary, DARE & Director General, ICAR, New Delhi presided over the function.

Gender Advancement for Transforming Institutions (GATI): The GATI lecture was delivered on June 6, 2022 by Dr. Ranjitha Puskar, Gender Research Programme Leader, IRRI, on the topic “Enhancing Impact of Agricultural Research: Imperative for Effective Gender Integration” and by Dr. Nisha Mendiratta, Advisor & Head, WISE-KIRAN Division & CCP, DST, New Delhi on the topic “Gender Advancement for Transforming Institutions (GATI) – A new initiative”.

Teachers' Day Lecture: The Teachers' Day Lecture was jointly organized by the PG School, and the Genetics Club, IARI on September 5, 2022. The dignitaries paid tributes to Dr. S. Radhakrishnan, the great philosopher, philanthropist and ex-President of India. Prof. R.B. Singh, Former Director, ICAR-IARI & Former President, NAAS, New Delhi delivered a thought provoking and introspective lecture. Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR, New Delhi presided over the function.

9.1.4 International Exposure

The excellence of IARI is recognized internationally. IARI has played a key role in the establishment of i) Afghanistan National Agricultural Sciences and Technology University (ANASTU), Afghanistan; and ii) Advanced Centre for Agricultural Research and Education (ACARE), Yezin Agricultural University, Myanmar.

ANASTU programme: The excellence of IARI is recognized internationally and has played a key role in the establishment of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan in 2012-14. Under ANASTU programme, the first three batches of M.Sc. Agronomy have already graduated (2016, 2018, 2021). The teaching and research guidance of 4th Batch was completed in online mode. To facilitate online teaching, a tele-education facility was established at the ICAR-IARI, New Delhi.

In 2019, three new M.Sc. courses on Horticulture, Plant Protection, and Animal Husbandry were introduced. The Horticulture and Plant Protection courses were taught at ICAR-IARI, New Delhi, and Animal Husbandry was taught at ICAR-IVRI, Bareilly. Besides, three new M.Sc. courses, Plant Breeding, Soil Science & Water Technology, and Agricultural Economics will start after the return of normalcy in Afghanistan.

ACARE Programme: Under the ACARE programme, to strengthen the post-graduate education and human resource development, IARI in collaboration with YAU, Myanmar successfully conducted two short term (2 weeks) training programmes for the stakeholders of Myanmar agriculture.

9.2 LIBRARY AND LEARNING RESOURCES

Since its inception in 1905, IARI library has been catering to the literature requirement of scientific community for more than 117 years. In its early collection there were only 5000 publications which were donated by the Secretary, Department of Agriculture, Govt of India. In the year 1934, due to devastative earthquake on 15th January the library along with the Institute shifted to the present campus in Delhi on 29th July, 1936. As a tribute to Prof M S Swaminathan, the eminent scientist and father of Green Revolution of India, the library was re-named as "Prof M S Swaminathan Library" on April 29, 2016. Which was changed to "Prof. M S Swaminathan National Agricultural Science Library" on January 17, 2020.

Prof. M S Swaminathan National Agricultural Science Library is playing a role of a national repository for agriculture related literature in India thus, library is one of the largest and finest agro-biological libraries in Southeast Asia housing over four lakhs research publications including books, monographs, reference materials, journals, annual reviews, abstracting and indexing journals, translated periodicals, statistical data publications, bulletins, reports, post-graduate theses of IARI, and ICAR research fellowship theses.

Library provides the services as lead centre to all ICAR sister institutes/SAUs and International institutes. The library has on its role 2144 active registered members *viz.* scientists, students, and technical/administrative staff. Apart from registered members, the library served approximately 50 to 100 users per day from different agricultural universities /ICAR institutes/SAUs who consults approximately 100 to 200 library publications/articles through online/ offline every day. The Library provides reference service, bibliographical services, documentation services, online international abstracting database searches services etc.

9.2.1 Acquisition Programme

9.2.1.1 Books

During the period library procured zero publications. The Library also acquired 65 gift publications, 270 IARI Theses and uploaded CDs of 320 Theses (Soft copy) on Krishikosh.

9.2.1.2 Serials

The Library procured 95 journals/serials through subscription, gifts and exchanges. It subscribed to 26 foreign journals and 69 Indian Journals, Total costing for Indian and foreign Journal is ₹ 68,09,269.00. The Library is also received 230 Newsletters, 20 bulletins, 59 annual reports and 27 Gratis Journals.

9.2.2 Document processing

Total number of document processed (classifying & cataloging) 414 that was consisted of 65 books, 270 post-graduate IARI theses, 20 bulletins and 59 Annual Reports.

9.2.3 Resource Management

Apart from 2144 active registered members, the library served 50 to 100 users per day who comes from different agricultural universities/ICAR Institutes who consulted approximately 200 to 300 documents every day. The number of new members registered was 280. During the period under report, 313 publications were issued and 333 publication returned. Under the Inter Library Loan System, 13 documents were issued to various institutions.

9.2.4 Document Delivery Service

Resource Management Section of Library provides a Document Delivery Services to different users of agricultural field through CeRA. Total number of hits are 13,711. Total login session was 675, searches were 3,305; full text and abstract views were 2,771. Total number of request received were 40 through CeRA.

9.2.5 J-Gate

Library also subscribed J- Gate Database covering 57000+ journals for 2022-23 amounting to ₹ 2,78,775.00. Total number of hits were 13,653 with total login session 667, 3,253 Searches, 2,768 full text and abstract views.

9.2.6. Krishikosh

Krishikosh provides a 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. The two products of E-Granth (i) Krishikosh and (ii) IDEAL are being used by all SAUs/DUs/CUs & ICAR Institutes. Up to Dec, 2022 library has uploaded 5890 theses.

9.2.7. E-Language Lab

With the help of library strengthening program, language lab was established with seating capacity of about 50 participants to facilitate english language classes for IARI foreign/ Indian students with modern facilities like 30 computers with internet facility, interactive board, interactive panel, head phones etc. Subsequently the language lab is also used for conducting trainings, LIS Course, summer and Winter School Courses of different divisions and Directorate for the benefit of Scientists/Technical staff.

9.2.8 LIS Course

The Library is actively involved in the Post Graduate teaching programme with one credit course entitled LIS (Library Information System) for M.Sc. & Ph.D. student of all discipline. The objective of this course is to train the students to search the literature of their interest & literature search tools.

9.3 AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

9.3.1 Preface

For modern farming technology, the major role for decision support system for farmers is Information and Communication Technologies (ICTs) and digital framework. This will help the farmers to connect with all recent information and enhance their knowledge. The activities of this unit are as follows

- To develop prediction and classification models using statistical techniques, Non-linear approach, Artificial Intelligence based technique, Convolutional Neural Networks, Bioinformatics tools, etc. in agriculture.
- To develop methodology, technology, process, web-based applications for e-resources and for knowledge management in agriculture.
- To provide internet connectivity, content development, e-mail services and website management for IARI and its Regional Stations.

9.3.2 Executive Summary

9.3.2.1 Epidemiology and forecasting of yield, insect-pests and diseases for value-added agro-advisory

A wide gap exists between the potential yield and that realized at the farmers' field. Among the factors contributing towards this yield gap are the biotic stresses that affect the crops. To control these menaces, weather-based prediction models, weather, forecast high-resolution remote sensing data and operational crop map in the GIS framework etc., can be integrated in a single framework *i.e*. Integrated Decision Support System (IDSS) for crop protection services. This *prototype* have all the three components (i) Operational focus (ii) Research priorities and (ii) Human Resources renewal.

9.3.2.2 Web-based forewarning system and Image analysis for yield and pests & diseases in crops

Developed and validated the forecast models (statistical as well as machine learning approach) for yield & major pests and diseases of Rice, Wheat, Cotton, Mustard, Chickpea and Pigeonpea at various locations using Agromet and SATMET data on various character *viz.* (i) Crop age at first appearance of pests (ii) Crop age at maximum population of pests (iii) Maximum pest population and (iv) Weekly monitoring of pests. The developed models were converted into web-based for systems.

9.3.2.3 Digital Repository- Krishikosh

Krishikosh is a digital repository (https://krishikosh.egranth.ac.in/) which captures, preserves, archives and provide policy based access to the intellectual output of Indian NARES. It is a unique repository of knowledge in agriculture and allied sciences, having collection of old and valuable books, institutional publications, technical bulletins, project reports, lectures, preprints, reprints, thesis, records and various documents spread all over the country in different libraries of Research Institutions and State Agricultural Universities (SAUs). A customized digital repository platform for users of NARES Institutions, where they can upload and manage their own contents for compliance to open access policy of ICAR.

9.3.2.4 Services provided by AKMU

Web applications development center at IARI developed many backend web applications along with its updates which was integrated on the ICAR-IARI website. IARI website hits during Jan.-Dec., 2022 – 3.3 million new users and 24 million page views (app. 67,000 page viewing on daily basis). AKMU is provides Internet connectivity to all the users of IARI. Now there is a major change in the working style of the institute as most of the activities were taken up online.

9.3.3 Scientific Report:

- District wise forecast models on yield of chickpea and pigeon pea were developed for Chhattisgarh and Madhya Pradesh. For this, district-wise data on area and productivity in chickpea and pigeon pea for Chhattisgarh and Madhya Pradesh were obtained from Directorate of Economics and Statistics, (Govt., of India) during 2005-06 to 2018-19. The satellite based agro-met products (spatial data) on maximum & minimum temperature, morning & evening relative humidity, bright sunshine hour and rainfall (MAXT, MINT, RHI, RHII, BSH and RF) were obtained from SAC Ahmedabad from 2005 to 2021 on daily basis for various districts of Chhattisgarh & Madhya Pradesh. SATMET data from 25 SMW to 2 SMW(of next year) and 41 SMW to 5 SMW(of next year) were used for development of models for Pigeon pea and Chickpea respectively. Weather indices based regression model and ANNs based models were utilized for development of district level forecast models. For each districts level, the performance evaluation measures considered is Mean Absolute Percentage Error (MAPE) and its showed that the predicted are in good agreement with the observed ones.

- Forewarning models for Pink Boll worm (*P. gossypiella)* and cotton bollworm (*Helicoverpa armigera*) at Raichur were developed for cotton crop. Models have been developed by training the data from 2005-06 to 2014-15 for population of bollworm incidence (larvae/5 plants). Models were validated for 2016-17 and 2017-18 *i.e.*, using subsequent years not considered for the model development. Weekly weather variables were considered for development of model on "crop-age at maximum population of pest"; "maximum population of pest"; maximum population of pest and weekly monitoring of pests at critical crop growth stages. Weather indices utilizing the weather data from 31 to 41 SMW were generated for maximum temperature (X_1), minimum temperature (X_2), relative humidity in morning (X_3), relative humidity in evening (X_4), rainfall (X_5), and bright sunshine hours (X_6) during 2005-06 to 2016-17. These developed weather indices were used as independent variables and character under study were used as dependent variables.
- Modified the forewarning models for pests of cruciferous vegetables (Diamond back moth, Spodoptera and Aphid) for *Kharif* & *Rabi* seasons on crop age at peak population and maximum population of aphids (data used from 29 SMW- 39 SMW); diamond back moth (DBM) and Spodoptera (data used from 29 SMW- 35 SMW). Historical data on pests and weather from year 2008-09 to 2017-18 were utilized for developments of models on various aspects.
- These developed models were also integrated in web based forewarning system (http://ccrpp.iari.res.in/coe-pest/)
- The process and algorithm of models development has been converted into python scripts, and process models were generated automatically upon data fed from database. The python libraries are utilized to ease the process. PHP (Hypertext Preprocessor) a general-purpose scripting language that are utilized to create dynamic web page of WordPress platform was integrated with python scripts.
- Data Extraction System: A PHP script and MySQL database are used to create an extraction mechanism for the data extraction system which are needed for model development or display of any changes in a given week or year. The weather variables are provided based on the user-selected week and year. This table can be exported in csv format for additional data analysis. Similar to this extraction system, a pest and disease extraction table is created, which will not only display the data by the user options but also provide basic statistics of the pests/diseases like max, min, median, standard deviation and variance of the displayed data.
- Climate has a strong effect on the distribution and abundance of insects with temperature being the main driver of key functions of insects including development, survival, and reproduction. In tri-trophic interactions between plants and temperature-dependent phenology for different stages (egg, larva, pupa, adult) of pod borer (chickpea) has been studied using the Insect Life Cycle Modelling (ILCYM, version 3.0). Temperature-dependent models or functions were used to model the demographic parameters of pod borer by employing the Insect Life Cycle Modelling and develop the phenology model that included development time and its variation, development rate, senescence, mortality, total oviposition, and relative oviposition frequency. The best-fit model was selected based on the Akaike Information Criterion (AIC), a well-known goodness-of-fit

indicator or other built-in statistics (R^2, Adjusted R^2, MSE). The smaller the value of the AIC, the better is the model fit. For the selection of the best functions, statistical criteria, and biological aspects of the species were considered.

- Created the Agricultural extension portal (e-Mitra) (https://ff.iari.res.in/) on the banner of farmers first and integrated the FAQ on various domain of agricultural commodity in this portal. Also initiated the AI based chatbot using natural language processing (NLP) for human-like conversations for FAQ and image analysis based on query from farmers.
- Bright sunshine hours are one of the important factors for crop yield models, but in spatial data instead of bright sunshine hour, cloud coverage is available. Based on the algorithm (Cloud cover has been converted into bright sunshine hours. In this process the following relationship is applied to the total amount of clouds:

$$C=(1-S/S_0)$$

Where S stands for sunshine hours and C for the monthly average of the percentage of the day time sky that is clouded. S_0 is the day length (bright sunshine hours). The day length S_0 (bright sunshine hours) can be calculated using the value of $\omega_s \omega_s$ when the

$$s_0 = \frac{2}{15}\omega_s$$

The value of δ and $\omega_s \omega_s$ can be calculated from

Eqs

$$\omega_s \omega_s = \arccos\left[-\tan(\delta)\tan(\varphi)\right]$$

$$\delta = 23.45 \sin\left[\frac{36(D+284)}{365}\right]$$

After the calculation of bright sunshine hours, it can be used in the crop yield model

- Developed a web application for the forecast of the BPH (Brown Plant Hopper) in rice crops using the thumb rule (If the number of rainy days is more than 2.4 mm rainfall and more than 30 days from June to September, these is a chance of an outbreak of BPH) utilizing three-tier architecture. The first tier is the Presentation tier: which is built with HTML5, cascading style sheets (CSS), and JavaScript, is deployed to a computing device through a web browser or a web-based application. The presentation tier communicates with the other tiers through application program interface (API) calls. The second tier is the Application tier: which may also be referred to as the logic tier, is written in a programming language such as Java and contains the logic that supports the application's core functions and can either be hosted on distributed servers in the cloud or on a dedicated in-house server, depending on how much processing power the application requires. The third tier is the Data tier which consists of a database and a program for managing read and write access to a database. MySQL is used to create the database. A drop-down option for choosing a crop is provided by the decision support system with prediction, location, district, and year for which prediction is to be performed. In the backend, the regression and thumb rules-based approaches have been used to predict the outcomes of the epidemic. A graphical representation is also provided for observed and predicted values.
- Used a Convolutional neural network (CNN) which is part of deep learning to extract input image features based on shape size and color. The input image is used by the feature extraction network. The neural network classification then works on the basis of the image features and produces the output. The neural network for feature extraction includes convolution layer piles and sets of pooling layers. As its name implies, the convolution layer also transforms the image using the process of convolution. It can be described as a series of digital filters. The layer of pooling transforms the neighbouring pixels into a single pixel. The pooling layer then decreases the image dimension. This is one of CNN's distinctive feature from other neural networks
- Various tools *viz*. keyword extractions, similarity measure, diffusion models, OCR conversion, updating in bulk uploading has been developed.

- Using the Scientometrics analysis, identification of the emerging scientific areas through keywords helps in monitoring early signals of new technologies.
- Updated the repository with real time data analytics, trending items, geographical spread of users visiting different parts of the repository.
- Organized three workshop cum sensitization program on "Uses of Digital Library for Strengthening Agricultural Knowledge in NARES" The topic covered in this program includes "Krishikosh- A digital repository for NARES"; "Consortium for e-Resources in Agriculture (CeRA)" and "Plagiarism and Regulations-Promotion of Academic Integrity and Prevention of Plagiarism in Higher Education Institutions" to the students and faculty of NARES
- Google analytics of Krishikosh during October 2017 - March 2022 indicates that 23.07 million hits are on Krishikosh website. India, United States, China, Philippines, Indonesia, Nigeria, Russia, Ethiopia, Nepal, Bangladesh are the top ten countries who have visited this digital platform. Krishikosh repository was viewed by 175 countries. The average daily thesis view from this repository is approximately 12428.
- Under e-Mitra platform, a knowledge base FAQ has been created for various commodity in agriculture. A database on MySQL has been created by taking commodity as a primary key and another table in which all queries and its response taken together are merged with the primary key table. These databases are integrated with the portal so that commodity wise FAQ can be viewed by the users especially farmers.
- Based on ajax, multiple graphical representations utilizing charts, bar graphs, pie charts, tables, etc. Additionally, various databases are also created for the graphical depiction of data. By utilizing these databases, a dashboard is established for real-time data access and displays the number at the time of database update. The graphical representation includes a reflection of the numbers and the complete information about the numbers displayed on the dashboard.

9.3.3.1 Services provided by AKMU

Web Applications Development Center at IARI developed many backend web applications along-with its updates which was integrated on the ICAR-IARI website. The list of web applications and its updates are listed below:

- Payment Gateway Integration with ICICI for all payments at the institute.
- Online seed portal for selling products from various divisions like SPU and Farm Publications.
- Complaint management system, a web application for handling complaints for services offered by AKMU
- Scientist Information Systems, a web application interface where all scientists can now update their information using their credentials online.
- Backend Web Applications for updating the Jobs/Tenders/News on the website.
- RTI Management System for maintaining the RTI page of the website. User can login and maintain the applications and their replies through this web application.
- A new website for IARI has been developed at AKMU which will be launched soon. Many new modules have been developed for this version of the website which will be revealed once the website is launched.
- Initiated the security audit of the ICAR-IARI website.
- IARI website hits during April 2021 to Dec, 2022 – 4.5 million new users and 24 million page view
- Cyber security attack from outside world (phishing, hacking, malicious activities, etc) – More than 20000 cyber-attack on daily basis
- Uploading of documents (events, jobs, tender, circular, order, etc.) – more than 1100 (Jan, 2022 to Dec., 2022) and updation of IARI website and Intranet on daily basis

AKMU is providing Internet connectivity to all the users of IARI. During the calendar year 2021, there was a major change in the working style of the institute as most of the activities were taken up online. Some of the activities during the time are as follows :

- The AKMU staff was working for the entire period under lockdown through remote services.
- A new server with better configuration was configured with the Zimbra software to provide mailing service to IARI users which are now working at a much faster pace.
- New DNS server was configured to provide the faster access to the sites hosted at IARI.
- A new web server was installed with WHM C Panel to provide the virtualized space for the website to all the end users. The software of C Panel was upgraded to a newer version. All the sites were migrated from older version of C Panel to the newer ones.
- Backup servers for IARI website and IARI mail services were created at library.
- Most of the meetings were conducted online during the lockdown period and support was provided for the conduct of such meetings.
- Provisions were made to monitor the data center temperature and humidity remotely.

Data Center at AKMU

10. PUBLICATIONS

An important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications are an integral component of the information system. During the reported period, the Institute scientists brought out quality publications in the form of research papers in peer reviewed journals, books/ book chapters, popular articles, etc. both in English and Hindi. Apart from these publications, the Institute brought out several regular and *adhoc* technical publications both in English and Hindi. The details of these publications are given below:

10.1 In-House Publications

10.1.1 Regular Publications (English)

- IARI Annual Report 2021 (ISSN: 0972-6136)
- IARI Current Events (Monthly)- 12 issues (Available only on IARI website)

10.1.2 Niymit Prakashan (Hindi)

- पूसा सुरभि (वार्षिक) (ISSN : 2348-2656)
- वार्षिक रिपोर्ट 2021 (ISSN : 0972-7299)
- प्रसार दूत (त्रेमासिक)
- भा.कृ.अ.स. सामयिकी (मासिक) (केवल संस्थान की वैबसाइट पर उपलब्ध)

10.1.3 Technical Publication

S. No.	Title Name of Book	Name of Division/Unit	Date of issue ISBN/ICN No.	ISBN/ICN No.
1.	Third Party Evaluation Report of FASAL (Forecasting Agricultural Output Using Space Agrometeorology & Land Based Observation) Scheme	Extension	February 14, 2022	978-93-83168-67-5
2.	अधेयता एवं नवोन्मेषी किसान– 2022 एक परिचय (Fellow and Innovative Farmer) An Introduction	Extension	March 04, 2022	978-93-83168-68-2
3.	Checklist on Bougainvillea Varieties	Floriculture and Landscaping	July 18, 2022	978-93-83168-69-9
4.	Techniques for Entomological Research	Entomology	January 07, 2022	TB-ICN: 267/2022
5.	Time Series Techniques for Forecasting in Agriculture	Economics	January 07, 2022	TB-ICN: 268/2022
6.	Identification and Management of Insects, Pest and Plant Pathogen Infecting Nutritional Crops	Plant Pathology	January 17, 2022	TB-ICN: 269/2022
7.	Smart Urban Farming Technology	CPCT	March 04, 2022	TB-ICN: 270/2022
8.	Improved Crop Cultivar for Enhancing Farmers'	Genetics	March 07, 2022	TB-ICN: 271/2022
9.	Technology for High Value Specially Melon Production: A Remunerative option for Proacted Cultivation	Vegetable Science	March 17, 2022	TB-ICN: 272/2022

10.	Seed Development Biology	Seed Science and Technology	March 21, 2022	TB-ICN: 273/2022
11.	Practical Manual on Production Technology of Underexploited Vegetable Crops (VSC-507)	Vegetable Science	March 21, 2022	TB-ICN: 274/2022
12.	POSHAN-V (Nutrition to Make Rural Women Shine)	Biochemistry	March 21, 2022	TB-ICN: 275/2022
13.	Water Footprint Assessment of Indian River Basins	Agricultural Engineering	March 26, 2022	TB-ICN: 276/2022
14.	Memories of Mina Swaminathan	Genetics	August 31, 2022	TB-ICN: 277/2022
15.	CRISPR-Based Plant Genome Editing Tools and Techniques	Plant Physiology	October 07, 2022	TB-ICN:278/2022
16.	Diversity, Genomics and Development of Robust Diagnostics for *Fusarium* SPP. Associated with Major Economically Important Diseases in India	Plant Pathology	October 07, 2022	TB-ICN: 279/2022
17.	Emerging Innovations in Plant Molecules for Achieving Food and Nutritional Security	Biochemistry	October 14, 2022	TB-ICN: 280/2022
18.	Nutri Dense Shiitake Mushroom a Diet for Healthier People	Biochemistry	November 10, 2022	TB-ICN: 281/2022
19.	Food Processing Technologies: Developing Smart Food for Boosting Human Health and Agripreneurship	Biochemistry	November 11, 2022	TB-ICN: 282/2022
20.	Manual of Immunochemistry	Biochemistry	November 11, 2022	TB-ICN: 283/2022
21.	Pearl Millet- The Pearl of Indian Agricultural for Developing for Smart Food for Future	Biochemistry	November 16, 2022	TB-ICN: 284/2022
22.	Diagnosis and Management of Economically Important Insect Pests in Agriculture	Entomology	November 21, 2022	TB-ICN: 285/2022
23.	Advanced Methods for Testing Quality Parameters of Biopesticide	Entomology	November 23, 2022	TB-ICN: 286/2022
24.	Ergonomics and Safety in Agricultural Operations	Engineering	December 16, 2022	TB-ICN: 287/2022
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25.	Naino Prodyogikee ka Krishi mai Mahtva	Physics	February 14, 2022	ICN :H-193/2022
26.	Kisanon ki Smridhi evam Vyvsyeekarn hetu Shakeeya Faslon kee Anumodit Kismen	Vegetable Science	March 04, 2022	ICN :H-194/2022
27.	Smart Shahree Krishi Prodygikee	CPCT	March 04, 2022	ICN :H-195/2022
28.	Sabjee Phasal calender : Masik Karya	Vegetable Science	March 07, 2022	ICN :H-196/2022
29.	Kisanon ki Aay Vridhi hetu Faslon kee unnat kismen	Genetics	March 07, 2022	ICN :H-197/2022
30.	Prakshetra Faslon ke Gunvatta beej Utpadan mai takneekee pragati	R.S. Karnal	March 11, 2022	ICN :H-198/2022
31.	Farmers First Project Tahat *Rabi* Faslon mai Beej Utpadan Takneek	R.S. Karnal	March 14, 2022	ICN :H-199/2022

32.	Krishi mai Urjaa	Publication Unit	July 05, 2022	ICN :H-200/2022
33.	Fasal Avshesh Prabandhan dwara Paryavarn Suraksha	Publication Unit	July 05, 2022	ICN :H-201/2022
34.	Kendra dwaraViksit gehoon kee Naveen Prajatiyan evam Sanstut Sasya Kriyayen	R.S. Indore	September 29, 2022	ICN :H-202/2022
35.	Mushroom Utpadan ki Vaigyanik Vidhiyan	Plant Pathology	December 06, 2022	ICN :H-204/2022

10.2 PUBLICATIONS AT A GLANCE

1.	**Research/Symposia Papers**	
a.	Research papers (with international impact factor or NAAS rating 6 and above) published in journals	**668**
b.	Symposia/conference papers	**245**
2.	**Books/Book Chapters**	
a.	Books	**22**
b.	Chapters in books	**154**
3.	**Popular Articles**	**291**

10.2.1 Research publications (NAAS rating >10)

- Adhikary S, Biswas B, Chakraborty D, Timsina J, Pal S, Tarafdar J C, Banerjee S, Hossain A, Roy S. 2022. Seed priming with selenium and zinc nanoparticles modifies germination, growth, and yield of direct‑seeded rice (*Oryza sativa* L.). *Scientific Reports* **12:** 7103
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- Chaithra M, Prameeladevi T, Bhagyasree S N, Prasad L, Subramanian S, Kamil D. 2022. Multilocus sequence analysis for population diversity of indigenous entomopathogenic fungus *Beauveria bassiana* and its bio-efficacy against the cassava mite, *Tetranychus truncatus* Ehara (Acari: Tetranychidae. *Frontiers in Microbiology* 13:1007017
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11. IP MANAGEMENT, PATENTS, TECHNOLOGY COMMERCIALIZATION AND AGRIBUSINESS INCUBATION ACTIVITIES

The mission of the Zonal Technology Management and Business Planning and Development (ZTM & BPD) Unit is, "Translating Research into Prosperity" which is achieved by doing IP management, technology commercialization and fostering entrepreneurship through business incubation. During the period, the unit has organized following activities:

11.1 TECHNOLOGY COMMERCIALIZATION

During the year 2022, under Lab to Land Initiative, Seventy-Seven (77) innovative technologies of ICAR-IARI were transferred to 120 industry partners resulting in revenue generation of ₹ 1,70,12,054 (₹ One Crore Seventy lakh Twelve Thousand Fifty Four only). These technologies included the Improved Pusa Wheel Hand Hoe, Improved Pusa Pre-Germinated Paddy Seeder, Improved Pusa Manual Paddy Thresher, Manual Operated Multi-Crop Vegetable Seed, Direct Paddy Seeder Planter, Power operated winnower, Pusa Basmati 1509, Seed Production Technology of Pusa nanha, Pusa Mustard 28, Palak-All Green, Onion-Pusa Red, PUSA Electronic Seed Metering Module for cultivators, Pusa Mustard 32, Pusa Mustard 33 etc.

11.2 CORPORATE MEMBER: 246

Revenue from membership: ₹ 1007500 (₹ Ten lakh seven thousand five hundred only)

11.3 IP MANAGEMENT

IPRs	Application / Registration No.	Name of Innovation/ Technology / Product/ Variety	Date of Filing / Registration	Application in Process*	Application Granted/ Registered**
Patent	**202211021108**	A compost turner cum mixer device and a method thereof	8/04/2022	Filed	
	202211021109	A constant head soil moisture application system and a method thereof	8/04/2022	Filed	
	202211021110	A paddy straw collector cum chopper with microbial culture applicator and a method thereof	8/04/2022	Filed	
	3981/DEL/2014	Process for Obtaining High Purity Phycocyanin from Cyanobacteria	01/06/2022	Granted	398346
	202111034651	An acid free premix sprayable biopolymeric composition	2/08/2022	Complete specification filed	
	202211042351	A process for the production of calcium-enriched pumpkin crisps through the atmospheric deep-frying	25/07/2022	Filed	

	202211039287	Bio pesticidal Multicomponent Oil Dispersions and Process	08/07/2022	Filed	
	202211056249	Moisture retaining pH resilient composition containing entomo-pathogenic nematodes	30/09/2022	Provisional Filing	
	• 13 patents were renewed • 5 Prior art searches for Inventions • Form 4 was filed for # 201711016288 • 1 response to NBA regarding Status Report for File No.421 • FER response filed for # 201711016288; 202011030310, 201911051754 • Form 28 submitted for Patent Number: 380017; 250349 • Renewal of Patent Numbers: 338098, 290085; 295150; 300102; 296712; 250349 • Form 28 submitted for Patent Numbers: 338098 • NBA matter and reply filed for INBA 2202103296 (Grow Indigo) • NBA matter and reply filed for INBA 2202102965 • NBA matter and reply filed for INBA 2202102971 • 3 FER filed for the application numbers:202011024290, 202011026699 and 202011028155 • 3 renewals for the patent number: 398346, 330282, 292524 • Form 27 (Working of Patents) filed for 24 Patents • Provisional Patent Application filed for application No: 202211056249				
Trade-marks	5481683	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481684	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481685	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481686	SHITIJ	09-June-2022	Filed	
	5481687	SHITIJ	09-June-2022	Filed	
	5481688	SHITIJ	09-June-2022	Filed	
	5481689	BEEJ	09-June-2022	Filed	
	5481690	BEEJ	09-June-2022	Filed	
	5481691	BEEJ	09-June-2022	Filed	
	5481692	PUSA KRISHI	09-June-2022	Filed	
	5481693	PUSA KRISHI	09-June-2022	Filed	
	5481694	PUSA KRISHI	09-June-2022	Filed	
	5481695	PUSA KRISHI	09-June-2022	Filed	
	5481696	ARISE	09-June-2022	Filed	
	5481697	ARISE	09-June-2022	Filed	
	5481698	ARISE	09-June-2022	Filed	
	5481699	PUSA KRISHI	09-June-2022	Filed	
	5481700	PUSA KRISHI	09-June-2022	Filed	
	5481701	PUSA KRISHI	09-June-2022	Filed	
	5481702	PUSA KRISHI	09-June-2022	Filed	
	5481703	UPJA	09-June-2022	Filed	

	5481704	UPJA	09-June-2022	Filed	
	5481705	UPJA	09-June-2022	Filed	
	5481706	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481707	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481708	AGRIINDIA HACKTHON	09-June-2022	Filed	
	5481709	SHITIJ	09-June-2022	Filed	
	5481710	SHITIJ	09-June-2022	Filed	
	5481711	SHITIJ	09-June-2022	Filed	
	5481712	BEEJ	09-June-2022	Filed	
	5481713	BEEJ	09-June-2022	Filed	
	5481714	BEEJ	09-June-2022	Filed	
	4399017	Jalopchar	12-Sep-2022	Registered	
	4430603	ARISE	29-Sep-2022	Registered	
	4430612	MAITRI	1-Nov-2022	Registered	
	4430613	MAITRI	1-Nov-2022	Registered	
	4430614	MAITRI	1-Nov-2022	Registered	
	• Written Submission Filed for 3 Trademark Applications • Trademark Hearing attended for 7 Trademark Applications • 5 Trademark granted for application number				
Copyrights		'CsExSLDb transcriptome.	27/01/2022	Filed	
	Diary Number: 1710/2022-CO/SW	Pusa infoseed software code	30/06/2022	Filed	

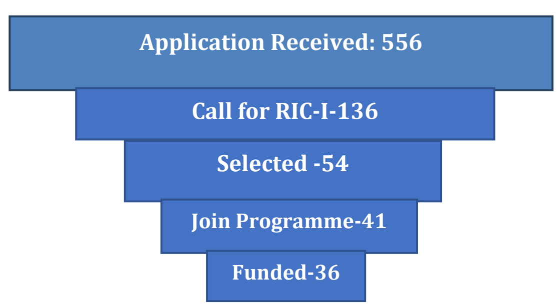
PPVFR

S. No.	Acknowledgement No.	Denomination	Crop Type	Year of Filling
1	REG/2022/0120	HD3385	Wheat	2022
2	REG/2022/0129	PB1847	Rice	2022
3	REG/2022/0128	PB1885	Rice	2022
4	REG/2022/0127	PB1886	Rice	2022

11.4 INCUBATION ACTIVITIES

11.4.1 Incubation Activities under RKVY-RAFTAAR Project

Seed (UPJA) stage incubation was launched on April 01, 2022: an incubation & business acceleration program to promote innovation and entrepreneurship in India's agri-startups ecosystem. The deadline for the program was on April 30, 2022. Pre-seed (ARISE) was launched on May 4, 2022: a moving from idea incubation & to business, the deadline for the program was May 25, 2022. These applications were evaluated by three experts (Technical, Business, and incubator team) and 136 applicants were invited to present their idea before the RIC-I committee members. Finally, 54 startups were selected after technical & business assessment by the Selection committee of RIC-1 for a two-month incubation program. And 36 startups were supported by RKVY-RAFTAAR funding.



11.4.3. Letter of support and Agreement with startups:

To attend the 2-month incubation programme a letter of support has been given to 54 startups. After a 2-month incubation programme, the RC committee (fund recommendation committee) recommended 36 startups for grant-in-aid.

11.4.3. Grant-in-aid to startups:

The grant-in-aid has been dispersed to 36 startups of last year's cohort (2021-22) in mid-June-2022. Accordingly, the agreement was signed with 36 startups before releasing the funds. The extension agreement was signed with 14 startups to release the third instalment under RKVY-RAFTAAR, DAC, Govt of India.

11.4.4 Incubation Activities under ABIC Project

Under ABIC, ICAR, 8 startups were Incubated and connected with IARI scientists for technical support. Mentoring sessions were arranged with corporate and business experts. For IP support, the IP session has been conducted with the IP team of the ZTM & BPD unit, IARI.

11.4.5 Incubation Activities under NIDHI-TBI, DST Project

Under the One-year Shitij incubation programme, Pusa *Krishi* has received 261 applications. Each application was evaluated by three evaluators (Technical, Business/ Finance and Incubator) and shortlisted 67 applications for the preliminary round where the startups pitched in front of the Jury members over a period of 3 days - January 19-21, 2022 and finally selected 31 startups out of which 24 participated in the program. Letter of support was given to 24 startups and provided business connect and technical experts.

11.4.6 Women Quake Program

It is a 3-day pre-incubation series that brings together women entrepreneurs with their path-breaking, daunting, and world-changing ideas. The program was launched on 16th February 2022 and the deadline for online application submission till March 6, 2022 for which we received a total of 31 applications, and 21 participants attended the three days programme. Three Days Workshops was a mix of learning, and discussions on Workshop based Sessions, Upskill Yourself for Future Business, Learn from the Best Mentors, Access to Knowledge Resources, Network & Community Building etc.

11.4.7 Beej

It is an online program for young entrepreneurs to learn how to generate, build & scale startup ideas in the agriculture sector. The Beej programme was launched on August 22, 2022 and the deadline of application was September 11. A 2022, total of 54 applications were received, and the programme was attended by 45 participants.

11.4.8 RIC Meetings for selection of startups for incubation programme and fund recommendations for following RABI:

RABI	Date of RIC 1	Date of RIC 2	Date of RIC 3	Date of RIC 4
Chaudhary Charan Singh University, Hisar	Cohort 4 (Nov 30, 2022)	Cohort 3 (March 02, 2022)	Cohort 1 (May 24, 2022) Cohort 2 (May 24, 2022)	
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur			2020- 2021 batch (March 29, 2022)	2019- 2020 batch (March 29, 2022)
IIT-BHU, Varanasi	Cohort 5 (Dec 7, 2022)	Cohort 4(Feb 14, 2022)	Cohort 1 (Dec 8. 2022) Cohort 3 (Dec 8, 2022)	
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur	Cohort 4 (May 25- 26, 2022)	Cohort 4 (Dec 01, 2022)	Cohort 1 (June 4, 2022)	

ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly	Cohort 4 (July 25-26, 2022)	Cohort 3 (Jan 28, 2022)	Cohort 1 (July 27 & 29, 2022)	
Punjab Agricultural University, Ludhiana	Cohort 4 (Jan 23-24, 2022)	Cohort 3 (Jan Jan 18-19, 2022)	Cohort 2 (July 15, 2022)	
Indira Gandhi Krishi Vishwavidyalaya, Raipur	Cohort 4 (June 1-2, 2022)	Cohort 4 (Nov 10-11, 2022)	Cohort 3 (August 29, 2022)	Cohort 1 (August 17, 2022) cohort 2 (August 18, 2022)
Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar	Cohort 5 (June 22, 2022) Cohort 6 (Nov 23, 2022)	Cohort 4 (July 26, 2022) Cohort 5 (Nov 23, 2022)	Cohort 1 (June 22, 2022)	
IIM, Kashipur	Cohort 4 (August 25-26, 2022)	Cohort 4 (Nov17-18, 2022)		Cohort 1 (Nov 15, 2022) Cohort 2 (Nov 16, 2022)

11.4.9 Shitij

A full-throttle capacity building, infrastructure, and other resources are provided to early-stage companies as part of the year-long incubation programme SHITIJ to help them find creative solutions to the major problems in agriculture. The initiative aims to unite innovators for a comprehensive 15-day mentorship programme where they may share knowledge and work together. They will get additional incubation in a one-year programme at Pusa Krishi, ICAR-IARI, expanding their network, resources, and rate of growth.

Shitij 2021: Shitij learning sessions were held from April 11–14, 2022, and April 18–21, 2022, to strengthen the innovation landscape and boost the engagement of startups in the agricultural sector. A total 15 online sessions were conducted.

Shitij 2022: Shitij 2022 was launched on October 17, 2022. There were 113 applications in all. On December 19 and 20, a meeting was organised to screen these businesses, during which 32 startups were chosen.

11.4.10 SAMARTH: Empower the Incubators

The Samarth was organized on June 04 & 05, 2022. The welcome remarks of the program were given by Dr. Neeru Bhooshan, CEO, Pusa Krishi, IARI. Dr. A.K. Singh, Director of IARI communicated about the gap in the agriculture sector and how the startup can fill the gap in the agriculture sector with innovation. After that chief guest Chhavi Jha Joint secretary, DAC, Govt of India explained the progress of the scheme over the last three years. Dr. Neeru Bhooshan, Dr. Charnjeet Kaur, Principal Scientist, Division of PHT, IARI, Dr. J.P.S. Dabas, Incharge, CATAT, IARI, Dr. A.K. Saxena, Retired Principal Scientist, Microbiology, Dr. Ramesh Mittal, Director, NIAM,, reviewed the progress of the 29 incubators on 2nd day (05.08.0202), the MIS portal was displayed by the RKVY-RAFTAAR Division to upload the online data. A detailed discussion was held on the platform to further improve the MIS portal as per the incubator's suggestion.

SAMARTH programme by Pusa Krishi

11.4.11 Upja

This programme aims to nurture early-stage innovators & entrepreneurs to transform the future of agriculture. It provides technology validation, mentoring & guidance, pilot opportunities, go-to market support, and industry linkage to startups with innovative solutions at MVP (Minimum Viable Product) stage. This programme has a provision of funding upto ₹ 25,00,000 per startup. It was launched on 1st April 2022. We received a total of 334 applications. On 5th of April preliminary result was announced and cohort announcement was done on 25th of May. 112 startups were shortlisted for the RIC-1 meeting and 46 startups were selected for the 2 months incubation programme.

11.4.12 ARISE

'Arise' intends to nurture & scale early-stage ideas & startups into sustainable businesses. The program provides access to business & technology validation, strong mentoring & advisory, market linkages & connections with a view to create impactful solutions in the agriculture ecosystem.

Under this program, a provision of grant in aid of upto ₹ 5,00,000 per start-up is made. The cohort announcement was done on 10th June 2022 after the presentations made by the startups in front of the expert RAFTAAR Incubation committee. In this programme we received a total of 232 applications and 30 startups were shortlisted for the RIC meeting.

11.4.13 Two-month incubation program

It has started on July 4, 2022, that included core mentoring sessions by industry and subject matter experts based on the focus area of the startup. Mentors helped the startups in diverse areas like; creating successful products, revamping the existing solutions, modifying the business model, finance, and best go-to-market strategies. Startups that required a new approach to reach out to the farmers with their best solution have been mentored to create new strategies for successful implementation.

There were a total of 28 learning sessions, 408 one on one mentoring sessions conducted by 30 industry and 18 business experts, and 22 expert speakers. After this and completing RIC II, out of 40 startups, thirty-eight (38) startups presented their innovation and technologies before the RC committee, and two (2) startups were absent. The committee discussed thirty-eight (38) proposals. Finally, twenty (20) startups were recommended for seed and sixteen (16) for pre-seed stage funding. On the culmination of Cohort 2020, an online valedictory ceremony for startups was organized on 3rd Sept 2022, where the incubates made a pitch to the audience and shared their experience of incubation at Pusa Krishi in front of Joint Director Research, IARI, New Delhi.

11.4.14 Agri – India Meet 2.0

Pusa Krishi conducted the first Agri India Meet in 2021, attracting participants from all corners of the industry in its ongoing effort to grow the ever-evolving agri-startup ecosystem advancing the course established by the first edition and our other recent projects. AIM 2.0, the second series of the Agri India Meet, was held from November 21 to December 3, 2022. Around 40 speakers participated in the 9 editions of Agri India Meet that we hosted. About 500 people registered for the event, and each episode attracted over 200 participants.

11.4 MARKETING & PROMOTION CAMPAIGN

11.4.1 Pusa Krishi Vigyan Mela

The Pusa Krishi Vigyan Mela took place from March 9 to 11, 2022. Shri Kailash Choudhary, the Union Minister of State for Agriculture & Farmers' Welfare, gave it a formal opening. "Self-sufficient Farmers with Technological Knowledge" was the subject. The fair's main draws included organic and natural farming, protected agriculture, hydroponic, aeroponic, and vertical farming, as well as smart/digital agriculture, agri startups, and farmers producer organisations (FPO). We helped 32 Startups to showcase and promote their technologies by providing them a marketing and networking platform in the form of stalls.

During Pusa Krishi Vigyan Mela, 2022

11.4.2 PM Kisan Samman Sammelan and Agri-start up Conclave

On October 17 and 18, 2022, the two-day Agri Startup Conclave & PM Kisan Samman Sammelan was held. This colloquium celebrated India's innovative agricultural innovations. The event, which encouraged discussion on current concerns and the best course of action, drew more than 15,000 farmers and FPOs, 500 agri-startups, senior government officials, lawmakers, business veterans, scientists, and academicians. The Agri Startup Conclave & Kisan Sammelan were organised under the direction of the Ministry of Agriculture & Farmers' Welfare and was hosted by Pusa Krishi, ICAR-IARI as knowledge partners. Around 266 startups, under 5 hangers including Post Harvest Technology, Precision in Agriculture, Farm Mechanisation, Waste to Wealth & Supply Chain showcased their technology and there were 4 Panel discussions on the topics "Startups Solving Hyper Local Problems of the Agricultural Value Chains", "Building an Eco-system for Farming as a Service", "Delivering Digital Public Goods to Farmers" and "International Experiences".

11.4.3 Kisan Bhagidari Prathmikta Hamari

The campaign ***"Kisan Bhagidari Prathmikta Hamari"*** was organized in village Daha at Baghpat, Uttar Pradesh on 26.04.2022. Total 12 start-ups interacted with 100+ farmers and demonstrated their technologies. The start-ups showed their technologies like an Animal repellent machine, rapid milk adulteration card, agri-input to increase the yield, low-cost mini potatoes harvester, sugarcane bud-stalk bud cuter machine, the mini turbine for electricity production, a diagnostic device for detection of mastitis in milk and, also introduced about the online platform to farmers to get the immediate opinion of farmers for various farm operations and activity. Dr. Neeru Bhooshan, CEO Pusa Krishi enlightened the various start-up innovations, and working operations of the RKVY-RAFTAAR scheme to get the benefits from the program. Dr. J.P.S Dabas, Head CATAT briefed about the IARI technologies and start-ups innovations that can be directly beneficial for the farmers, and also guided the formation of the Farmer's Production Company

PM Kisan Samman Sammelan and Agri-start up Conclave

Kisan Bhagidari **campaign**

(PFO) for easy installation of new technologies in the field and further motivate the processing process of agri- produce.

11.5 AGREEMENTS SIGNED

36 Agreements were signed with startups for Business, Technical, IP, Physical Space and funding support from IARI. A total of 120 agreements were signed with the industries for the commercialization of IARI technologies from January 2022 to December 2022.

11.6 OTHER ACTIVITIES

76 IARI startups showcased their technologies at *PM kissan Sammelan and Agri- startups Conclave* was held on October 17-18, 2022 at Pusa *Mela* Ground.

11.6.1 Trainings and Capacity Building Programs Organized:

S. No.	Name of Programme (Training/workshop/Seminar etc.) Organized	Date of Programme	Participants (No)
1	**IPR Awareness Program** With the objective to build greater awareness and develop insights into the complex mechanism of creation, ownership, and protection of Intellectual Property (IP), three days "IPR Awareness Program" was launched by Pusa Krishi, ZTM-BPD via online video conferencing mode. The areas covered in this 3-day program were: Overview of IPR and Relevance; Introduction to copyrights Act; Trademark; Industrial Design; Introduction to Patents; and IP Management and Strategy.	February 21-23, 2022	38
2	**IP WORKSHOPS** Pusa Krishi organised the practical programme to study "Patent Search & Drafting". The three-day event has covered a variety of topics, including how to start using your patents and why it's crucial for your company. This class was beneficial for entrepreneurs, inventors, and anybody interested in learning more about patent hunting and drafting who has a basic to intermediate understanding of patents.	June 22-24, 2022	39

3	**Online IP Workshop on Patent Drafting and prosecution of AI and ML Inventions** A workshop to build ideas and solutions related to Artificial Intelligence and Machine Learning technologies was conducted to learn searching and drafting of patent applications related to Artificial Intelligence and Machine Learning technologies.	September 27-28, 2022	15
4	**Agripreneurship Development Program** A 3-day ADP training program on "**Spirulina cultivation and value-added product formulations"** was organized from 4th to 6th July by ZTM & BPD Unit, CCUBGA & Division Microbiology, ICAR - IARI. This program was organized to train the entrepreneurs, progressive farmers and students on cultivation, processing, and formulation of value-added products from spirulina biomass.	July 4-6, 2022	23
5	**Agripreneurship Development Program** A 3-day ADP training program was organized on "**Agripreneurship Development Programme on Processing techniques of horticultural and arable crops**" at ZTM & BPD Unit along with Division of FS & PHT, ICAR-IARI.	August 22- 27, 2022	13
6	**Agripreneurship Development Program** A 5-day ADP training session on "**Processing of Millets & Alternate Grain Foods"** was organised by ZTM & BPD Unit, CCUBGA & Division of Food Science, and PHT, ICAR - IARI. This programme was set up to educate budding businesspeople, forward-thinking farmers, and students on how to grow, prepare, and create value-added goods from spirulina biomass.	November 21-25, 2022	15

Memorandum of Understanding (MoU) between IARI, New Delhi and M/S. Jain Irrigation Systems Limited (JISL) Jalgaon – 425 001, Maharashtra For COLLABORATIVE EDUCATION, RESEARCH AND EXTENSION

Memorandum of Understanding (MoU) between IARI, New Delhi and Banda University of Agriculture and Technology (BUAT) , Banda, U.P on 20th August 2022 for "Collaborative Research/ Extension/Seed Production Programme "

Memorandum of Understanding (MoU) between IARI, New Delhi and Quality Council of India (QCI) *DPIIT, Ministry of Commerce, GoI* on 3rd August 2022 for "Institutional Collaboration and Coordination for Training and Capacity Building Programs Envisaging National Level Activities in the Domain of Agriculture"

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, centers, 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 phenomics 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 focused 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 such 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, Bill & Melinda Gates Foundation, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The number of externally funded projects in operation during the period from 01.01.2022 to 31.12.2022 is given below:

Name of Funding Agency	**Number of Projects**
Within India Department of Biotechnology (DBT), Department of Science & Technology (DST), National Committee Plasticulture Application in Horticulture (NCPAH), Council of Scientific and Industrial Research (CSIR), Department of Agriculture and Cooperation (DAC), Indian Meteorological Department (IMD), Board of Research in Nuclear Sciences (BRNS), Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), Space Application Centre (SAC), Ministry of Human Resource and Development (MHRD), National Bank for Agriculture and Rural Development (NABARD), NITI Aayog, Ministry of Environmental, Forest and Climate Change (MoEF&CC), UP Council of Agricultural Research (UPCAR), Rashtriya Krishi Vikas Yojna (RKVY), Ministry of Food Processing Industries (MoFPI), National Thermal Power Cooperation (NTPC), Ministry of Steel, Central Pulp & Paper Research institute (CPPRI), Department of Scientific & Industrial Research (DSIR), Indian Council of Agricultural Research (ICAR), Ministry of Electronics & Information Technology (Meity), Central Council for Research in Ayurvedic Science (CCRAS) and Delhi Research implementation & innovation foundation (DRIIV)	220
Outside India Bill & Melinda Gates Foundation & UK Department of International Development (DFID), Bill & Melinda Gates Foundation, ICAR-International Rice Research Institute, HarvestPlus-International Food Policy Research Institute, USA, Centre for Agriculture and Bioscience International (CABI), United Kingdom, International Fertilizer Development Centre (IFDC), USA, Heinrich Heine University (HHU), Germany, United Kingdom Research and Innovation (UKRI)	16
Total	**236**

13. AWARDS AND RECOGNITIONS

- Dr. A.K. Singh, Director, ICAR-IARI received the Fellowship of National Academy of Sciences, India (NASI).
- A team led by Dr. A.K. Singh, Director, ICAR-IARI received Nanaji Deshmukh ICAR award for Outstanding Interdisciplinary Team Research in Agricultural and Allied Sciences 2021.
- Dr. Rajbir Yadav, Principal Scientist, Division of Genetics received the Fellowship of National Academy of Agricultural Sciences (NAAS), India.
- Dr. H.K. Dikshit, Principal Scientist, Division of Genetics, received the Fellowship of National Academy of Agricultural Sciences (NAAS), India.
- Dr. Radha Prasanna, Principal Scientist, Division of Microbiology received the Fellowship of National Academy of Agricultural Sciences (NAAS), India.
- Dr Kalyan K Mondal, Principal Scientist, Division of Plant Pathology received the fellowship of National Academy of Agricultural Sciences (NAAS), India.
- Dr. C.M. Parihar, Senior Scientist, Division of Agronomy was elected as Fellow-National Academy of Agricultural Sciences (NAAS), India.
- Dr. Charanjit Kaur, Head (Acting) & Principal Scientist, Division of Post-harvest technology, was elected as NAAS Fellow.
- Dr Tushar K Dutta, Senior Scientist, Division of Nematology received Fellowship of NAAS, India.
- Dr. Debashis Chakraborty, Principal Scientist, Division of Agricultural Physics received Fellow of the National Academy of Agricultural Sciences (NAAS), India.
- Dr. Dinesh Singh, Principal Scientist, received Fellow of Asian PGPR Society 2022, conferred by Asian PGPR Society, USA
- Dr. Prolay Kumar Bhowmick, Senior Scientist, Division of Genetics received Associateship of National Academy of Agricultural Sciences, India.
- Dr. Vignesh Muthusamy, Senior Scientist, Division of Genetics received Associateship of National Academy of Agricultural Sciences, India.
- Dr Amalendu Ghosh, Senior Scientist, Division of Plant Pathology received Associateship of National Academy of Agricultural Sciences, India.
- Dr. Vignesh Muthusamy, Senior Scientist, Division of Genetics received Young Scientist Award, National Academy of Agricultural Sciences, New Delhi.
- Dr Amalendu Ghosh, Senior Scientist, Division of Plant Pathology received Young Scientist Award, National Academy of Agricultural Sciences, New Delhi.
- Dr. Haritha Bollinedi, Scientist, Division of Genetics, received NASI Platinum Jubilee Young Scientist Award 2022 of National Academy of Sciences India, Prayagra.
- Dr. Vignesh Muthusamy, Senior Scientist, Division of Genetics received NASI Platinum Jubilee Young Scientist Award of National Academy of Sciences India (NASI).
- Dr. Chellapilla Bharadwaj, Principal Scientist, Division of Genetics received Hon. Adjunct Associate Professor, The UWA Institute of Agriculture, the UWA, Perth
- Dr. A.K. Singh, Director, ICAR-IARI received Shri Ram Chandra Rao Memorial National Award by ANGRAU, Andhra Pradesh.
- Dr. Mukesh K. Dhillon, Principal Scientist, Division of Agricultural Entomology, elected as Fellow of the Royal Entomological Society.

- Dr Chellapilla Bharadwaj, Principal Scientist, Division of Genetics received Eminent Scientist Award of Agrivision 2022
- Dr. Subhash Babu, Scientist, Division of Agronomy, received NESA Young Scientist of the Year Award-2020 of National Environmental Science Academy, New Delhi.
- Dr. Rajkumar U. Zunjare, Scientist, Division of Genetics received Fellow of Indian Society of Genetics and Plant Breeding (ISGPB), Division of Genetics, ICAR-IARI, New Delhi.
- Dr. Rajkumar U. Zunjare, Scientist, Division of Genetics received Srinivasa Ramanujam Memorial Award of ISGPB, New Delhi.
- Dr. Firoz Hossain, Principal Scientist, Division of Genetics received Dr. B.P. Pal Medal, ICAR-IARI, New Delhi.
- Dr. H.K. Dikshit, Principal Scientist, Division of Genetics received Dr. A.B. Joshi Memorial Award (Biennial) of ISGPB, New Delhi
- Dr. G.P. Mishra, Principal Scientist, received Dr. Harbhajan Singh Memorial Award (Biennial) of ISGPB, New Delhi.
- Dr. Vikas VK, Senior Scientist, Regional Station Wellington received Fellow, National Academy of Biological Sciences (NABS), India.
- Dr. Kajal Kr. Biswas, Principal Scientist, Division of Plant Pathology elected as Fellow, National Academy of Biological Sciences (NABS), India.
- Dr. Manoj Khanna, Principal Scientist, Division of Water Technology Centre, received Fellow of Indian Society of Agricultural Engineers (ISAE).
- Dr. S.P. Singh, Principal Scientist, Division of Agricultural Engineering, received Fellow of Society for Sugar Research & Promotion, New Delhi,
- Dr. S.P. Singh, Principal Scientist, Division of Agricultural Engineering, received Fellow of International Society for Noni Science, Chennai.
- Dr Manish Srivastav, Professor & Principal Scientist, Division of Fruit and Horticulture Technology, received fellowship from Society for Horticulture Research and Development.
- Dr. Susama Sudhishri, Principal Scientist, Division of Water Technology Centre, received Fellow of Indian Association of Soil and Water Conservationists, ICAR-IISWC, Dehradun.
- Dr. C.M. Parihar, Senior Scientist, Division of Agronomy was elected as Fellow, Maize Technologists Association of India-2020.
- Dr A.K. Goswami, Senior Scientist, Division of Fruit and Horticulture Technology received fellowship from International Society of Noni Science.
- Dr. Markandey Singh, Principal Scientist, Division of Floriculture& Landscaping, received Fellow of Society of Tropical Agriculture, New Delhi.
- Dr. Y.S. Shivay, Principal Scientist, Division of Agronomy received Fellow of the 'Crop and Weed Science Society' for the year 2020–21.
- Dr A.K. Goswami, Senior Scientist, Division of Fruit and Horticulture Technology, received Fellowship from Society for Community Mobilization for Sustainable Development.
- Dr. Livleen Shukla, Principal Scientist, Division of Microbiology, received "Outstanding Women Researcher Award" at 7th Asian PGPR International Conference, Malaysia.
- Dr. J. Berliner, Senior Scientist, received AZRA Young Scientist Award.
- Dr. R.N. Padaria, Joint Director (Extn) received IARI's 2nd Best Agriculture Extension Scientist Award 2022.
- Dr. Ganapati Mukri, Senior Scientist, received Dr. NN Singh Young Scientist Award of Maize Technologists Association of India.
- Dr.Nanjundan J, Senior Scientist, received Scientist of the Year Award.
- Dr. C.M. Parihar, Senior Scientist, Division of Agronomy received Best Teacher Award-2021 of ICAR-Indian Agricultural Research Institute, New Delhi.

- Dr. Sagar D., Scientist, Division of Agricultural Entomology received NESA Scientist of the year Award-2022 from National Environmental Science Academy, New Delhi.
- Dr Rajendra Kumar, Principal Scientist, received Honorary Fellowship Award-2021 conferred by SRDA- Society for Recent Development in Agriculture.
- Dr. Kajal Kr. Biswas, Principal Scientist, Division of Plant Pathology was elected Secretary, Indian Phytopathological Society, New Delhi
- Dr. Tusar Kanti Bag, Principal Scientist, received Fellow, Indian Association of Hill Farming, Barapani, Meghalaya
- Dr Shumaila Sahid, Scientist received Dr. Rajendra Prasad Excellence Scientist Award 2022
- Dr. Vijay, Principal Scientist, Division of Seed Science and Technology received RMSI Fellow Award by Range Management Society of India, ICAR-IGFRI, Jhansi.
- Dr. S.S. Rathore, Principal Scientist, Division of Agronomy, received Fellow- Indian Society of Agronomy.
- Dr. S.S. Rathore, Principal Scientist, Division of Agronomy received fellowship of Indian Association of Hill framing.
- Dr. S.S. Rathore, Principal Scientist, Division of Agronomy was elected NESA Fellow- National environmental Science academy.
- Dr GK Mahapatro, Principal Scientist, Regional Station Pune, received Eminent Scientist Awards – 2022 by Society of Agricultural Research & Social Development, New Delhi.
- Dr. S.K. Yadav, Principal Scientist, Division of Soil Science and Technology received Distinguished Researcher in Seed Science and Technology Award by the Venus International Research Awards.
- Dr. Kapila Shekhawat, Senior Scientist, Division of Agronomy received PS Deshmukh Young Agronomist Award, 2021.
- Dr. Reeta Bhatia Dey, Senior Scientist, Division of Floriculture & Landscaping received Ghosh Young Scientist Award from Indian Academy of Horticultural Sciences.
- Dr. Reeta Bhatia Dey, Senior Scientist, Division of Floriculture & Landscaping received Young Scientist Award from Tech Horticultural Society-Meerut.
- Dr. Namita, Senior Scientist, Division of Floriculture& Landscaping received Outstanding Horticultural Woman Scientist Award from SHRD-Society for Horticultural Research and Development (SHRD), Ghaziabad.
- Dr. Sapna Panwar, Scientist, Division of Floriculture& Landscaping received HTHS Gold Medal Award, from Tech Horticultural Society, Meerut, U.P.
- Dr. Anchal Dass, Principal Scientist, Division of Agronomy received Outstanding Scientist Award-2021 from Society of Tropical Agriculture, New Delhi.
- Dr. R.S. Bana, Senior Scientist, Division of Agronomy received ISA Associateship Award of Indian Society of Agronomy.
- Dr.Vijay Pooniya, Senior Scientist, Division of Agronomy, received Dr. P.S. Deshmukh Young Agronomist ISA Award-2019.
- Pravin K. Upadhyay, Scientist, Division of Agronomy, received P.S. Deshmukh Young Agronomist Award by the Indian Society of Agronomy.
- Dr. Vishal Tyagi, Scientist, Division of Agronomy received Best Ph.D. thesis award during International Agronomy Congress held at PJTSAU, Hyderabad.
- Dr. Mona Nagargade, Scientist, Division of Agronomy, received Young Scientist Award on the occasion of 71st foundation day of ICAR-Indian Institute of Sugarcane Research, Lucknow.
- Dr. K.K. Bandyopadhyay, Principal Scientist, Division of Agricultural Physics received Fellow, Indian Society of Soil Science.

- Dr. Ananta Vashist, Principal Scientist, Division of Agricultural Physics received Fellow Diamond achiever award 2022 by Council for Academic Performance & Appraisal, New Delhi.
- Dr. Debarup Das, Scientist, Division of Soil Science received Mosaic Company Foundation Award 2019-2020.
- Dr. Lekshmy Sathee, Senior Scientist, Division of Physiology received ASPB-Plantae fellow.
- Dr. Ashish Khandelwal, Scientist, Division of Environmental Science received Seth Lachhiram Chudiwala Medal-2021 for the best Ph.D. thesis of the Division of Agricultural Chemicals.
- Dr. O.N. Tiwari, Principal Scientist, Division of Microbiology received Prof. Vallabhaneni Sita Rama Das Excellence Award, by VIGNAN foundation for Science, Technology & Research, Guntur, A.P.
- Dr. Roaf Ahmed, Scientist, Division of Agricultural Engineering received AIASA Young Scientist Award-2022 and CNHi Industrial Recognition Award for contribution in crop residue management.
- Dr. S. Subramanian, Principal Scientist and Head, Division of Agricultural Entomology received Outstanding Agricultural Scientist Award from Dr. B.V. David Foundation, Chennai.
- Dr. Sachin S. Suroshe, Principal Scientist, Division of Agricultural Entomology received Best Scientist Award from Society of Plant Protection Sciences, ICAR-NCIPM, New Delhi.
- Dr. P.R. Shashank, Scientist, Division of Agricultural Entomology received Young Entomologist Award 2021.
- Dr. P.R. Shashank, Scientist, Division of Agricultural Entomology received Doctoral fellowship at University of Florida, USA.
- Dr. Sagar D., Scientist, Division of Agricultural Entomology received TN Anantha Krishnan Young Scientist Award by Prof TN Anantha Krishnan Foundation, Chennai.
- Dr. Suneha Goswami, Senior Scientist, Division of Agricultural Biochemistry received "Young Women Scientist Award" from Society for Community Mobilization for Sustainable Development.
- Dr. Asha Devi, Scientist, Division of Agricultural Economics received Dr. R.T. Doshi Award.
- Dr. R.R. Burman, Principal Scientist, Extension received Special Recognition Award by Society for Community Mobilization for Sustainable Development (MOBILIZATION).
- Dr. Sujit Sarkar, Scientist, Division of Agricultural Extension received 'Best Community Mobilizer Award' from Society for Community Mobilization for Sustainable Development (MOBILIZATION).
- Dr. Girijesh Singh Mahra, Scientist, Division of Agricultural Extension received Young Scientist Award-2022 by Society for Community Mobilization for Sustainable Development (MOBILIZATION).
- Dr. Sujit Sarkar, Scientist, Regional Station Kalimpong received Best Farmer Mobilizer Award, from Society for community mobilization for sustainable development.
- Dr. Chander Parkash, Principal Scientist, Regional Station Katrain received IAHS Fellowship.

14. BUDGET ESTIMATES & UTILIZATION

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E) for the year 2022-23 under Unified Budge

											(Rs. In Lakhs)
		B.E. 2022-23					R.E. 2022-23				
S. No.	Head	Other than NEH & TSP	NEH	TSP	SCSP	Grand Total	Other than NEH & TSP	NEH	TSP	SCSP	Grand Total
1	2	3	4	5	6	7	8	9	10	11	12
	Grants for creation of Capital Assets (CAPITAL)										
1	Works										
	A. Land										
	B. Building										
	i. Office building	1112.00		0.00	0.00	**1112.00**	112.00		0.00	0.00	**112.00**
	ii. Residential building	1307.00		0.00	0.00	**1307.00**	2307.00		0.00	0.00	**2307.00**
	iii. Minor Works	160.00		0.00	0.00	**160.00**	160.00		0.00	0.00	**160.00**
2	Equipments	471.00	0.00	0.00	50.00	**521.00**	471.00	0.00	89.00	50.00	**610.00**
3	Information Technology	52.00		14.00	50.00	**116.00**	52.00		5.00	50.00	**107.00**
4	Library Books and Journals	47.00		5.00	0.00	**52.00**	47.00		0.00	0.00	**47.00**
5	Vehicles & Vessels	23.00		0.00	0.00	**23.00**	23.00		0.00	0.00	**23.00**
6	Livestock	3.00		0.00	0.00	**3.00**	3.00		0.00	0.00	**3.00**
7	Furniture & fixtures	52.00		11.00	0.00	**63.00**	52.00		11.00	0.00	**63.00**
8	Others	0.00		0.00	0.00	**0.00**	0.00		0.00		**0.00**
A	**Total – CAPITAL (Grants for creation of Capital Assets)**	**3227.00**	**0.00**	**30.00**	**100.00**	**3357.00**	**3227.00**	**0.00**	**105.00**	**100.00**	**3432.00**
	Grants in Aid - Salaries (REVENUE)										
1	Establishment Expenses										
	Salaries										
	i. Establishment Charges	24800.00				24800.00	26000.00	0.00	0.00	0.00	26000.00
	ii. Wages	0.00									
	iii. Overtime Allowance	0.00									

	Total – Establishment Expenses (Grant in Aid - Salaries)	**24800.00**	**0.00**	**0.00**	**0.00**	**24800.00**	**26000.00**	**0.00**	**0.00**	**0.00**	**26000.00**
Grants in Aid - General (REVENUE)											
1	**Pension & Other Retirement Benefits**	22000.00				**22000.00**	24000.00				**24000.00**
2	**Traveling Allowance**										
	A. Domestic TA / Transfer TA	84.00		0.00	0.00	**84.00**	84.00	0.00	0.00	0.00	**84.00**
	B. Foreign TA	0.00		0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**
	Total – Traveling Allowance	**84.00**	**0.00**	**0.00**	**0.00**	**84.00**	**84.00**	**0.00**	**0.00**	**0.00**	**84.00**
3	**Research & Operational Expenses**					**0.00**					**0.00**
	A. Research Expenses	652.00	31.00	10.00	269.00	**962.00**	1152.00	31.00	10.00	269.00	**1462.00**
	B. Operational Expenses	924.00	125.00	20.00	350.00	**1419.00**	1905.00	125.00	148.00	350.00	**2528.00**
	Total - Research & Operational Expenses	**1576.00**	**156.00**	**30.00**	**619.00**	**3260.00**	**3057.00**	**156.00**	**158.00**	**619.00**	**3990.00**
4	**Administrative Expenses**										
	A. Infrastructure	2875.00			54.00	**2929.00**	3375.00		0.00	54.00	**4429.00**
	B. Communication	26.00			0.00	**26.00**	26.00		0.00	0.00	**26.00**
	C. Repairs & Maintenance				0.00	**0.00**	0.00		0.00	0.00	**0.00**
	i. Equipments,Vehicles & Others	309.00			52.00	**361.00**	309.00		0.00	52.00	**361.00**
	ii. Office building	563.00			54.00	**617.00**	563.00		0.00	54.00	**617.00**
	iii.Residential building	476.00			54.00	**530.00**	476.00		0.00	54.00	**530.00**
	iv. Minor Works	189.00			0.00	**189.00**	189.00		0.00	0.00	**189.00**
	D. Others (excluding TA)	675.00			0.00	**675.00**	875.00		0.00	0.00	**875.00**
	Total - Administrative Expenses	**5113.00**	**0.00**	**0.00**	**214.00**	**5327.00**	**6813.00**	**0.00**	**0.00**	**214.00**	**7027.00**
5	**Miscellaneous Expenses**					**0.00**					
	A. HRD	52.00			27.00	**79.00**	52.00	0.00	0.00	27.00	**79.00**
	B. Other Items (Fellowships, Scholarships etc.)	1039.00	47.00	34.00	108.00	**1228.00**	1539.00	47.00	34.00	108.00	**1728.00**

	C. Publicity & Exhibitions	121.00		3.00		**124.00**	121.00	0.00	3.00	0.00	**124.00**
	D. Guest House – Maintenance	61.00				**61.00**	61.00	0.00	0.00	0.00	**61.00**
	E. Other Miscella-neous	173.00	36.00	10.00	32.00	**241.00**	273.00	36.00	0.00	32.00	**341.00**
	Total - Miscella-neous Expenses	**1446.00**	**83.00**	**37.00**	**167.00**	**1733.00**	**2046.00**	**83.00**	**37.00**	**167.00**	**2333.00**
	Total Grant in Aid-General	**8219.00**	**239.00**	**67.00**	**1000.00**	**9525.00**	**12000.00**	**239.00**	**195.00**	**1000.00**	**13434.00**
	Total (Pension+-General)	**30219.00**	**239.00**	**67.00**	**1000.00**	**31525.00**	**36000.00**	**239.00**	**195.00**	**1000.00**	**37434.00**
B	**Total Revenue (Grants in Aid - Salaries +Pen-sion+ General)**	**55019.00**	**239.00**	**67.00**	**1000.00**	**56325.00**	**62000.00**	**239.00**	**195.00**	**1000.00**	**63434.00**
	Grand Total (Capital + Rev-enue)	**58246.00**	**239.00**	**97.00**	**1100.00**	**59682.00**	**65227.00**	**239.00**	**300.00**	**1650.00**	**66866.00**
	Grand Total (Capital +Gen-eral)	**11446.00**	**239.00**	**97.00**	**1100.00**	**12882.00**	**15227.00**	**239.00**	**300.00**	**1100.00**	**16866.11**

Note: Sub Head wise allocation under Revised Estimate 2022-23 is tentative and is subject to change based on final expenditure figures.

15. STAFF POSITION, APPOINMENTS, PROMOTIONS AND TRANSFERS

(As on 31.12.2022)

Sl. No.	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	06	05
2)	Principal Scientist	61	27
3)	Senior Scientist/Scientist (S.G.)	128	104
4)	Scientist	373	321
	Total	**568**	**457**
B.	**TECHNICAL STAFF**		
1)	Category III	11	07
2)	Category II	275	152
3)	Category I	278	239
	Total	**564**	**398**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	33	20
2)	Group B	279	194
3)	Group C	110	91
	Total	**422**	**305**
D.	**SKILLED SUPPORT STAFF**	**740**	**549**

15.1 SCIENTIFIC STAFF

15.1.1 APPOINTMENT

Name of the Employee	Name of the post	Place of Posting	Date of Appointment
Dr. K.K. Gangopadhyay	Principal Scientist	Vegetable Science	August 25, 2022
Dr. Chandan Kumar Gupta	Senior Scientist	Environmental Science	December 19, 2022
Dr. Manoj Kumar Yadav	Scientist	RS, Karnal	March 25, 2022
Dr. Ruchi Bansal	Scientist	Plant Physiology	April 01, 2022
Dr. Rahul Gajghate	Scientist	RS, Indore	April 01, 2022
Dr. Neeraj Kumar	Scientist	Genetics	April 01, 2022
Ms. Monalisha Pramanik	Scientist	WTC	April 04, 2022
Dr. Mona Nagargade	Scientist	Agronomy	April 06, 2022
Dr. Vishal Tyagi	Scientist	Agronomy	April 18, 2022

Dr. Susheel Kumar Sharma	Scientist	Plant Pathology	July 04, 2022
Dr. Dolamani Amat	Scientist	Microbiology	August 11, 2022
Dr. Misha Madhvan M	Scientist	Agricultural Extension	August 22, 2022
Dr. Krishnashis Das	Scientist	Microbiology	August 22, 2022
Dr. Soma Gupta	Scientist	Genetics	August 29, 2022

15.1.2 TRANSFER

Name of the Employee	Name of the post	Post after transfer	Date of transfer
Dr. Sanjay Kumar Singh	Head (Acting)	Director, ICAR - IIHR, Bengaluru	December 12, 2022
Dr. A. Sarangi	Principal Scientist	Director, ICAR-IIWM, Bhubneswar	December 08, 2022
Dr. Abhijit Kar	Principal Scientist	Director, ICAR-NISA, Ranchi	October 31, 2022
Dr. Balraj Singh	PC, AICRP Honey Bee	Vice Chancellor, SKNAU, Jobner	October 14, 2022
Dr. Indra Mani	Head (Acting)	VC, VNMKV, PARBHANI	August 01, 2022
Dr. Yvonne Angel Lyngdoh	Scientist	Scientist	October 01, 2022
Dr. Manimaran B.	Scientist	Scientist	September 03, 2022
Dr. Mohammad Hashim	Scientist	Scientist	August 17, 2022
Dr. Ruma Das	Scientist	Scientist	April 30, 2022
Dr. Namita Das Saha	Scientist	Scientist	April 16, 2022
Dr. Partha Saha	Scientist	Scientist	April 16, 2022
Dr. Bhagyasree S.N.	Scientist	Scientist	March 29, 2022

15.2 TECHNICAL STAFF

15.2.1 APPOINTMENT

Name of the Employee	Name of the post	Place of Posting	Date of Appointment
Sh. Akshay Kumar HM	Senior Technical Officer	Plant Pathology	18.11.2022

15.2.2 PROMOTIONS

Name of the Employee	Name of the post	Post after Promotion	Date of promotion
Sh. Mohan Singh	SSS	T-1	10.10.2022
Sh. Chandveer Singh	SSS	T-1	06.10.2022
Sh. Mohan Lal	SSS	T-1	10.10.2022
Sh. Raj Kishore	SSS	T-1	10.10.2022
Sh. Tilak Raj	SSS	T-1	10.10.2022
Sh. Uma Shankar	SSS	T-1	10.10.2022
Sh. Tilakeshwar Prasad	SSS	T-1	10.10.2022
Sh. Jagdish Chandra	SSS	T-1	17.10.2022
Smt. Babita	SSS	T-1	07.10.2022
Sh. Javed Ahmad	SSS	T-1	03.11.2022

15.2.3 TRANSFER

Name of the Employee	Name of the post	Posting place	Date of transfer
Sh. Uttam Singh	Teachnical Assistant	Transferred to IGFRI, Jhansi	19.06.2022
Sh. Anil Kumar	Sr. Teachnical Assistant	Transferred to Acharya Narendra Deva University of Agricultural & Technology, Kumarganj, Ayodhya (UP)	24.05.2022
Sh. Chandra Bahnu Singh	Sr. Teachnical Assistant	Transferred to ICAR-DRMR, Bharatpur (Rajasthan)	17.02.2022
Sh. Pawan Kumar Malik	Technical Officer	Transferred from CPRI- Shimla	01.04.2022
Sh. Alok Kumar Singh	Sr. Technician	Transferred to ICAR-IISR, Lucknow	31.03.2022
Sh. Sonu Olla	Technical Assistant	Transferred from ICAR-NDRI, Karnal	31.03.2022
Sh. Pramod Paswan	Sr. Technician (driver)	Transferred from Banaras	15.07.2022
Smt. Monika Rai	Technical Assistant	Transferred from ICAR-National Dairy Research Institute Karnal	11.08.2022
Sh. Praveen Kumar	Sr. Technical Assistant	Transferred from ICAR-Sugarcane Breeding institute Coimbatore	23.08.2022
Smt. Anjali Singh	Technical Assistant	Transferred to CIRG Magdoom Mathura	18.10.2022

15.3 ADMINISTRATIVE STAFF

15.3.1 PROMOTIONS

Name of the Employee	Name of the post	Post after Promotion	Date of promotion
Sh. Pushpendra Kumar	CAO (Senior grade)	JD (A)/ Sr. Registrar	02.08.2022
Sh. Janjeev Kumar Sinha	CAO	CAO (Senior Scale)	16.03.2022
Sh. Ajay Kumar Soni	SAO	CAO	26.03.2022
Sh. Keshav Dev	Deputy Director (OL)	Joint Director (OL)	02.07.2022
Sh. Radhey Shyam Bhatt	FAO	SFAO	04.04.2022
Smt. Nilima Minj	AAO	AO	20.05.2022
Sh. Vijender Kumar	AAO	AO	20.05.2022
Sh. Satyendra Kumar	AAO	AO	20.05.2022
Sh. Rajesh Sharma	AAO	AO	20.05.2022
Sh. Suresh Singh	AAO	AO	20.05.2022
Sh. Kishan	AAO	AO	30.05.2022
Sh. Sushil Kumar Katariya	AAO	AO	10.08.2022
Sh. Subhash Chandra	PS	PPS	03.08.2022
Smt. Sangeeta Mehta	PS	PPS	03.08.2022
Smt. Sangeeta Sharma	PS	PPS	03.08.2022
Smt. Anita	PS	PPS	03.08.2022
Smt. Sushma Tanwar	PS	PPS	03.08.2022
Sh. Satyender Singh	PS	PPS	18.10.2022

Sh. Vijender Kumar Udar	PS	PPS	18.10.2022
Sh. Rahul	Assistant	AAO	17.06.2022
Ms. Subhda Gahlot	Assistant	AAO	17.06.2022
Sh. Surender Singh	Assistant	AAO	17.06.2022
Sh. Munesh Chand Meena	Assistant	AAO	17.06.2022
Sh. Anil Kumar Dabbas	Assistant	AAO	17.06.2022
Sh. Rohit Yadav	Assistant	AAO	17.06.2022
Sh. Vikas Sanwal	Assistant	AAO	17.06.2022
Sh. Narendra Kumar	Assistant	AAO	17.06.2022
Smt. Lata Sood	Assistant	AAO	17.06.2022
Sh. Ramesh Chand	Assistant	AAO	17.06.2022
Smt. Veena Kumar	Assistant	AAO	17.06.2022
Sh. Philip Kujur	Assistant	AAO	17.06.2022
Sh. Virendra Kumar	Assistant	AAO	01.07.2022
Smt. Phoolwati	Assistant	AAO	05.07.2022
Sh. Harish Kumar Narang	Assistant	AAO	01.08.2022
Ms. Rupesh Gupta	Assistant	AAO	18.08.2022
Smt. Kamlesh Kumari	Assistant	AAO	22.11.2022
Smt. Swapnil Rstogi	Assistant	AAO	22.11.2022
Sh. Tribhuvan Rai	UDC	Assistant	01.01.2022
Smt. Madhubala	UDC	Assistant	30.06.2022
Sh. Shiv Kumar Yadav	UDC	Assistant	30.06.2022
Ms. Jyotsna Gnnade	UDC	Assistant	22.11.2022
Sh. Tirth raj Meena	UDC	Assistant	22.11.2022
Sh. Sunil Kumar	UDC	Assistant	22.11.2022
Sh. Sanjeev Kumar	UDC	Assistant	22.11.2022
Smt. Kavita	UDC	Assistant	22.11.2022
Sh. Anil Chintaman Waka-dikar	UDC	Assistant	22.11.2022

15.3.2 TRANSFERS

Name of the employee	Name of the Post	Post after transfer	Date of Transfer
Smt. Sanjeevan Prakash	Comptroller	Comptroller	02.08.2022
Sh. Piyush Shukla	SAO	CAO	09.05.2022
Sh. Dharam Dass Verma	Comptroller	Sr. Comptroller	05.08.2022
Sh. Chhuttan Lal Meena	AFAO	FAO	25.05.2022
Sh. Anil Kumar Sidharth	FAO	FAO	03.07.2022
Sh. Umesh Chand Sharma	SAO	SAO	03.06.2022
Sh.AmrendraKishore	AO	AO	08.07.2022
Sh. Aman Deep Punia	Assistant	Assistant	01.06.2022

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 is followed. Five per cent of the total numbers 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 2022-23, twenty one (21) physically challenged students (11 M.Sc./M.Tech and 10 Ph.D.) were admitted against the reserved seats for differently abled candidates. However, in the event of there being no eligible suitable differently abled candidates in the earmarked discipline, to fill up the mentioned number of seats, such unfilled seats shall be transferred to other disciplines, where eligible suitable differently abled candidates are available for filling these seats.

16.2 NUMBER OF BENEFICIARIES AND THEIR PERCENTAGE IN RELATION TO TOTAL NUMBER OF BENEFICIARIES

The number of beneficiaries with disabilities and their percentage in relation to total number of beneficiaries as on December 31, 2022 are as follows:

Category	Total number of beneficiaries	Number of beneficiaries with disability	Percentage (%)
Technical	379	06	1.58
Administrative	287	09	3.14
Skilled Support Staff	483	06	1.24

17. OFFICIAL LANGUAGE (RAJBHASHA) IMPLEMENTATION

Article 343 of the Constitution, says that Hindi shall be the Official Language of the Union Government. To implement the objectives in letters and spirit, ICAR-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) is constituted by the institute under the chairmanship of Director and the Committee ensures compliance of policy and rules of official language Act 1963 and O.L. rules of 1976. All the Joint Directors, Head of Divisions and Comptroller are ex officio 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, subcommittees 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 program of the Department of Official Language, Ministry of Home Affairs, Govt. of India, an OL Inspection Committee was constituted under the chairmanship of Dr. Indramani, Head, Agriculture Engineering Division. 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/Center, etc. and submitted inspection reports. A total 17 OLIC Inspections were conducted during the period reported upon.

17.2 AWARD SCHEMES/COMPETITIONS

During the year 2022 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. During the year following activities were organized:

17.2.1 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 implanted as per the directives of the Department Employees of the institute were given cash awards for doing their maximum official work in Hindi in the whole year.

17.2.2 Hindi Vyavahar Pratiyogita

Hindi Vyavahar Pratiyogita was organized amongst the different Divisions and Sections of Directorate separately and two Divisions and Sections each were awarded a shield for doing maximum work in Hindi during the whole year. In the period under report Agronomy and Entomology Division amongst the divisions, Pay bill and Personnel -3 Sections amongst the Sections and Regional station Kalimpong, Regional station Katrain, Kullu Ghati amongst the Regional stations were chosen to give the prizes.

17.2.3 Awards for Popular Science Writing in Different Journals

A competition for popular science writing was organized for scientists/technical officers of the institute and winners were awarded first, second and third consolation prizes of ₹ 7000/-, 5000/- and 3000/ respectively for their published articles in different journals.

17.2.4 Pusa Vishisht Hindi Pravakata Puraskar

Pusa Vishisht Hindi Pravakta Puraskar was given jointly to two scientists for their outstanding lectures in different training programs. Evaluation was done on the basis of recommendations of course coordinator and feedback of the trainees. The Puraskar carries a cash prize of ₹ 10,000/- and a certificate.

17.3 HINDI *CHETNA MAAS*

This year Hindi *Chetna Maas* was celebrated from September 01 to 30, 2022. This month on September 01, 2022 "Hindi Poem Recitation" competition was organized. The inauguration ceremony of the program of Hindi *Chetna Maas* was held on September 01, 2022 by Dr. Viswanathan Chinnusamy, Joint Director (Research), Dr. S.S. Sindhu, Joint Director (Education) and Dean, Dr. Bhopal Singh Tomar, Joint Director (Extension), Mrs. Seema Chopra, Director (OL), ICAR, Mr. Paramjeet Yadav AD (OL), ICAR was the guest of honour on the occasion. In order to encourage the officials/employees to do their official work in Hindi, various competitions were organized. Hindi Poem Recitation, extempore, writing a story or poem based on a picture, Hindi noting and drafting, quiz, Hindi Typing and general knowledge competition (only for the skilled supporting staff of the institute) were organized. A total of 07 competitions were organized. Employees from all the categories of the institute participated in these competitions enthusiastically. Hindi Week/Hindi Day/Hindi Fortnight was also celebrated in different divisions and regional stations of the institute. Many competitions were organized and participants were given prizes and certificates.

Glimpses of Hindi *Chetna Maas*

Dignitaries releasing bulletin during inauguration ceremony of hindi *chetna maas*

17.4 HINDI COMPETITIONS ORGANIZED BY DIVISIONS OF THE INSTITUTE

17.4.1 Biochemistry Division

On September 09, 2022, the division organized various Hindi competitions such as Hindi calligraphy, dictation and quiz competition at the divisional level. In which Ms. Sunita, Assistant Director (Official Language) was invited as the chief guest. Also, Dr. Dinesh Kumar Sharma, Professor and Principal Scientist, Center for Environmental Science and Climate Resilient Agriculture, Dr. Atul Kumar, Principal Scientist, Division of Seed Science and Technology and Dr. Girijesh Singh Mehra, Scientist, were members of the jury. Officers/ employees of the division participated with enthusiasm.

Participants and jury at Biochemistry division in occasion of hindi competition program

Prize distribution ceremony of Hindi competition programme

17.4.2 Agricultural Extension Division

In the division on the occasion of Hindi Day, August 08, 2022, various Hindi competitions were organized at the divisional level. To make the competitions successful, all the officers, employees, students and researchers of the division participated in various competitions with full cooperation. The program was presided over by the chairman of the division, Dr. Ravindra Padaria. Various competitions *viz*. calligraphy contest, poetry reading speech on the topic "The nature of Indian education changes with the new education policy" quiz competition, speaking your introduction in Hindi (only for skilled support staff) were organized. Six photo frames (which have thoughts of great poets, writers or social reformers on Hindi language) were also released in the programme. Dr. Girijesh Singh Mehra, Rajbhasha Nodal Officer was the coordinator of the program and in the end, he also gave formal thanks to everyone. Dr. Dinesh Kumar Sharma, Principal Scientist, Division of Environmental Sciences, Dr. Archana Singh, Principal Scientist, Division of Biochemistry Dr. Atul Kumar, Principal Scientist, Division of Seed Science and Technology were the judge of the programme.

17.4.3 CATAT

A one-day Hindi competition program organized by the Divisional Official Language Implementation Committee at CATAT, was organized on September 24, 2022 at the Seminar Room, CATAT in which all the staff from CATAT, ATIC and Pusa Agricultural Products Sales Center were eligible to participate. A total of 4 competitions were organized under this, *viz*.

1. Speech - Topic: Contribution of mobile revolution
2. Dictation - dictation by listening to the paragraph being spoken
3. Memoir - Introduction in Hindi and sharing any one childhood experience (Only for skilled support staff, daily wage earners)
4. Question Forum – Audio Visual (Group Competition)

Dr. Dinesh Sharma, Principal Scientist, Environmental Science Division and Dr. Girijesh Mehra, Scientist, Agricultural Extension Division were present as judges in the above mentioned competitions. Joint Director (Extension) Dr. B.S. Tomar was invited as guest of honour. He presented mementos and certificates to the winners. The participants, who did not win the prize, were also awarded certificates. The chief guest and judges gave feedback to all the

Releasing of Photo frames by dignitaries

Guests, participants and staff during hindi competition programme

participants and encouraged them to work in Hindi. Shri Yogesh Kumar took the responsibility of vote of thanks and thanked the chief guest, jury, organizers, participants and all other staff for their cooperation.

17.4.4 Agricultural Engineering Division

In view of the Hindi Chetna Maas and to encourage the use of Hindi, a competition in various subjects of Hindi was organized in the Agricultural Engineering Division auditorium room from 3.00 pm to 5.00 pm on 13/09/2022. The programme was presided over by Mrs Sunita, Assistant Director, OL as the chief guest. Dr. P.K. Sharma, Divisional Head, Agriculture Engineering Division welcomed all the participants and staff in the program. In this regard, a jury (Dr. Adarsh Kumar (President), Dr. S.P. Singh (Member) and Dr. H.L. Kushwaha (Member)) was constituted to organize Hindi competition. In this program, competitions were organized on the topic of Hindi poetry dictation, Hindi essay and Hindi question forum and the winning participants were given first, second, third prizes and consolation prizes. At the end of the programme, Dr. Dilip Kumar Kushwaha, Hindi Rajbhasha Nodal Officer thanked the Chief Guest, Head of the division, Jury and participants for the successful organization of the program.

18. TRANSFER OF TECHNOLOGY

Application of latest technologies and practices is vital for effective resource management and enhancing crop productivity and income. Therefore, the institute lays immense emphasis upon transfer of technologies to accelerate their rate of diffusion and adoption. The institute carried out programmes such as Mera Gaon Mera Gaurav (MGMG), Schedule Cast Sub Plan (SCSP), and development of NEH region. Pusa *Krishi Vigyan Mela* and training programmes were organized for the capacity building of farmers.

18.1. Interventions under Scheduled Caste Sub Plan (SC-SP)

18.1.1. Demonstrations of improved varieties and input support

The main objective of the scheme is to give a thrust to economic development of families of SC categories below the poverty line, by providing resources for filling the critical gaps. Since the schemes/programmes for SCs may be depending upon the local occupational pattern and the economic activities available, the Staes/UTs have been given full flexibility in utilizing the allocation with the only condition that it should be utilized in conjunction with SCP and other resources available from other sources like various Corporations, financial institution etc. The Institute has been implementing SC-SP programme since 2019.

During 2022, 5724 SC farmers were covered in seven districts of two states. The institute organized a total of 10412 demonstrations of its improved varieties of paddy, wheat, mustard, lentil, chickpea and vegetables including palak, carrot, onion, garden pea and vegetable kits for kitchen garden. IARI improved varieties have recorded 10-17 per cent yield increase over the local checks in these demonstrations across the locations. During *Kharif* 2022, 10615 SC farmers were covered in 23 districts of three states. Demonstrations of IARI improved varieties of paddy, mungbean, pigeon pea and vegetables were organized. Several farmers-scientists interfaces and training programmes were organized across the districts. Seven training programmes for SC farmers were organized under at different locations on improved crop management technologies of paddy, mungbean, mustard and vegetables. Critical inputs other than quality seeds of IARI improved varieties, including Zinc fertilizer and plant protection chemicals were also distributed to the farmers under this programme. Small tools and implements including spades (1200 Nos.), *khurpa* (950 Nos.) as well as Knapsack manual (440 Nos.) and battery operated (120 Nos.) sprayers were distributed to SC farmers and farm labourers.

18.1.2 Training under SC-SP project

Sr. No.	Title of training	Location	Date	No. of Participants
1	Seed distribution cum Training programmes organized during January to December -2022	Village-Ajnara Block-Shikarpur Dist- Buldnashar	March 22, 2022	750
2	*Kisan Goshthi* under Farmer Participatory Farmer Priority cum Training programmes organized during *Rabi* 2022-23	Village KheraKisan Distirct Aligarh	April 28, 2022	500
3	*Kisan Gosthi* cum Training programmes organized during *Rabi* 2022-23	KVK Ghazibad KanchanNagla G B Nagar KVK Mau	May 05, 18, 19, 2022	1250
4	*Kisan Gosthi* and seed distribution cum Training programmes organized during *Rabi* 2022-23	KVK Ghazipur	November 25, 2022	140

5	Training programme (*Chapual Charcha*) organized during *Rabi* 2022-23	ICAR-IARI New Delhi	November 25, 2022	30
6	World Soil day celebration	Village Rajpura Block-Khair District –Aligarh	December 02, 2022	350

18.1.3 Quality Seed: Free distribution of wheat & rice under Schedule Cast Sub Project at Regional Station, Pusa, Bihar

S. No.	Year		Farmers (Nos.)	Districts (Nos.)
1.	*Kharif*-2022	PS-5	4520	05
		Pusa-44		
		Pusa Sambha-1850		
		PNR-381		
2.	*Rabi*-2022-23	HD-2967	438	01
		HD-3086		
		HI-1563		

Free distribution of wheat seed under Schedule Cast Sub Project at Village Panchayat - Biroul District Darbhanga dated December 21, 2022

18.1.4 On-farm training programme under SC-SP

Under SCSP-2021-22 Special grant from ICAR-IARI, New Delhi, one day on-farm training programme was organized at Doddani village in Kothagiri taluk in Nilgiris district on January 6, 2022. About fifty farmers participated in this training. All farmers were exposed to the standing crop of Samba wheat (var. 1098) which was grown from the seeds distributed from our station. Agronomical practices, marketing, value addition and the impact analysis of off-line training etc., were discussed with farmers. The entire programme was covered and telecasted in different channels and printed versions in English and Tamil languages.

SC-SP On-farm Training

18.2 Interventions under Tribal Sub Plan

18.2.1 Wheat, soybean and maize demonstrations in Tribal Area (TSP)

A total of 31 demonstrations of nine new wheat varieties (HI 8802, HI 8805, HI 8823, HI 1605, HI 1544, HI 8663, HI 8737, HI 8759 and HI 1634) with recommended package of practices were conducted in four tribal villages *i.e.* Sherkund, Sejgarh and Gokalyakund of block Manpur, Distt. Indore and village Kagdipura of Nalcha block, district Dhar M.P. in 11.95 ha area (0.38 ha average demonstration). The average yield of test varieties was 39.94 q/ha against 21.81 q/ha of check varieties.

During *Kharif*, 21 demonstrations of latest soybean varieties (JS 2034 and JS 2069) in 5.25 ha area (0.25 ha average demonstration) and 25 maize demonstrations of two hybrid varieties (Super-82 and Kanak) in 6.25 ha area (0.25 ha average demonstration) were conducted in above villages. Average yield of soybean recorded was 10.40 q/ha in these demonstrations against 7.50 q/ha check yield. Increase in yield was 2.87 q/ha or 41.6% in these demonstrations compared with three check varieties *i.e.* JS 335, JS 9305, JS 9560 grown by farmers with their own practices. Whereas, average yield of maize recorded was 26.20 q/ha in these demonstrations against 12.20 q/ha check yield. Increase in yield was 14 q/ha or 117% in these demonstrations compared with local check varieties grown with farmers' own practices.

18.2.2 Vegetables Minikit (Okra, Brinjal, Sponge Gourd, Tomato, Spinach, Bottle Gourd, Bitter Gourd) Demonstrations TSP *Kharif* 2022

A total of 60 vegetables minikit demonstrations (females 40 and males 20) were conducted in five tribal villages *i.e.* Sherkund, Sejgadh, Gokliyakund, of Manpur block, District Indore and Jirapura & Kagdipura of Nalcha block District Dhar, M.P. in 7.2 ha area (0.12 ha. average demonstration). Average number of pickings per family was recorded 12.5 with average monetary value in local market equivalent to ₹ 376/- during the season.

18.2.3 Training program under TSP

One-day training program was organized on "Improved technologies of fruits and cereal crops" on March 10, 15 and 16 for Scheduled Tribe farmers in Mehala (Chamba), Lari and Batseri (Kinnaur) of HP. Hundred farmers participated in of these each training. Kits containing fungicide, nutrients, shade net, tree guard, anti-hail net, anti-bird net, apple plants, folders were distributed to the farmers. During scientist-farmers interaction queries of farmers were addressed. Similarly, three days training program was organized on "Improved production technologies for fruits, vegetables and potatoes" on November 27-29, 2022 at Sapni (Kinnaur) of HP. Two hundred farmers participated in the training program. Kits containing fungicide, nutrients, folders were distributed to the farmers. During scientist-farmers interaction queries of farmers were addressed.

18.3 *MERA GAON MERA GAURAV* (MGMG)

The MGMG programme is aimed to increase the farmer-scientist interface to reduce the delay in delivery of authentic information to the target group of farmers. To promote the direct interface of

Activities under MGMG

Total No of Groups formed	No. of Scientists Involved	No. of villages covered	No. of field activities conducted	No. of messages/ advisory sent	Farmers benefited (No.)
121	503	621	1922	737	13668

Name of activity	No. of Activities Conducted	No. of Farmers Benefitted		
		General	SC/ST	Total
Visit to village by teams	116	1813	486	2299
Interface meeting/ Gosthies /trainings	217	283	159	442
Training organized	65	1285	878	2163
Demonstrations conducted	96	1189	1145	2334
Mobile based advisories (No.)	16	551	623	1174
Literature support provided	121	1971	1172	3143
Awareness created	449	1716	243	1959
Grand Total	**1330**	**10779**	**5878**	**16657**

scientists with the farmers and to hasten the lab to land process, *Mera Gaon Mera Gaurav* is being implemented by IARI in 121 clusters comprising of 621villages by 503 scientists of the Institute along with IASRI and NBPGR. The objective of this scheme is to provide farmers with the required information, knowledge and advisory regularly by adopting villages. Under MGMG, 1922 field interventions were made benefitting 13668 farmers.

Under MGMG at IARI Regional Station, Kalimpong, a total of five training programmes, 200 demonstrations and 10 awareness programmes covering 400 farmers were conducted. Improved technologies of Darjeeling mandarin (Nucellar seedling, grafted planting materials, mulching technique to control fruit fly), healthy sucker of Varlangey cultivar of large cardamom, seed of major vegetables (brinjal, cabbage, cauliflower, tomato, chilli, green peas, bottle gourd, bitter gourd etc) and growing rootstock of Darjeeling mandarin were promoted under the programme.

18.4 PUSA KRISHI VIGYAN MELA 2022

Pusa Krishi Vigyan *Mela* 2022, themed "*Takniki Gyan Se Aatmnirbhar Kisan*" was organized at the IARI *mela* ground from March 9-11, 2022. The *mela* was inaugurated by Sh. Kailash Choudhary, Hon'ble Minister of State for Agriculture and Farmers Welfare, Government of India. The inaugural function was presided over by Dr. Trilochan Mohapatra, Secretary, DARE & Director General, ICAR. Dr. M. Angamuthu, Chairman, APEDA, Dr. A.K. Singh, DDG (Ag. Extension), ICAR, Dr. T.R. Sharma, DDG (Crops Science), ICAR, Dr. A.K. Singh, Director ICAR-IARI and Dr. B.S. Tomar, Joint Director (Extension), IARI also graced the occasion. IARI Fellow Awards were bestowed to five farmers on this occasion.

Hon'ble MoS for Agriculture and Farmers Welfare, Sh. Kailash Choudhary appreciated the *mela* for providing a unique platform for interaction among farmers, startups and experts from all over the country. He reiterated the Government's and IARI's efforts to provide technological empowerment and implement the governmental programme for the benefit of the farmers. He urged all the farmers to reap maximum benefits from the newly developed varieties and innovative technologies. He also informed that the government provides a platform for agricultural development from seed to market through various initiatives and programmes. He further stressed for self-reliant farmers through technological empowerment and knowledge enhancement. He added that financial assistance was also provided by increasing the agricultural budget over the years to help in realizing the long-cherished dream of the Hon'ble Prime Minister in developing the Atmanirbhar Bharat. He also emphasized that 10 thousand new Farmers Producer Organizations are being formed in the country with the financial assistance of ₹ 6,865 Cr. He also appreciated the IARI fellow farmers present for their progressive outlook towards agriculture. Various

Pusa Krishi Vigyan *mela* inauguration by Sh. Kailash Choudhary, Hon'ble Minister of State for Agriculture and Farmers Welfare, Government of India

progressive farmers and farm women and startups attended the Mela.

Farm technologies developed by the Institute for sustainable agricultural development were displayed in a huge thematic *pandal*. Besides, live demonstrations on improved crop varieties, vegetable production technology, IFS models, farm machinery and Pusa Farm Sun Fridge were laid out to provide First-hand experience to farmers. Farmers were provided free 'farm consultancy services', including soil and water testing at the *mela* site by agricultural scientists. IARI agro-advisory services, display of new technologies in the thematic pandal, farmer-scientist interactions, free distribution of farm literature, flower show, vegetable cultivation and kitchen gardening demonstrations, residue recycling technology, Pusa farm sun fridge were the major attractions of *the mela*.

New technologies in the thematic pandal

Two hundred twenty stalls of ICAR Institutes/ SAUs, KVKs, Govt./PSUs, agri-startups, NGOs, SHGs, FPOs, innovative farmers and other private entrepreneurs were displayed. Among the stalls, around 55 to 60 were progressive farmers and their organizations. More than 70,000 visitors from different parts of the country, including farmers, farm women, extension workers, entrepreneurs, students and others visited the *mela*. Also, for the first time, many stakeholders could benefit from the live webcasting of the *mela* in different parts of the country.

Five technical sessions on "Digital Smart Agriculture" (Session 1); "Protected, Vertical, Hydroponic and Aeroponic farming for higher productivity and income" (Session 2); "Promotion of Agricultural Export for prosperity" (Session 3); "Organic and natural farming" (Session 4) and 'Innovative Farmers Meet' (Session 5) and 'Agri-start up and farmer producers organization' (session 6) were organized on different themes of agricultural importance. Scientists of different disciplines also addressed the farmers' queries during the three days of *the mela*. On the last day (11 March), in the forenoon, session five on 'Innovative Farmers Meet' was chaired by Dr. K.V. Prabhu, Chairperson, PPV & FRA, as Chief Guest. In this session, the awardee Innovative and Fellow Farmers shared their rich farming experiences and the innovations they practised.

Drone technology in Agriculture

Seeds of high-yielding varieties of Basmati rice (118.5 t), Mungbean (5.1t), bajra (0.15 t), Pigeonpea (0.5 t) and vegetable kits (3500) were sold through both Pusa Seed Sale Counter and online orders and with a revenue of ₹1.04 crore.

Seed Sale during *mela*

Four publications useful for farmers and agri-entrepreneurs including Fellow and Innovative Farmers: 2022, crop cultivars for farmers' prosperity,

Publications released during *Mela*

Smart Peri-urban agricultural technologies and vegetable varieties for farmers prosperity and entrepreneurship development (2000-2020) were released. Also, three improved paddy varieties resistant to bacterial blight and blast, *viz*., PB 1885, PB 1847 and PB 1886 were released for the first time for the visiting farmers.

During the valedictory function, IARI Innovative Farmers' Awards were bestowed upon 36 farmers, including five women farmers belonging to 22 States/UTs of the country by Dr. A.K. Singh, Director, ICAR-IARI. The programme was concluded with a formal vote of thanks proposed by Dr. B.S. Tomar, Joint Director (Extension), IARI.

IARI Innovative Farmers' Awards

18.5 Training and Capacity Building

The Institute organized 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 Faculty Training". In addition, some special training/ workshops courses were also organized for the benefit of professionals, farmers and extension workers.

18.5.1. Training programmes organized by divisions and regional stations

Name of the training programme	Dates/Month	No. of trainees
Division of Soil Science and Agricultural Chemistry		
18th Advanced Level Training in Soil Testing, Plant Analysis and Water Quality Assessment	January 05-25, 2022	11
19th Advanced Level Training in Soil Testing, Plant Analysis and Water Quality Assessment	September 01-21, 2022	12
Division of Agricultural Engineering		
Ergonomics and Safety in Agricultural Operations to Enhance Farmer's Productivity and Well-Being	November 16-18, 2022	24
Division of Food Science and Post Harvest Technology		
Agripreneur Development Program: Processing Techniques of Horticultural and Arable Crop	August 22-27, 2022	18
Agripreneurship Development Programme on Processing of Millets and Alternate Food Crops	November 21-25, 2022	14
Division of Microbiology		
Training on PUSA decomposer technology for licencees	June 3-4, 2022	
Training on *Spirulina* cultivation and value-added products formulation at CCUBGA, IARI, New Delhi	July 4 -6, 2022	
Workshop on 'Computational Biology – Genomics, Metagenomics/ Microbiome and Proteomics' organized by Division of Microbiology, ICAR - IARI, New Delhi in collaboration with Academy of Microbiological Sciences & Association of Microbiologist of India (AMI) – Delhi Unit	April 29, 2022	
Division of Entomology		
15 days workshop on Techniques for entomological research at the Division of Entomology IARI New Delhi	December 24, 2021 to January 7, 2022	10
Workshop cum training on Scientific beekeeping	March14-16, 2022	50
ICAR sponsored 15 days Online training programme for technical staff "Diagnosis and management of economically important insects in Agriculture	November 9-23, 2022	34
DPPQ&S Sponsored Five days Hands on Training on Advance Methods for Testing of Quality Parameters of Biopesticides	November 28 to December 02, 2022	10
Division of Plant Physiology		
NAHEP sponsored Short term training program on "CRISPR-based Plant Genome Editing: Tools and Techniques	October 11-21, 2022	49
Division of Agricultural Economics		
NASF assisted short training course on "Price Forecasting of Agricultural Commodities"	February 21- March 02, 2022	50

CAFT training programme on "Concepts and Methods for Sustainable Food System Analysis	November 02-22, 2022	17
NAHEP Sponsored training programme on "Advanced Research Methods and Essential Skills for Social Sciences"	December 12-22, 2022	30
Regional Station, Indore		
Wheat and wheat seed Production Technology	January 01, 07, 2022	32 + 40
On Farm Training "Plant Protection and Rouging in Wheat Demonstrations"	January 13, 2022	51
Wheat Production Technology	January 24, 2022	80
Wheat & wheat seed production technology and Durum wheat uses and processing.	February 1, 17, 19, 23 and 25, 2022	40+40+40+40+80
Field Day and On Farm Training " Wheat Production Technology, FPO formation and PM Beema Yojana"	February 24, 2022	150
Field Day and On Farm Training " Wheat Production, Harvesting and Storage"	March 03, 2022	130
Field Day/Kisan Mela and On Farm Training " Wheat Production, Harvesting and Storage"	March 05, 11, 2022	460+110
Wheat Production, Harvesting and Storage	March 16, 26, 2022	30+25
Durum Wheat Exporters Meet	April 04, 2022	30
Wheat Straw Management	April 18, 2022	130
Wheat Production, Harvesting and Storage	April 25, 2022	10
Wheat and wheat seed Production Technology	May 22, 2022	40
Training in soybean, Maize and kharif Vegetables production technology for Tribal Areas	June 16, 2022	49
Seed distribution, on- Farm Training and sowing (Soybean, Maize and Mixed Vegetables) in Tribal Areas"	June 24, 2022	42
Seed distribution, on- Farm Training and sowing (Soybean, Maize and Mixed Vegetables) in Tribal Areas"	June 29, 2022	47
On- Farm Training and sowing (Soybean, Maize and Mixed Vegetables) in Tribal Areas"	July 06, 2022	42
Wheat and Wheat Seed Production Technology	September 16, 23 and 27, 2022	50+75+45
Wheat Production Technology	October 17, 2022	215
Training on wheat and wheat seed Production Technology	October 27, 2022	34
Pre sowing training on wheat and wheat seed Production Technology	November 01, 2022	36
HRM and Agricultural Education and Wheat and Wheat Seed Production Technology	November 03, 2022	42
Field Training in wheat sowing Methodology	November 15, 17, 2022	40+35
Wheat and Wheat Seed Production Technology	November 11, 2022	135
Regional Station, Kalimpong		
Improved farm technologies for enhanced livelihood security at Dhupguri, Phansidewa and Kalimpong	January 10-12, 2022; March 09, 2022; February 25-26, 2022	200
Training on Darjeeling mandarin	April 3, 2022	50

Training on Large cardamom	April 4, 2022	50
Regional Station, Karnal		
प्रक्षेत्र फसलों के गुणवत्ता बीज उत्पादन में तकनिकी प्रगती	07–09 मार्च, 2022	25
रबी फसलों में बीज उत्पादन तकनिकी	10–12 मार्च, 2022	28
Regional Station, Katrain		
Farmers training program on 'Vegetable Cultivation, under SCSP scheme.	February 22, 2022	40
Farmers training program on 'Commercial flower production' under SCSP scheme.	March 24, 2022	60
Regional Station, Pusa, Bihar		
Dhan ki gunwatta beej utpadan takniki	June 23, 2022	300
Adhik Aay ke liye dhan ki phasal me beej utpadan takniki	June 25, 2022	500
Kharif ki phasalon ki aadhunik utpadan takniki	June 26, 2022	500
Dhan phasal utpadan ki aadhunik takniki	June 29, 2022	500
Kharif phasalon ki navin utpadan takniki	July 02, 2022	500
Seed Production Unit		
• The training entitled "Subji *Beej utpadan ke dwara krishko ki amdani badana. Organized at Dhraoo, Khurja, B.S.*	March 26, 2022	50

18.5.2 Training Programmes Organized by Centre for Agricultural Technology Assessment and Transfer (CATAT)

On Campus Trainings

Four on-campus training programmes were organized for agriculture officials and progressive farmers of different States. These programmes were attended by 107 participants from Rajasthan and NCR Delhi.

S. No.	Name of the training programme	Dates/Month	Number of trainees
1.	Integrated nutrient, pest and disease management	August 17, 2022	25 Farmers /officials of the Development Deptt. Delhi
2.	Pre-seasonal training on Kharif crops (Maize, paddy, jowar, Bajra, Arhar, urad, millets, vegetables and flowers)	August 25-26, 2022	25 Farmers /officials of the Development Deptt. Delhi
3.	Training on millet crops	August 25-26, 2022	25 Farmers /officials of the Development Deptt. Delhi
4.	Production and post-harvest technology of horticultural crops sponsored by ATMA, Sawai Madhopur (Rajasthan)	December 16-22, 2022	32 Farmers /officials

Off-campus Trainings/ Field Days:

- One-day training on 'Nuti-gardens' for 30 farmers of Kanvi Village, Hapur (UP) under the SC-SP Scheme on November 11, 2022.
- Organised Kisan Diwas and Swachhta Abhiyan on at village Sujanpur Akhara, Ghaziabad, UP on December 23, 2022.

19. SERVICE THROUGH QUALITY SEED & PLANTING MATERIALS

19.1. SEED PRODUCTION OF FIELD CROPS (January 1 to December 31, 2022)

19.1.1 Seed production at Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seed of 58 varieties of cereals, pulses and oilseeds was 684.423 tonnes, which encompasses of nucleus seeds (10.085 tonnes), breeder seeds (137.313 tonnes) and TFL/IARI seeds 537.025 tonnes (46.370 and 490.655 tonnes) at the Institute farm and under farmer participatory seed production programme, respectively) at Seed Production Unit, ICAR-IARI, New Delhi. Crop-wise details of the production of various classes of seed are given below in Table.

Details of seed production at Seed Production Unit & Farmer's Field

Crop	No. of varieties	Classes of Seeds* (t)				Total Production (t)
		NS	BS	IARI Seeds /(TFL)		
				At Institute	Under FPSP	
Wheat	13	8.500	127.500	16.146	221.690	373.836
Paddy	12	0.002	1.500	13.859	239.233	254.594
Chickpea	09	1.001	0.960	5.093	8.307	15.361
Pigeon pea	02	0.050	1.200	0.500	0.250	2.000
Lentil	03	0.340	3.020	4.311	5.129	12.800
Moong	04	0.100	1.000	0.400	8.165	9.665
Mustard	08	0.050	1.783	5.615	7.881	15.329
Maize	04	0.042	0.350	-	-	0.392
Bajra	01	-	-	0.446	-	0.446
Total	**58**	**10.085**	**137.313**	**46.370**	**490.655**	**684.423**

*NS-Nucleus Seed, BS-Breeder Seed, TFL- Truthful Label Seed (IARI Seed), FPSP- Farmers Participatory Seed Production

Fund generated = ₹ 9, 38, 37, 472.00 (*including flowers & vegetables crops)

19.1.2 ICAR-IARI Regional Station, Karnal

Seed production of field crops: At IARI-Regional Station, Karnal, 359.839 tonnes seed of cereals, pulses, oil seeds and other crops were produced during *Rabi* 2021-22 and summer/ *Kharif* 2021. A total of 2.183 t nucleus, 152.124 t breeder and 205.532 t of IARI seed were produced.

Details of seed production at ICAR- IARI RS, Karnal

Crop	No. of Crops	No. of Varieties	Seed Production (t)			
			NS	BS	IARI	Total
Cereals	6	32	2.182	149.864	203.66	355.706
Pulses	3	4	0.001	1.74	0	1.741
Oil seeds	1	5	0	0.52	0.472	0.992
Others	1	1	0	0	1.4	1.4
Total	**11**	**42**	**2.183**	**152.124**	**205.532**	**359.839**

Fund generated = ₹ 2.90 crore (including vegetable, fruit and flower crops)**

Trials

- Four Common Varietal Trials (CVT-1A, CVT-1B, CVT-3A and CVT-6A (HY) of promising wheat lines of the Institute's breeding programme were conducted. There were 22 entries in CVT-1A, 20 in CVT-1B, 22 entries in CVT-3A and 14 entries in CVT-6A (HY) including checks.
- GOT (Grow out Test) of different nucleus, breeder and IARI seed lots of wheat and rice produced at the Regional Station as well as at the farmers' fields.

19.1.3 ICAR-IARI Regional Station, Pusa (Bihar)

Seed production of field crops: At ICAR- IARI Regional Station, Bihar, 827.55 quintals of quality seed was produced including breeder, nucleus and TFL seeds of different crops.

Details of seed production at ICAR- IARI RS, Pusa (Bihar)

Season	Crop	Variety	Category wise seed production (q)			
			NS	BS	TFL	Total
***Kharif*-2021**	Paddy	Pusa Sugandha 5	--	--	71.20	71.20
		Pusa -44	--	--	60.25	60.25
		Pusa Samba -1850	--	--	72.20	72.20
		PNR-381	--	--	49.15	49.15
		Total			**252.80**	**252.80**
Summer-2022	Moong	Pusa Vishal	--	--	10.05	10.05
		Pusa 1431	--	--	04.69	04.69
		Total			**14.74**	**14.74**
		Dhaicha			**06.10**	**06.10**
***Rabi*-2021-22**	Wheat (processed seed)	HD -2967	12.50	401.80	04.00	418.30
		HD-3086	--	30.00	--	30.00
		HD-2733	0.40	06.40	--	06.80
		HD-3249	2.05	24.60	--	26.65
		HI-1563	--	09.60	--	09.60
		HD-3171	0.41	12.20	--	12.61
		HI-1612	01.23	10.00	--	11.23
		CSW-18	0.42	01.20	--	01.62

		HD 3226	0.60	--	--	0.60
		HD 3118	0.45	--	--	0.45
		Total	**18.06**	**495.80**	**04.00**	**517.86**
	Lentil	PSL-9	--	04.83	02.325	07.155
		PDL-1	--	06.50	03.505	10.005
		L-4717	--	04.60	--	04.60
		Total	--	**15.93**	**05.83**	**21.76**
	Mustard	Pusa Agrani	--	--	01.50	01.50
		Pusa Vijay	--	--	02.15	02.15
		Pusa -27	--	--	05.485	05.485
		Total	--	--	**09.135**	**09.135**
	Pea	Pusa Shree	--	--	01.90	01.90
		PusaPragati	--	--	01.47	01.47
		Total	--	--	**03.37**	**03.37**
	Chickpea	C-3043	--	--	01.72	01.72
		Pusa-256			0.065	0.065
		Total			**01.785**	**01.785**
		Grand total	**18.06**	**511.73**	**297.76**	**827.55**

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed

Fund generated = ₹ 69,11,923 (*including fruit crops)**

19.1.4 ICAR-IARI Regional Station, Dharwad

Crop	**Name of variety**	**Classes of seeds (t)**				**Total (t)**	**Fund generated (₹.)**
		NS	**BS**	**IARI Seeds/(TFL)**			
				At Institute	**Under FPSP**		
Chickpea	BGD 111-1	0.18		√		0.23	**57040.00**
	BGD 103		0.05	√			

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed

19.1.5 ICAR- IARI Regional Station, Indore

Crop	**Name of Variety**	**Classes of Seeds (t)**				**Total (t)**	**Fund Generated (₹)**
		NS	**BS**	**IARI Seeds (TFL)**			
				At Institute	**Under FPSP**		
Wheat	HI 1605, HI 1544, HI 1633, HI 1634, HI 1636, HI 8663, HI 8713, HI 8737, HI 8759, HI 8777, HI 8823, HD 4728	13.5	265.05	-	-	278.55	**2,06,88,637**

NS-Nucleus seed, BS-Breeder seed, TFL-Truthfully labeled seed, FPSP-Farmers participatory seed production

19.2. SEED PRODUCTION IN HORTICULTURAL CROPS (January 1, 2022 to December 31, 2022)

19.2.1 Vegetable Crops

Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seed of 31 varieties of 22 horticultural crops (Vegetables & Flower) was 17,496.45 Kg, which comprises of nucleus seeds (159.75 Kg), breeder seeds (1114.7 Kg) and IARI seeds/TFL seeds 16,222.0 kg (4,607.0 and 11,615.0 Kg) at the Institute Farm and under Farmer Participatory Seed Production programme, respectively). Crop-wise details of the production of various classes of seed are given here under:

Seed production of flowers & vegetables crops at Seed Production Unit & Farmer's Field

Crop	No. of varieties	Classes of seeds* (kg)				Total production (kg)
		NS	BS	IARI Seeds /(TFS)		
				At Institute	Under FPSP	
Palak	02	12.0	120.0	1403.0	1530.0	3065.00
Amranth	01	1.0	-	215.0	-	216.0
Methi	02	5.0	105.0	311.0	1264.0	1685.00
Bottle gourd	02	2.0	10.2	15.5	514.0	541.7
Sponge gourd	01	0.5	6.0	15.0	314.0	335.50
Cowpea	01	-	-	-	715.0	715.0
Turnip	01	1.0	-	30.0	-	31.00
Radish	01	5.0	117.0	259.0	1065.0	1446.00
Carrot	02	5.0	-	355.0	1321.0	1681.00
Bathua	01	0.5	-	2.0	-	2.50
Veg. Mustard	01	1.0	-	249.0	-	250.0
Onion	03	1.0	5.5	106.0	1337.0	1449.50
Onion bulb	02	-	750.0	-	-	750.0
Brinjal	01	0.5	-	7.0	-	7.50
Tomato	01	0.25	-	15.0	0.50	15.75
Cherry Tomato	01	-	-	1.0	-	1.0
Garden pea	01	120.0	-	1544.0	1395.0	3059.00
Okra	01	2.0	-	-	1925.0	1927.00
Marigold	01	0.5	1.0	11.5	34.0	47.00
Muskmelon	01	-	-	-	145.5	145.5
Sem	01	2.0	-	33.0	-	35.0
Fababean	01	0.5	-	-	45.0	45.5
Corriander	01	-	-	35.0	-	35.0
Bitter gourd	01	-	-	-	10.0	10.00
Total	**31**	**159.75**	**1114.7**	**4607.0**	**11615.0**	**17496.45**

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed (IARI Seed) &FPSP- Farmers Participatory Seed Production

Fund generated = *

ICAR-IARI Regional Station, Karnal, Haryana

At ICAR-IARI Regional Station, Karnal total 2,548.35 Kg seed of 36 varieties of 14 vegetable crops was produced during *Rabi* 2020-21 and summer/*Kharif* 2021. A total of 40.005 Kg nucleus, 1272.645 Kg breeder and 1235.70 Kg of IARI seed were produced.

Seed production of vegetable crops during *Rabi* 2021-22 and Summer/*Kharif* 2022

Type	No. of Crops	No. of Varieties	Seed Production (kg)			
			NS	BS	TL	Total
IARI RS, Karnal	14	36	40.005	1272.645	1235.70	2548.35

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed (IARI Seed)

Funds generated = **

ICAR-IARI Regional Station, Kattrain, Himachal Pradesh

Seed production (kg)				Revenue from seed sale (Rs. Lakh)	Revenue from others (Rs. Lakh)
Nucleus	Breeder	IARI-TFL	Total		
201.60	240.52	1974.10	2416.22	24.68	4.07

Total Funds Generated ₹ 28,75,000

19.2.2 Fruit Crops

Division of Fruits and Horticultural Technology, ICAR- IARI, New Delhi

Crop & variety	Nos. of planting material
Mango	
Amrapali	1950
Mallika	9300
Pusa Arunima	5530
Pusa Surya	1750
Pusa Lalima	2453
Pusa Pratibha	556
Pusa Shrestha	375
Pusa Peetamber	675
Pusa Manohari	2465
Pusa Deepshikha	70
Citrus	
Kagzi Kalan	1021
Pusa Round	178
Pusa Sharad	262
Pusa Udit	315
Pusa Abhinav	294
Pusa Arun	11
Grape	
Pusa Navrang	102
Pusa Urvashi	124
Pusa Trishar	625
Pusa Aditi	315
Pusa Swarnika	138
Pusa Purple Seedless	106
Papaya	
Pusa Nanha	62
Fund generated	**₹ 12,56,250**

ICAR- IARI Reginal Station, Karnal

S. No.	Crop	Cultivar	No. of planting material
1.	Mango	Amrapali, Mallika, Dashari, Arunima, Surya, Langra, Ramkela, Shrestha, Chau-sa, Lalima, Pitamber, Pratibha	850
	Lemon	Kagzi Kalan	463
	Guava	Allahabad Safeda	117
	Rose		05
	Total		**1435**

Funds generated: **

ICAR- IARI Regional Station, Pusa, Bihar

S. N.	Crop	Variety	Seed & saplings	Production
1.	Papaya	Pusa Dwarf	TFL Seed (Kg)	0.80
			Saplings (Nos.)	3881
2.	Mango	PusaArunima	Saplings (Nos.)	419
		Amrapali	Saplings (Nos.)	359
		Mallika	Saplings (Nos.)	357
3.	Litchi	Shahi	Saplings (Nos.)	235
		China	Saplings (Nos.)	53
4.	Citrus	KagziKalan	Saplings (Nos.)	192
		Total		**5,496**

Funds generated: ***

ICAR-IARI Regional Station, Kalimpong

S. N.	Crop	No. of planting material
1.	Budded Darjeeling Mandarin	1000
2.	Seedling of rootstock for Mandarin	8000
3.	Licoris Bulb	3000
4.	Lilium	1000
	Total	**13,000**

Funds generated: ₹ 60,000

19.2.3 Ornamental Crops

Total 14.0 Kg of marigold (P. Arpita, P. Bahar, P. Deep, P. Basanti) was produced at the ICAR- IARI Regional Station, Karnal.

S. No.	Crop	Variety	Quantity (kg)	Centre/Location
1.	Marigold	P. Arpita, P. Bahar, P. Deep, P. Basanti	14.00	IARI RS, Karnal

Fund generated: **

20. MISCELLANY

I. Scientific Meetings Organized

a) Workshops	28
b) Seminars	20
c) Summer institutes/Winter school	2
d) Farmers' day (s)	32
e) Others	485
Total	**567**

II. Participation of Personnel in Scientific Meetings

India

a) Seminars	326
b) Scientific meetings	258
c) Workshops	190
d) Symposia	108
e) Others	54
Total	**936**

Abroad

a) Seminars	07
b) Scientific meetings	13
c) Workshops	03
d) Symposia	03
e) Others	08
Total	**34**

III. Ongoing Projects at IARI as on 31.12.2022

(A) Research Projects	**:**	**236**
School of Crop Improvement	:	62
School of Horticultural Sciences	:	49
School of Crop Protection	:	20
School of Natural Resource Management	:	54
School of Basic Sciences	:	15
School of Social Sciences	:	33
ZTM & BPD Unit	:	1
FOSU	:	1
(B) Number of on-going contract research /consultancy/contract service project	**:**	**10**
School of Crop Improvement	:	00
School of Horticultural Sciences	:	03
School of Crop Protection	:	02
School of Natural Resource Management	:	05
School of Basic Sciences	:	00
School of Social Sciences	:	00

List of sanctioned contract research project in 2022

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Budget
	Dr. Ram Asrey (PI), Principal Scientist, Division of FS&PHT	Bio-efficacy Evaluation of UPH 2121 on stored potato under controlled condition	United Phosphorus Limted	13.05.2022	12.05.2023	₹ 10,38,005
	Dr. Rajiv Kumar Singh (PI), Principal Scientist, Div of Agronomy.	Evaluation of POLY-4 (Polyhalite) in rice-wheat system and other major crop under Indo-Gangetic plains for enhanced yield, K and S use efficiency	SIRIUS Minerals India Pvt. Ltd.	11.05.2022	10.05.2024	₹ 6,56,911

	Dr. T.K. Das, Principal Scientist, Division of Agronomy, PI	Evaluation of phytotoxicity and bioefficacy of Kifix (Imazapic 175 g/kg+ Imazapyr 525 g/kg WG (BAS 714 01 H) on herbicide tolerant rice variety Pusa Basmati 1985) of IARI	BASF India Limited, New Delhi -110 037	07.09.2022	06.09.2023	₹ 10,14,025/-
	Dr. Arti Bhatia, Principal Scientist, Environment Science	"Quantifying CO_2 equivalent emission in rice, wheat and maize under improved agricultural management practices using simulation tools"	Grow Indiga Pvt. Ltd.	28.09.2022	27.09.2025	₹ 22,74,967
	Dr. R.S. Bana, Senior Scientist, Division of Agronomy	"Effect of novel fertilizer formulations on productivity, biofortification and nutrient-use efficiency of major cereal rotations"	Sulphur Mills Ltd	28.09.2022	27.09.2024	₹ 55,27,958
	Dr. V.B. Patel, PS, Div. of FHT,	Evaluation of effect of POLY-4 (Polyhalite) on kinnow mandarin	Sirius Minerals India Pvt Ltd	30.11.2022	29.11.2025	₹ 55,40,220/-

List of sanctioned consultancy project in 2022

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Budget
1.	Dr. S.S. Sindhu, Head, Division of Floriculture and Landscaping	Third party Audit of tree plantation survival of Horticulture, CPWD (Lutyens Zone of VVIPs Bungalows/Buildings and others)	CPWD	25.08.2022	21 Man-days	₹ 2,44,319/-
2.	Dr. Ravinder Kaur Principal Scientist WTC	Designing Jalopchar™ Technology based Tertiary-wastewater treatment facility for rejuvenation of Badkal lake under smart city mission of Faridabad smart city Limited	Faridabad Smart City Limited, Faridabad, Haryana-121 001	07.12.2022	20 Mandays	₹ 9,44,000/-

List of sanctioned contract service project in 2022

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Budget
1.	Dr. Santosh Watpade, Scientist, IARI RS, Shimla	Evaluation of Mancozeb 75% WP against apple scab and sooty blotch diseases in apple	Dow AgroSciences India Pvt Ltd	18.04.2022	18.04.2024	₹ 13,28,529
2.	Dr. A.K. Shukla, P.S., RS, Shimla	Evaluation of NA-89 18.19% SC for the management of European Red Mite and two-spotted spider Mite in Apple	Biostad Pvt Ltd	24.05.2022	23.05.2024	₹ 14,74,828

IV. All India Coordinated Research Projects in Operation during the year January 1, 2022 to December 31, 2022

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
5. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
6. All India Coordinated Research Project on Soybean
7. All India Coordinated Research Project on Fruits
8. All India Coordinated Research Project on N.S.P.(Crops)
9. All India Coordinated Research Project on Mustard
10. All India Coordinated Research Project on Wheat
11. All India Coordinated Research Project on Rice
12. All India Coordinated Research Project on Pulses
13. All India Coordinated Research Project on Vegetable
14. AINP on Whitegrubs and other Soil Arthropods (AINPWOSA)
15. All India Coordinated Wheat & Barley Improvement Project (AICW&BIP)
16. Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)
17. All India Coordinated Research Project on Vegetable Crops
18. Adhoc Cooperating Center of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal
19. All India Coordinated Research Project on Ergonomics & Safety in Agriculture (ESA)
20. All India Coordinated Research Project on Pearl Millet
21. All India Coordinated Research Project on Rapeseed-Mustard
22. All India Network Research Program on Onion & Garlic (AINRPOG)
23. Engineering interventions for enhanced nutritional security of pearl millet during milling and storage under AICRP on Pearl Millet
24. All India Coordinated Research Project on Fruits-PAPAYA

V. Resource Generation (2022-2023)

1) Consultancy & other services

Consultancy services: nil

Contract research: ₹7520880.00/-

Contract service: ₹22211952.00/-

Training: ₹ 44086425.00/-

Total (A): ₹ 73819257.00/-

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed: ₹ 57021938.00/-

(b) Commercialization: ₹ 2635660.00/-

(c) Prototype manufacturing: ₹ 2150879.00/-

Total (B): ₹ 61808477.00

3) Post Graduate School receipt

Training Programme

(a) Foreigners & Indians: Nil

M.Sc./Ph.D. Programme

(b) Institutional economic fee from foreign scholars under Work Plan: Nil

(c) Receipt from Registrar (A) Account No. 5432 (9029.201.4314) all fees except institutional economic fee: ₹ **0.00**

(d) Receipt deposited in Director's Account No. C-49 (9029.305.17) for theses evaluation, PDC & Misc. (does not include refund of IARI scholarship by students): **₹74,64,286/-**

Total (C): ₹ 74,64,286/-

Grand Total (A+B+C): ₹ 73819257.00 + ₹ 61808477.00+ ₹ 74,64,286.00= ₹ 143,092,020.00

VI. Suggestions Given / Decisions Taken at the Meetings of Senior Management Personnel Academic Council (January 1, 2022 to December 31, 2022)

- Introduction of following new programs (i) UG Programme (ii) Diploma/Certificate Courses (iii) Sandwich Ph.D. degree program (iv) Induction of International Faculty (v) Self-finance scheme for Indian, foreign nationals and Non-Resident Indian students
- Adoption of New Dress Code by IARI from 60th Convocation (2022) onwards
- Approval of Courses/Syllabi for all the teaching disciplines of IARI as per BSMA recommendations
- Institution of Divisional gold medal in the Division of Soil Science and Agricultural Chemistry in the memory of Dr. K.N. Synghal
- Modification of existing nomenclature of (i) Floriculture and Landscaping Architecture" as" Floriculture and Landscaping (ii) 'Agricultural Extension' as 'Agricultural Extension Education'

Research Advisory Committee

RAC meeting of ICAR-IARI, New Delhi was held in hybrid mode on 22-23 December, 2022 under the Chairmanship of Prof. R.B. Singh, former Director, IARI and Former President, National Academy of Agricultural Sciences (NAAS), New Delhi. The RAC members who physically participated in the meeting were Prof. Nazeer Ahmad, Former VC, SKAUST(K), Srinagar, Dr. H.C. Sharma, Former VC, YSPUHF, Solan, Dr. Mruthyunjaya, Former Director, ICAR-NIAP, New Delhi, Dr. K.K. Narayan, Founder & Director, Sthayika Seeds Pvt Ltd, and Director & CEO, Agrigenome Director Research, PAU, Ludhiyana, Dr. A.K. Singh, Director, ICAR-IARI, New Delhi, Dr. D.K. Yadava, ADG (Seed) ICAR, and Dr. Viswanathan Chinnusamy, Joint Director (Research) and member Secretory RAC. In addition, Dr. Anupama Singh, Dean and Joint Director (Education), Dr. R.N. Padaria, Joint Director (Extension), Dr. Man Singh, project Director, WTC, Shri Pushpendra Kumar, Joint Director (Administration) and Senior Registrar and Shri D.D. Verma, Senior Comptroller, all Heads of the Divisions, In-charges of different units at IARI and Principal Investigators of the in-house projects also attended the RAC meeting. All Heads of regional Stations of IARI and all scientists of IARI attend the RAC meeting online.

School coordinators made school-wise presentations for research achievements, which were followed by the presentations by Dean & Joint Director (Education) on achievements of postgraduate School, Joint Secretary (Finance)/Sr. Comptroller on Financial matters and Chief Administrative Officers on various administrative matters. After thorough deliberations on the presentations, the recommendations of RAC along with comments of Crop Science Division are placed below for kind perusal and necessary action:

School of Crop Improvement

- Enhanced efforts to harness heterotic pools and development of suitable hybrids for increasing the area under hybrid rice in the Country

- IARI must take lead in research on false smut resistance in rice
- Emphasis may be given on hybrid mustard development for increasing yield as hybrid mustard is gaining popularity among farmers. Urgency for attaining self-sufficiency in edible oil can hardly be overemphasized.
- The issues associated with storability of "00" mustard need to be addressed
- Efforts need to be made to tackle the corn borers, as it is a major devastating pest.
- Commercialization of the maize hybrids released to be pursued more vigorously. Hybrids in late maturity group, hybrids tolerant to water logging stress, and turcicum blight resistance need to be developed to spread to larger areas.
- Wheat genetic stock and varieties to combat celiac disease may be developed for meeting export potential.
- Pre-breeding in wheat for heat tolerance may be strengthened
- The genetic background of popular varieties, namely HD2967 and HD3806, should be widened with genes for nutritional quality and disease resistance
- Chickpea varieties with resistance to Ascochyta blight need to be developed for hilly areas
- A trait segment-based breeding approach need to be taken-up on priority
- The school of Crop improvement need to work in close collaboration with the Private sector to work in close collaboration with the Private sector similar to the Crop Consortium model of ICRISAT, integrating the science of discovery with science of delivery.

School of Horticultural Science

- Seed Production and licensing of released vegetable and flower crop varieties must be taken up for popularizing IARI varieties
- Hybrid varieties along with complete package of agronomic practices must be developed for major vegetables.
- In biofortified vegetables, the serving size for meeting RDA may be worked out.
- Emphasis may be given on urban horticulture. Varieties suitable for organic farming in urban horticultural need to be identified/developed. Adoption of Protected Horticulture should be scaled-up.
- Control measure to manage codling moth pest in apple in the apple growing areas of Ladakh needs to be developed and disseminated.
- Research collaboration with Horticulture universities may be strengthened.
- Generation, dissemination, and adoption of new technologies for on-farm processing, value-addition, and prevention of post-harvest losses should be given priority along the value-chain.

School of Natural Resource Management

- Scientific Studies on zero budget natural farming and nano-urea on productivity of crop need to be conducted, and the finding should be communicated to the policy makers as policy briefs.
- Heavy metal accumulation in vegetables grown in diver beds may be quantified and people must be educated.
- Sun fridge need to be promoted, and research and development for reducing the cost of Sun fridge need to be taken up for its wider adaptability.
- Develop technologies and innovations to eliminate carbon and water footprints and ultimately achieve Net Zero.
- Intensify research on micro-biome management leading to improved soil health, carbon economy and climate resilience.
- Triple wins (enhanced productivity, resilience, and mitigation) of Climate Smart Agriculture must be realized on high priority. For this, it will be essential to adopt Precision Agriculture, artificial Intelligence, IOT, and Blockchain technologies.

School of Crop Protection

- Work on resistance against Tospovirus in tomato and enation leaf curl virus (ELCV) in Okra needs to be strengthened
- Use of dsRNA-based crop protection methods need to be developed.
- A brainstorming to be organized with scientist and experts on bioprospecting and biocontrol to critically analyse the exiting situation and prepare effective future pathway clearly defined outcomes and impacts.
- Research on Digital diagnosis and making image-based repositories of pests and pathogens need to be strengthened.
- The School of Plant Protection must strengthen its collaboration with School of Crop Improvement and School of Basis Science for identification of mechanisms and genes for biotic stress resistance, and their use in crop improvement and management.
- As IARI evolves as a global university and Green Development being its high priority, the institute in collaboration with private sector, should strive to develop and commercialize "Green Molecules" for pest and disease management.

School of Basic Sciences

- The big data generated in phenomics may be used to create model plants with all desirable characters that serve as basis for parental selection with desirable component traits, trait pyramiding and precision breeding.
- Nitrogen use efficiency must be measured in phenotyping experiments with the actual measurement of nitrogen uptake and utilization efficiency with the global standard methods for Identification of donors and QTLs for the component traits
- Significant efforts have been made to identify QTL using biparental populations and MTAs (Marker Trait Associations) with GWAS analysis for Abiotic stress tolerance and nutrient use efficiency. The findings must be taken forward to validate them in different genetic backgrounds and utilization in marker assisted breeding.
- Genome editing for nutritional quality improvement in addition to yield/stress tolerance need to be given emphasis.
- Similar to the technologies developed for the promotion of use of pearl millet, effort should be made to optimize dough quality of some of the other coarse millets such as little millet/Proso millet/Finger millet/Foxtail millet/Barnyard millet for chapati making or baking quality. Use of Buckwheat and Quinoa should also be explored in food biochemistry and making food products. This will further brighten Government of Indian leadership in the celebration of international Year of Millets in 2023.
- Molecular biology of plant host-pathogen/pest interaction may be explored

School of Social Sciences

- Transformation of economic surplus from new IARI technologies to farmer's welfare need to be studied.
- An assessment of consumption of nutri-cereals, especially millets, and their impact on human nutrition and health may be taken up.
- A study on low participation of APMC markets and farmers in e-NAM and lower e-NAM prices as compared to Agmark.net prices in e-NAM and the to improve participation rate, monetary incentives, and higher prices in e-NAM need to be studied.
- Impact of soil health card on soil health, fertilizer consumption, increase in crop yield and reduction in cost may be analysed.
- Science-evidenced policy papers/briefs on lacunae in major national agricultural development programs with suggestions for mid-course corrections and future directions may be brought out.
- Association between malnutrition and socio-economic and agro-biological factors needs to be analysed.

- There are serious discrepancies in socio-economic indicators, such as Global Hunger Index, Global Development Index, etc., published by International Organization *viz*., FAO, World Bank and by national agencies. These asymmetries need to be resolved in order to heave reliable assessment and planning. IARI in collaboration with other concerned institutes should take lead in scientifically resolving the issue.

Post Graduate School

- International Agricultural Innovation Centre should be established for making IARI as global university.
- Changes in course curriculum in the context of science and technology innovation need to be done.
- Agriculture should have close interaction with Science, Technology, Engineering and Mathematics, and Land Grant concept should be changed to World Grant approach.
- The government schemes for international faculty attraction may be pursued to get some international faculty
- Expertise with the alumni of IARI need to be utilized in teaching program

Zonal Technology Management & Business Planning and Development unit (ZTM & BPD unit)

- Students and faculty of IARI may be motivated to take up startup and entrepreneurial activities. Conducive training/incubation and policy environment may be created for the same.
- Patented technologies of IARI can be given to startups for commercialization with needed handholding. Youth and women may particularly be encouraged for the purpose.

VII. National and International visitors during January 1 to December 31, 2022

List of visitors from January 1 to December 31, 2022		
S.No.	**Details of Visit**	**Date of Visit**
1.	The delegation from Lebanon, Mr Louis Lahoud, Director General visited at IARI, New Delhi	01.06.2022
2.	The Nepalese delegation led by Dr Dil Bahadur Gurung visited IARI	04.06.2022
3.	The Israel's delegation visited IARI	10.06.2022
4.	Parliamentary Standing Committee on Science & Technology, Environment, Forests and Climate Change visited IARI	29.06.2022
5.	Visit of U.P. Governor in IARI	26.07.2022

Delegation from Lebanon visited ICAR-IARI, New Delhi

Nepalese delegation visited ICAR-IARI

Parliamentary Standing Committee on Science & Technology, Environment, Forests and Climate Change visited ICAR-IARI, New Delhi

Visit of U.P. Governor to ICAR-IARI, New Delhi

Israel delegation visited ICAR-IARI, Delhi

Appendix 1

Members of Board of Management of IARI

(As on 31.12.2022)

Chairman

Dr. A.K. Singh
Director, ICAR-IARI, New Delhi

Members

Dr. Rashmi Aggarwal
Dean & Joint Director (Education) (Acting), IARI

Dr. Prakash Shastri,
Professor (Plant Pathology),
College of Agriculture, Rajmata Vijiyaraje Scindia krishi Vishwavidyalaya (RVSKVV),
Khandwa, M.P.

Shri Akhilesh Kumar,
Shyama Bhavan, MathiyaZirat,
Motihari, East Champaran (Bihar)

Dr. Rajendra Prasad S,
Vice-Chancellor,
University of Agricultural Sciences, Bangaluru, Karnataka

Dr. A.K. Singh
Agriculture Commissioner
Deptt. of Agril. and Cooperation,
Ministry of Agriculture, Krishi Bhawan, New Delhi

Prof. Dr. Pratap Bhanu Singh Bhadoria,
Agri. & Food Engg., IIT Kharagpur

Dr. V.P. Singh, Padamshree,
Ex-principal Scientist, Division of Genetics

Shri Ramkumar Saharawat,
Garhi, Sakhawatpur, Tehsil Budhana, District- Muzaffanagar

Dr. T.V.R.S. Sharma,
Former Emeritus Scientist & Principal Scientist,
Central Island Agricultural Research Institute, Garacharma, Port Blair

DDG, Crop Science,
ICAR-Krishi Bhavan, New Delhi

Dr. Triveni Dutt,
Director, IVRI, Izzatnagar, Bareilly (U.P.)

Dr. Rajbir Yadav,
Head, Division of Genetics,
IARI, New Delhi

Dr. Alka Singh,
Head, Division of Agricultural Economics,
IARI, New Delhi

Dr. Pramila Krishanan,
Head, Division of Agricultural Physics,
IARI, New Delhi

Dr. Anupama Singh,
Head, Division of Agricultural Chemicals,
IARI, New Delhi

Dr. S.S. Sindhu,
Head, Division of Floriculture & Landscaping,
IARI, New Delhi

Smt. Sanjeevan Prakash,
Comptroller, IARI, Jharkhand

Sh. Madhup Vyas
Secretary-cum-Commissioner (Development),
Govt. of NCT of Delhi

Member - Secretary

Sh. Pushpendra Kumar
Joint Director (Adm.), IARI

Appendix 2
Members of Research Advisory Committee of IARI
(As on 31.12.2022)

Chairman
Dr. R.B. Singh
Former President NAAS and
Member National Commission on
Farmers, New Delhi

Members
Prof. (Dr.) Nazeer Ahmad
Director,
ICAR-CITH & former VC,
SKAUST (K), Srinagar

Dr. H.C. Sharma
Ex-Vice Chancellor
YSPUHF, Solan

Dr. Praveen Rao
Vice Chancellor
PJTSAU, Hyderabad

Dr. Mruthyunjaya
Former Director
ICAR-NIAP, New Delhi

Dr. K.K. Narayanan
Founder Director, Sthayika Seed
Pvt. Ltd. &
Director & CEO of Agrigenome
Labs Pvt. Ltd. Banguluru

Dr. S.P.S. Khanuja
Ex-Director
CIMAP, Lucknow

Dr. Sanjay Kumar
Director
CSIR-Institute of Himalayan
Bioresource Technology,
Palampur, H.P.

Dr. Navtej Singh Bains
Director Research,
PAU, Ludhiana

Dr. A.K. Singh
Director,
ICAR-IARI, New Delhi

DDG (CS), ICAR Krishi Bhawan
As per the nomination on the
Management Committee under
Rule 66(a) (5)

Member – Secretary
Dr. C. Viswanathan
Head and Principal Scientist
Division of Plant Physiology
ICAR-IARI, New Delhi

Appendix 3

Members of Academic Council of IARI

(As on 31.12.2022)

Dr. A.K. Singh Director		Chairperson
Dr. Anupama Singh Dean & Jt. Director (Edn.)		Vice-Chairperson
Deputy Director General (Edn.), ICAR	Member	Dr. R.C. Agrawal
Directors of IASRI, NIPB, NBP-GR, CIAE, IIHR, IIAB, NIBSM and NIASM	Members	Dr. Rajender Parsad Director (IASRI)
		Dr. Ajit Kumar Shasany Director (NIPB)
		Dr. G.P. Singh Director (NBPGR)
		Dr. C.R. Mehta Director, CIAE, Bhopal
		Dr. S.K. Singh Director, IIHR, Bengaluru
		Dr. Arunava Pattanayak Director, IIAB, Ranchi
		Dr. P.K. Ghosh Director, NIBSM, Raipur
		Dr. Jagadish Rane (Additional Charge) Director, NIASM, Baramati
Joint Director (Res.)	Member	Dr. C. Viswanathan
Joint Director (Extn.)	Member	Dr. R.N. Padaria
Four Eminent Scientists/ (Out-side Members)	Members	Prof. B.D. Singh Professor Emeritus School of Biotechnology Banaras Hindu University, Varanasi-221005 Dr. C. Devakumar Former ADG, ICAR A-61, Second Floor, Inderpuri, New Delhi-110012 Dr. V.V. Sadamate Former Advisor, Agriculture (Planning Commission) C-309, Kendriya Vihar, Sector-56 Gurgaon-122011

		Dr. V.S. Tomar Former Vice-Chancellor, JNKVV H.No.DH33A, Deendayal Nagar, Gwalior-474020, Madhya Pradesh
Project Director, WTC	Member	Dr. Man Singh (Additional Charge) Water Technology Centre
Associate Dean	Member	Dr. Atul Kumar
26 Professors of teaching disciplines at IARI	Members	Dr. (Ms.) Neera 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. P. Krishnan Professor, Agricultural Physics
		Dr. Cini Varghese Professor, Agricultural Statistics
		Dr. T.K. Das Professor, Agronomy
		Dr. Anil Dahuja Professor, Biochemistry
		Dr. Anil Rai Professor, Bioinformatics
		Dr. Alka Arora Professor, Computer Application
		Dr. Debjani Dey Professor, Entomology
		Dr. D.K. Sharma Professor, Environmental Sciences
		Dr. K.P. Singh Professor, Floriculture and Landscaping
		Dr. Manish Srivastav Professor, Fruit Science
		Dr. Anju Mahendru Professor, Genetics
		Dr. Sunil Pabbi Professor, Microbiology
		Dr. Debasis Pattanayak Professor, Molecular Biology and Biotechnology
		Dr. M.R. Khan Professor, Nematology
		Dr. Veena Gupta Professor, Plant Genetic Resources

		Dr. Robin Gogoi Professor, Plant Pathology
		Dr. (Ms.) Renu Pandey Professor, Plant Physiology
		Dr. Ram Asrey Professor, Post Harvest Management
		Dr. Monika Atul Joshi Professor, Seed Science & Technology
		Dr. S.P. Datta Professor, Soil Science & Agricultural Chemistry
		Dr. R.K. Yadav Professor, Vegetable Science
		Dr. Man Singh Professor, Water Science & Technology
Master of Halls of Residences	Member	Dr. Anil Sirohi
Comptroller	Member	Shri. D.D. Verma
Elected Faculty Representatives (2)	Members	Dr. Mahendra Kumar Verma Principal Scientist, Fruit Science
		Dr. Praveen Kumar Singh Principal Scientist, Vegetable Science
Incharge, IARI Library	Member	Shri Deep Chand
Elected Students of PGSSU(2)	Members	Mr. Vislavnath Ram Vilas Pashwan President PGSSU
		Mr. Sahil Kumar Students' Representative to the Academic Council
Registrar	Member Secretary	Shri Pushpendra Kumar

Appendix 4

Members of Extension Council of IARI

(As on 31.12.2022)

Chairperson
Dr. A.K. Singh, Director, IARI, New Delhi

Members
Dr. Anupama, Head, Agricultural Chemicals, School coordinator, Plant Protection

Dr. Rajbir Yadav, Head, Genetics & School Coordinator, Crop Improvement

Dr. P. Krishanan, Head, Agril. Physics and School Coordinator, Natural Resource Management

Dr. C. Vishwanathan, Head, Plant Physiology, and School Coordinator, Basic Sciences

Dr. S.S. Sindhu, Head, Floriculture, School Coordinator, Horticultural Sciences

Five Scientists representative of IARI

Dr. Sunil Pabbi, Head, Microbiology, IARI

Dr. S.K. Singh, Head, Fruits and Horticulture, IARI

Dr. B.S. Tomar, Head, Veg. Sci., , IARI

Dr. Gyanendra Singh, I/C. Seed Production, Unit, IARI

Dr. J.P.S. Dabas, I/c CATAT, IARI

One Project Coordinator/Project Director

Dr. Man Singh, Project Director, WTC, IARI

One Scientist, from IARI Regional Research Station

Dr. R.N. Yadav, Head, IARI Regional Station Karnal

One Representative of Deptt. of Agriculture, MOA

Dr. P.K. Singh, Agril. Commissioner, MOA & FW

Representatives of Delhi Administration

Sh. Chandra Pal Singh, Extension Officer, Agril. Deptt., Delhi Govt.

One Extension Scientist representative of Livestock Development and Animal Health Cover

Dr. Mahesh Chander, Head (Extension), ICAR-IVRI, Izzatnagar-243122, Bareilly

Director (Farm Information), Directorate of Extension, MOA

Dr. Shailesh Kumar Mishra, Director (Farm Information Unit) Directorate of Extension, KrishiVistar Sadan, Behind Agro. Division, IARI Campus New Delhi

Dy. Director General (AE), ICAR

Jt. Director (Extension), IARI, New Delhi

Jt. Director (Research), IARI, New Delhi

Jt. Director (Admn.), IARI, New Delhi

Member-Secretary
Dr. R.N. Padaria, Head, Ag. Extension, IARI, New Delhi

Dr. Neil Devasahayam, World Vision India (V.O. Representative) 16, Pant Marg, New Delhi 110001 neil_devasahayam@wvi.org

Mr. Rajesh Aggarwal, Managing Director, (Agro Industry Representative) Insectiside India Limited, 401-402, Lusa Tower, Azadpur Commercial Complex Delhi-33) 9810089093 (email: rajesh@insecticidesindia.com)

Sh. Arvind Jha (DD Representative)/Marcel Tirkey
The Additional Director General
DD Kisan CPC, 175, Asian Games Village Complex
Siri Fort, New Delhi

Sh. Shiv Nandan Lal (The Additional Director General Representative)
All India Radio, Akashwani Bhawan
New Delhi

Sh. D.D. Verma, Sr. Comptroller, IARI, New Delhi-12

Farmers:
Shri. Pritam Singh, Panipat (HR)

Shri Sukhjeet Singh, Sangrur , Punjab

Appendix 5

Members of Institute Research Council (IRC)

(As on 31.12.2022)

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 31.12.2022)

Chairman
Dr. A.K. Singh
Director, IARI, New Delhi

Members (Official side)
Joint Director (Extension), IARI, New Delhi

Joint Director (Research)

Head, IARI, Regional Station, Karnal

Head, Regional station, Shimla

Comptroller, IARI, New Delhi

Secretary (Official side)
Joint Director (Adm.), IARI, New Delhi

Members of the Staff Side (Elected)

Sh. Yogesh Kumar
AAO, Agril. Extension, Secretary (Staff side), IARI, New Delhi

Sh. Pankaj Kumar,
UDC, Directorate

Sh. Ashwani Kumar,
Assistant, Directorate

Sh. Raj Kumar
UDC, Directorate,

Sh. Sunil Kumar,
Sr. Technician, Agril. Engineering

Sh. Ganesh Rai
Sr. Technical Assistant, Division of Entomology

Sh. Rakesh Kumar
Sr. Technician, Agril. Engineering

Sh. Bhavesh Kumar
Sr. Technician, ME Unit, Directorate

Sh. Raj Pal
SSS, Directorate

Sh. Bijender Singh
SSS, CATAT

Sh. Shashi Kant Kamat
SSS, Agril. Physics

Sh. Raju
SSS, Directorate

Appendix 7

Members of Grievance Committee of IARI

(As on 31.12.2022)

Chairperson
Dr. B.S. Tomar
Joint Director (Extn.) (Acting)

Members (Official Side)
Dr. Raj Singh
Head, Agronomy (Acting)

Sh. Ravinder Singh,
Chief Admin. Officer., Directorate

Sh. Harshit Aggarwal,
Sr. Admn. Officer, Directorate

Members of the Staff Side (Elected)
Dr. A. Nagaraja,
Principal Scientist, Division of Fruit & Horti. Technology

Sh. Dharampal,
STA, Division of Seed Science and Technology

Ms. Shivani Bidhuri,
Assistant, Directorate

Sh. B.N. Rai,
SSS, FHT

Member-Secretary
Smt. Vinita,
AAO, IMC

Appendix 8

Personnel

(As on 31.12.2022)

Directorate

Director
Dr. A. K. Singh

Joint Director (Research)
Dr. Chinnusamy Viswanathan

Dean & Joint Director (Education)
Dr. Anupama Singh

Joint Director (Extension)
Dr. R.N. Padaria

Joint Director (Adm.) & Registrar
Mr. Pushpendra Kumar

Principal Scientist (PME)
Dr. Pramod Kumar

Incharge, Publication Unit
Dr. Anil Dahuja

Comptroller
Mr. D.D. Verma

Chief Administrative Officers
Mr. Sanjeev Kumar Sinha

Agricultural Chemicals
Head (Acting)
Dr. Suman Gupta
Professor
Dr. (Ms.) Neera Singh

Network Project Coordinator
Dr. Vandana Tripathi

Agricultural Economics

Head (Acting)
Dr. Alka Singh

Professor
Dr. Alka Singh

Agricultural Engineering

Head (Acting)
Dr. P.K. Sharma

Professor
Dr. D.K. Singh

Agricultural Extension

Head (Acting)
Dr. Rashmi Singh

Professor
JD (Extension)

Agricultural Physics

Head (Acting)
Dr. P. Krishnan

Professor
Dr. P. Krishnan

Agronomy Head (Acting)

Dr. Raj Singh

Professor
Dr. T.K. Das

Biochemistry Head (Acting)

Dr. Aruna Tyagi

Professor
Dr. Anil Dahuja

Entomology Head (Acting)

Dr. Debjani Dey

Professor
Dr. Debjani Dey

Floriculture and Land-scaping

Head (Acting)
Dr. S.S. Sindhu

Professor
Dr. K.P. Singh

Fruits and Horticultural Technology

Head (Acting)
Dr. O.P. Awasthi

Professor
Dr. Manish Srivastava

Genetics

Head (Acting)
Dr. Rajbir Yadav

Professor
Dr. Anju Mahendru Singh

Microbiology & CCUBGA

Head (Acting)
Dr. Sunil Pubbi

Professor
Dr. Rajiv Kaushik

Nematology

Head (Acting)
Dr. Harender Kumar

Professor
Dr. M.R. Khan

Plant Pathology

Head (Acting)
Dr. Robin Gogoi

Professor
Dr. Robin Gogoi

Plant Physiology

Head (Acting)
Dr. Ajay Arora

Professor
Dr. Renu Pandey

Food Science & Post Harvest Technology

Head (Acting)
Dr. Vidya Ram Sagar

Professor
Dr. Ram Asrey

Seed Science and Technology
Head (Acting)
Dr. S.K. Chakraborty
Professor
Dr. S.K. Chakraborty

Soil Science and Agricultural Chemistry
Head (Acting)
Dr. Nayan Ahamed
Professor
Dr. S.P. Datta

Vegetable Science
Head (Acting)
Dr. B.S. Tomar
Professor
Dr. Ramesh Kumar Yadav

Centre for Environment Science and Climate Resilient Agriculture (CESCRA)*
Head (Acting)
Dr. Bhupinder Singh
Professor
Dr. D.K. Sharma

Water Technology Centre
Project Director (Acting)
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
Joint Director (Research)

Agricultural Knowledge Management Unit (AKMU)
Incharge
Dr. Amrender Kumar

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. Gyanendra Singh

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*Formerly Division of Environmental Sciences and including Nuclear Research Laboratory.

Mandate

- Basic, strategic and anticipatory research in field and horticultural crops for enhanced productivity and quality.
- Research in frontier areas to develop resource use efficient integrated crop management technologies for sustainable agricultural production system.
- Serve as centre for academic excellence in the areas of post-graduate and human resources development in agricultural science.
- Provide national leadership in agricultural research, education, extension and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards.

Azadi Ka Amrit Mahotsav

ISSN 0972-6136

ICAR-Indian Agricultural Research Institute
Pusa, New Delhi-110012
Tel.: 011-25843375, 25842367, Fax: 011-25846420
E-mail: director@iari.res.in Website: www.iari.res.in