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Annual Report 2023

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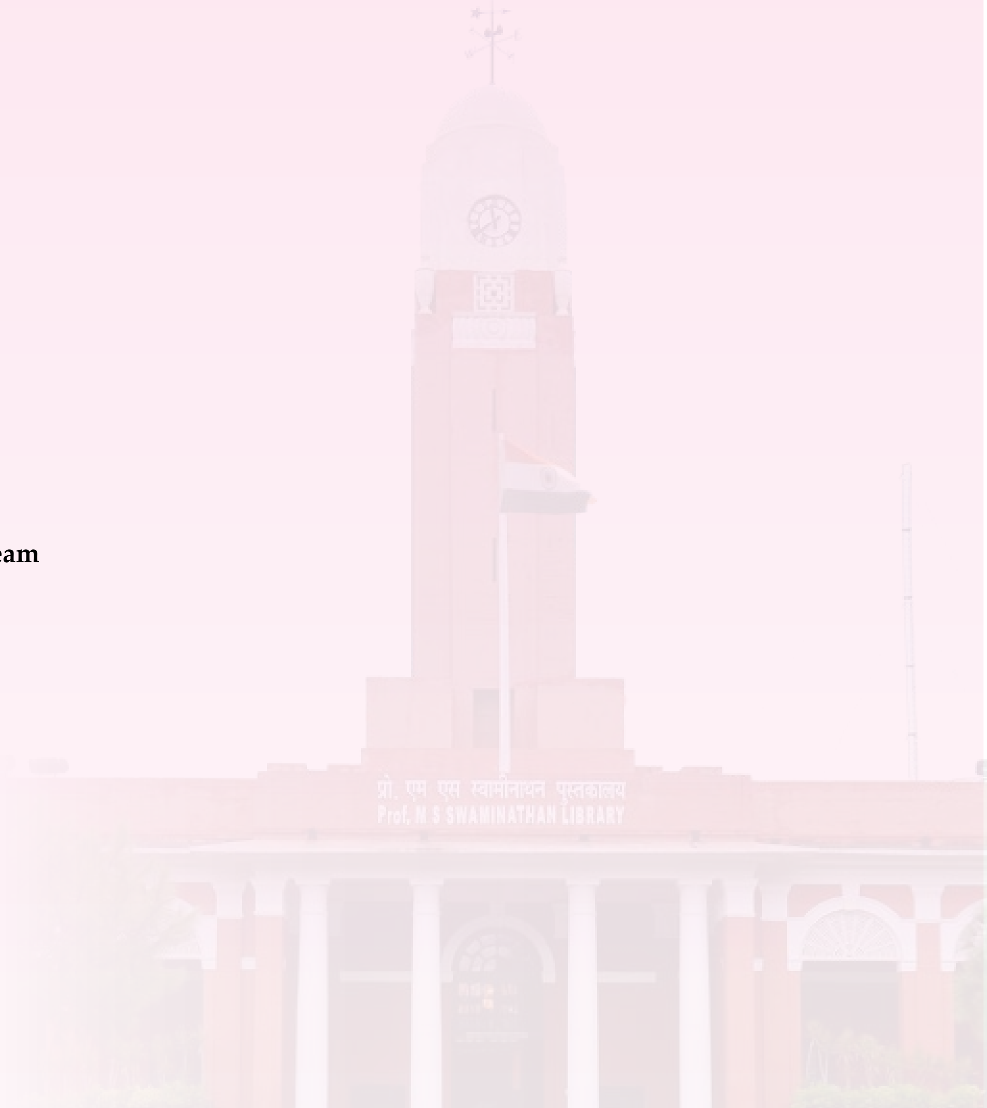

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PREFACE

Sustainable crop production to meet the food demand of our population faces numerous challenges, including climate change, soil degradation, limited resources, biodiversity loss and significant food wastage. IARI spearheaded research to meet these challenges through the development of climate-smart varieties and disruptive technological innovations in crop management that will ensure a resilient and sustainable food system for future generations.

During 2023-24, a total of 25 varieties/hybrids across various field crops were developed and released through integrated conventional and genomics-assisted breeding. Notable amongst these were high-yielding varieties of wheat such as HD 3386, HD 3388, HD 3390 and HD 3410 for diverse agroecologies and a MAS-derived variety, HD 3437, possessing resistance to leaf and stripe rusts. A milestone was achieved with the release of the first-ever grain oat variety in India, JWGO-01, offering new avenues for cultivation.

In rice, the traditional landrace "Kalanamak" was improved. Two varieties, namely Pusa Narendra KN1 and Pusa CRD KN2 were released targeting specific geographical indications areas in eastern Uttar Pradesh, promising improved yield and non-lodging trait against the traditional landrace "Kalanamak". Towards saving water and minimizing paddy stubble burning, two short-duration rice varieties, Pusa 2090 and Pusa 1824 were released, demonstrating >20% yield superiority over the popular variety, Pusa 44. Furthermore, the development of the first two-line rice hybrid, Pusa JRH-56 marked a notable advancement in rice breeding efforts.

The Institute is leading the genome editing program for crops. IARI developed drought and salt tolerance (DST) gene-edited lines of mega rice cultivar MTU1010 with enhanced drought and salt tolerance and yield. These are among the first set of genome-edited lines that were exempted from Rules 1989 and entered the national field testing in India.

In maize, two high-yielding field corn hybrids namely, PJHM-2 and PJHM-(R)-3 were also released. In pursuit of nutritional security, two improved chickpea varieties, Pusa Chickpea 3057 and Pusa Chickpea 10217 with increased yield and drought resilience, respectively and the first CGMS-based pigeon pea hybrid, Pusa Arhar Hybrid-5 were released. Similar efforts were directed towards developing salt-tolerant varieties in mung bean (PMS-8; PMD-9 and PMD-10) and lentil (PSL-17 and PSL-19), expanding their cultivation in saline-prone areas. Breeding for improvement in the quality of various crops led to the release of double zero quality mustard varieties (Pusa Double Zero Mustard-35 and Pusa Double Zero Mustard-36) possessing low erucic acid and glucosinolates and MAS-derived Kunitz trypsin inhibitor-free soybean variety, DS9421 and iron and zinc enriched pearl millet hybrid, Pusa 1801. IARI-bred biofortified and specialty corn hybrids were found to be superior for bioethanol production and would be promoted to meet the target of 20% blending of bioethanol in petrol. An MoU was signed with Uttar Pradesh Distiller's Association to collaborate and provide energy sector self-sufficiency.

In vegetable crops, new varieties of brinjal (Pusa Chota Baingan-1), bitter gourd (Pusa bitter gourd 2) and tomato (Pusa TOLCV Cherry Tomato Hybrid-1) for protected cultivation were released for NCT Delhi. For the first time in the country, two dwarfing rootstocks of mango, namely, Pusa Moolvrant-1 and Pusa Moolvrant-2 were released, which will help to reduce the height of the grafted mango and facilitate the better management of the orchard. In flower crops, varieties of rose like Pusa Lakshmi and Pusa Bhargava and marigold, Pusa Parv were developed for aesthetic and commercial value.

A plant protein blended product with 84.44% protein content, well-balanced essential amino acids, 89.61% protein digestibility and enhanced physicochemical properties was developed for the vegetarian population using protein isolates from peanut, chickpea and brown rice employing steam infusion technology.

The impact of climate change on 11 crops, alongside the benefits of adaptation were evaluated and documented in the Third National Communication to the United Nations Framework Convention on Climate Change. Improvisation of Pusa Soil Test and Fertilizer Recommendation (STFR) meter expanded its application for analysis of fourteen parameters.

Innovation in precision agriculture included solar-powered Variable Swath Herbicide Applicator (VarSHA) robot for precise application of weedicide. Deep-learning algorithms and multispectral data analysis enabled the identification of rice varieties and seed morphological diversity. The public-private partnership resulted in the formulation of EPN powder enriched with *Steinernema thermophilum* for pest management alongside a cost-effective, eco-friendly kairomone-based fruit fly management kit named 'PusaMeFly Kit'.

Economic analysis revealed substantial benefits from rice (cv. Pusa Basmati 1509 with INR 8732.51 crores) and wheat (cv. HD 3086 with INR 3533.88 crores), while the adoption of e-NAM trade platforms increased farmer's price realization by 52 % as compared to non e-NAM farmers. The Institute's video-based extension model "Pusa Samachar" garnered a viewership of 1.3 million individuals.

Pusa Krishi Vigyan *Mela* based on International Millet Year theme "श्री अन्नों द्वारा पोषण खाद्य अवं पर्यावरण सुरक्षा" was organised on March 2-4, 2023 and attracted more than one lakh farmers. During the *mela*, the institute honored 40 farmers as 'IARI Fellows' and 'IARI Innovative Farmers'. IARI secured three patents, six trademarks and three copyrights during this year. The commercialization of 64 technologies generated a revenue of INR 4.75 crore for IARI. A partnership with Social Alpha (powered by Bill & Melinda Gates Foundation) and IIT Kanpur aimed to promote the agripreneurial ecosystem in the country.

Embracing the National Education Policy 2020, IARI initiated undergraduate teaching and admitted 398 students to undergraduate, 298 to M.Sc./M.Tech and 408 to Ph.D. programmes. IARI also expanded its collaboration with 16 hub clusters of 70 ICAR institutes to harness the scientific manpower in a bid to upscale its stature to a global university.

The scientists of the Institute published 779 research papers in scientific peer-reviewed journals with a 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 the Board of Management, Research Advisory Committee, Academic Council, etc. This year, the Institute also successfully completed the review by Quinquennial Review Teams (QRT) for the period of 2017-2022.

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. Himanshu Pathak, Secretary, DARE & Director General, ICAR for guiding the institute and providing financial support for fulfilling the planned activities.

I acknowledge the funding agencies such as NASF (ICAR), NAHEP (ICAR), DBT, DST and other national & international agencies for funding projects for the financial year 2023 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.

Date: March 28, 2024
Place: New Delhi

(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.

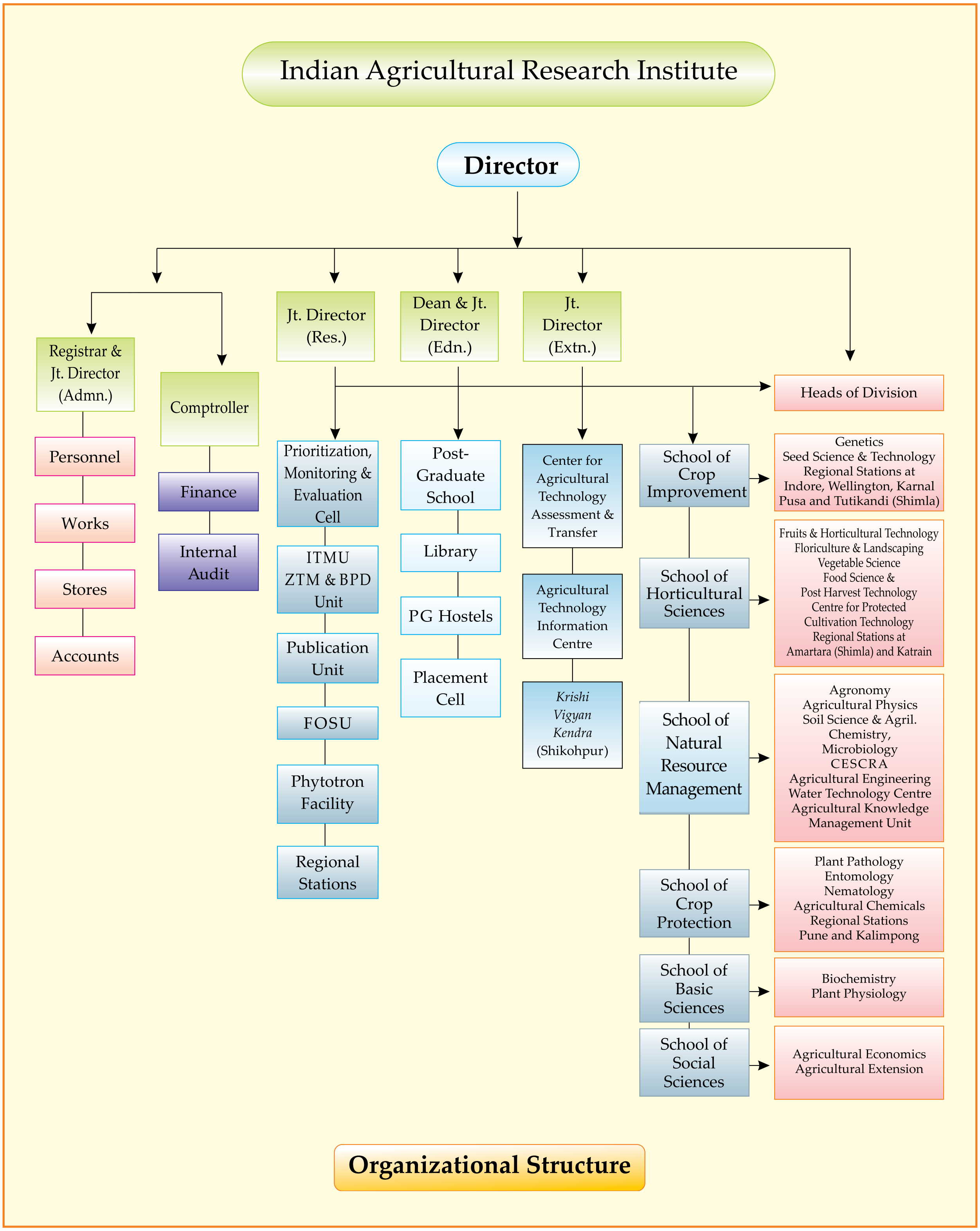
The growth of India's agriculture during the past more than 100 years is closely linked with the research done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high-yielding varieties of all major crops that occupy vast areas throughout 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 that have been patented and licensed and are being widely used in the country. Over the years, IARI has excelled as a center 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 an altitude of 228.6 meters above mean sea level. The climate is sub-tropical and semi-arid, with warm and dry summers and cold winters. The long- term average (1984-2020) of maximum temperature in hot period ranged from 32.9 to 40.5 C and in winters ranged from 18.3 to 34.1° C. the minimum temperature ranged from 15.8 to 33.6° C in hot period and 5.3 to 24.4° C in winter. The long-term average rainfall from June to September is 584.6 and 81.2 mm in winter. The daily maximum temperature during the hot period (April 2023-September 2023) ranged from 25.2°C to 44.0°C and the daily minimum temperature ranged from 13.8 to 29.4°C. Winter sets in from mid-November and is delightful. June to September are rainy months during which 941.4 mm of rainfall was received in 2023. During winter 148.5 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 2643 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹ 70974.70 lakh (Unified Budget) for the year 2023-24.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Director
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Accounts
Comptroller
Finance
Internal Audit
Jt. Director (Res.)
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ITMU ZTM & BPD Unit
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Library
PG Hostels
Placement Cell
Jt. Director (Extn.)
Center for Agricultural Technology Assessment & Transfer
Agricultural Technology Information Centre
Krishi Vigyan Kendra (Shikohpur)
Heads of Division
School of Crop Improvement
Genetics
Seed Science & Technology
Regional Stations at Indore, Wellington, Karnal Pusa and Tutikandi (Shimla)
School of Horticultural Sciences
Fruits & Horticultural Technology
Floriculture & Landscaping
Vegetable Science
Food Science & Post Harvest Technology
Centre for Protected Cultivation Technology
Regional Stations at Amartara (Shimla) and Katrain
School of Natural Resource Management
Agronomy
Agricultural Physics
Soil Science & Agril. Chemistry,
Microbiology
CESCRA
Agricultural Engineering
Water Technology Centre
Agricultural Knowledge Management Unit
School of Crop Protection
Plant Pathology
Entomology
Nematology
Agricultural Chemicals
Regional Stations Pune and Kalimpong
School of Basic Sciences
Biochemistry
Plant Physiology
School of Social Sciences
Agricultural Economics
Agricultural Extension
Organizational Structure

EXECUTIVE SUMMARY

School of Crop Improvement

ICAR-Indian Agricultural Research Institute (IARI), New Delhi, known as the seat of the 'Green Revolution' has developed a number of high-yielding varieties of major crops that play vital roles in achieving the country's food and nutritional security and enhancing farmers' income. During 2023-24, 43 varieties/hybrids in field crops were identified/released for cultivation in various agroecologies of the country.

- In cereals, fifteen varieties of wheat (HD 3386, HD 3388, HD 3390, HD 3410, HD 3437, HD 3406, HD 3407, HD 3411, HD 3369, HI 1650, HI 1653, HI 1654, HI 1655, HI 8826 and HI 8830), five varieties of rice (Pusa Narendra KN1, Pusa CRD KN2, Pusa 2090, Pusa 1824 and Pusa JRH 56), eight hybrid varieties of maize (APH-4, APTQH-5, PJHM-2, AH-8181, ABHS4-2, APCH-2, APCH-3 and AFH-7) and one variety of oat (JWGO-01) were developed.
- In millet, Pusa 1801, a pearl millet hybrid was developed.
- In pulses, three varieties of chickpea (Pusa JG 16, Pusa Chickpea 3057 and Pusa Chickpea 10217), one hybrid variety of pigeon pea (PAH-5), three varieties of mungbean (PMS-8, PMD-9 and PMD-10) and two varieties of lentil (PSL-19 and PSL-17) were developed.
- In oilseeds, three varieties of mustard (Pusa Mustard-34, Pusa Double Zero Mustard-35 and Pusa Double Zero Mustard-36) and one variety of soybean (DS-9421) were developed.
- Pusa Basmati 1121, Pusa Basmati 1509 and other IARI-bred Basmati varieties grown in 1.6 of 1.8 million ha total area under Basmati cultivation have the major share in the Basmati export market (INR 34,000 crores annually). While, in wheat, 'HD 2967', 'HD 3086' and other varieties developed at IARI are cultivated in 13 million ha of area and contribute to more than 50 million tonnes of grains valued at INR 87,000 crores annually. The varieties of mustard developed at the Institute also recorded the highest share (34%) in seed indent.

School of Horticulture Sciences

Division of Vegetable Science developed five vegetable varieties *viz*. Pusa Prasanskrit & Pusa Cocktail in tomato, Pusa Sem-6, Pusa Purple Broccoli 1, Pusa Lal Bhindi-1, Pusa Cauliflower Hybrid-102 and Pusa Parthenocarpic Cucumber Hybrid-1 which were released by Delhi State Seed Sub-Committee NCT, Delhi. Additionally, Pusa Chhota Baingan-1 and Pusa Protected Bitter gourd-2 were identified by Institute Identification Committee for their special traits.

- ICAR- IARI Regional Station, Pune also developed a dwarf and early maturing tomato selection 'Seln 25'. In addition, Seln-BLG-1 chilli, tolerant to leaf curl and moderately resistant to thrips with higher yield potential was also identified. ICAR-IARI Regional Station, Katrain were identified the capsicum genotypes, KTGC-17, KTOC-1, KTRC-12 and KTYC-8 with superior performance. Cauliflower lines viz. KTCF-33, KTCF-26, KTCF-46, KTCFH-534, KTCFH-515 and KTCFH-5137 were found promising for off-season (summer) cultivation in Kullu Valley, HP with good quality curds under high temperature conditions.
- In mango, NH-17-1, NH-18-4, NH 20-2, NH-19-2, H-12-5, and H-3-2 hybrids were identified for their attractive red peel, medium to big-sized fruits and moderate total soluble solids (TSS). A DNA bar code of 24 IARI mango hybrids was also generated and constructed a high-resolution linkage map using 4,613 SNPs markers. QTLs governing mango

fruit colour were found to be located on Chr 3 and 18 and for fruit firmness on Chr 11 and 20.

- In citrus, the ACSH-7-13 hybrid with very thin peel and higher juice content and ACSH-6-17 and ACSH-7-18 with fewer seeds were identified. In guava, hybrid 7A with white pulp and hybrid 8 F with pink pulp, suitable for table and processing purposes were identified.
- In rose, the lines RH-2-2018 (BRRS-2) was found suitable for loose flower and garden display, whereas, RH-1-2021 only for garden display. In marigold, Af/SR- 15-1 and Fr/14-6 were found to be suitable for landscaping as well as potted/bedding growing. In gladiolus, Pusa Sinduri was released by CVRC for zones II, IV and VI (West Bengal, Punjab, Delhi and Rajasthan).
- In chrysanthemum, Pusa Udai, an open-pollinated seedling of Lalpari, having a long stem and attractive green foliage suitable for open and polyhouse was identified. In ornamental kale, early colour development and head formation types, Ktok-6, Ktok-13 and Ktok-1 were identified. In lilium, a new germplasm PKLH-14 having trumpet shaped male sterile line showed significant difference for days to flowering and plant height over the female parent was developed.
- Plant genetic resources serve as the 'gold mine' for the crop improvement programme as wild relatives and un-adapted germplasm are a rich reservoir of the novel genes for higher productivity, biotic and abiotic stress tolerance and nutritional quality. During 2023-24, 11 germplasm lines across wheat (3), barley (2), lentil (1), mungbean (1), urdbean (2) and cucumber (2) were registered as unique genetic stocks at NBPGR, New Delhi and granted IC numbers.

School of Crop and Natural Resource Management

Research was focused on developing resource-efficient crops and cropping systems-based technologies for diverse agro-ecologies through multi-disciplinary research, ultimately enhancing farm productivity and farmers' income.

- An integrated farming system model has been promoted, which involves crop, dairy, fishery, poultry, duckery, apiary, boundary plantation, biogas unit, and vermicompost under irrigated conditions for small farmers in North India. This model has increased productivity, production efficiency, gross returns, water productivity, and water footprint.
- Conservation agriculture (CA)-based rice-wheat, cotton-wheat, maize-wheat, pigeon pea-wheat, and maize-mustard systems were developed as remunerative alternatives to rice-wheat.
- Research on carbon highlighted the quantity and quality of soil organic carbon (SOC) under long-term (50 years) fertilization/manuring, soil C stocks in long-term temperate plantation crops (apricot, apple, peach, walnut, almond, cherry, and plum plantations) in Srinagar, soil C dynamics in different land-use systems of Assam and inorganic C sequestration through enhanced weathering.
- Developed STCR-based equation for fertilizer recommendation in wheat, improved soil K recovery by 2-3 sub-surface K fertigations in maize, enhanced N-use efficiency by application of polymer-based novel fertilizer products and solubilization of soil P and its acquisition by plants from recycled rice straw.
- A resource inventory of water bodies was made in the Nuh watershed in Mewat, Haryana and Delhi using RS and ArcGIS tools, which revealed 488 existing bodies in the NCT of Delhi and drought prediction was made for the NCT of Delhi using IMD gridded data and CHIRPS products.
- A monthly reference evapotranspiration machine learning model using limited meteorological data was developed, and the crop water footprint of wheat was determined for the north-western agro-climatic zone and an operational guideline using the WinSRFR model for designing basin irrigation systems as a ready reckoner was developed for

farmers to enhance irrigation application efficiency by more than 70%.

- Jalopchar technology, with a wastewater treatment capacity of 1 lakh litres per day (LPD), was commissioned at ICAR-CCARI, Goa, and ICAR-IISWC, Dehradun, in 2023 under the Swachhta Action Plan of the Government of India.
- Developed/fabricated many low-cost and energy-efficient tools/ implements such as Pusa electronic seed metering module for cultivators, variable swath herbicide applicator (VarSHA) for beneficial use by the farming communities involving operations related to crop sowing, intercultural, harvesting, threshing to preservation and storage of crops.
- Developed tractor-operated fold-able electronic seeding equipment, IoT-enabled devices for custom hiring services, semi-automatic pineapple harvester, infrared drum dryer processor, oil extraction technology for black cumin seed, intelligent cauliflower harvester, solar-powered/ battery-operated harvester for leafy vegetables and solar-powered on-farm cold storage system (Farm Sun-fridge).
- Futuristic techniques like post-harvest ultraviolet-C treatment were used for retaining the quality and enhancing the shelf-life of bitter gourd, hot water-mediated reduction of pesticide residue in apple and development of nano-cellulose-based edible coating.
- Developed overripe banana-based puffed snacks and pea pod powder incorporated into instant noodles and muffins. Further, the technology for multi-millet gluten-free pasta using moringa and beetroot has also been standardized.
- Various microbial strategies were developed to improve stress tolerance and nutrient management under changing climate conditions. Several drought-tolerant cyanobacterial strains, *viz. Anabaena* sp. (SGR4, SGR7), *Nostoc* sp. (SGR1, SGR3, SGR12), *Neowestielliopsis* sp. (SGR8), *Calothrix* sp. (SGR5, SGR11), *Fischerella* sp. (SGR16), *Hapalosiphon* sp. (SGR2) were characterized for plant growth promotion (PGP) traits.
- Pusa Decomposer was improved for low-temperature decomposition by screening microbial isolates for cellulase, xylanase, silicase, and laccase activity at 15°C and facilitated the application of 'Pusa Decomposer' in nearly 19.55 lakh acres during 2023 in the states of Uttar Pradesh, Haryana, Punjab and Delhi.
- The climate change impacts and adaptation gains were assessed for 11 crops and these were reported by India in the Third National Communication to the United Nations Framework Convention on Climate Change which was released in December 2023 and vulnerable districts/ agro-climatic zones (ACZs) for adaptation prioritization of wheat crop 2030-RCP 4.5 and the impact of climate change on wheat productivity in RCP 4.5 were analyzed.
- The interactive effect of elevated ozone (O_3) and carbon dioxide (CO_2) was evaluated on wheat and pollination ecosystem services in Indian mustard and microbes such as *Lysinibacillus* sp., *Bacillus* sp., *Pseudomonas* sp. and *Bacillus siamensis* were identified for efficient chromium removal from wastewater.

School of Crop Protection

The research is focused on diagnostics, identification of sources of resistance and integrated management of important pests and pathogens of national importance.

- Novel diagnostic tools were developed for early and quick detection of diseases like LAMP-based for *Magnaporthe* spp. and an isothermal RT-RPA assay for citrus yellow vein clearing virus (CYVCV), and a CRISPR-Cas12a based lateral-flow based dip-stick assay for chilli leaf curl virus.
- Studies unravelled the infection of emerging pathogens/pathotypes/virulent strains like *Bipolaris sorokiniana* inciting spot blotch of barley, fungi associated with Post Flowering Stalk Rot (PFSR) in maize, *Fusarium fujikuroi*. The first-ever report on fenugreek phyllody and witches' broom disease of peas has been established.

- A CRISPR-Cas-based strategy was developed for managing the papaya ring spot virus. Several biocontrol agents were identified for the management of different pathogens and nematodes.
- The biochemical regulation of hibernation and non-diapause in *Chilo partellus* was elucidated through transcriptomics and metabolomics approaches.
- Functional mutants associated with phosphine resistance in the Dihydrolipoamide dehydrogenase gene were characterized in *Tribolium castaneum* and *Rhizopertha dominica*.
- Two promising dsRNA constructs *viz*., ECR, Chitin synthase and an attractant lure were developed for the management of whitefly, *Bemisia tabaci*.
- A native *B. thuringiensis* (BtVKK5) isolate and two dsRNA constructs exhibited insecticidal activity against *Spodoptera. frugiperda*. The pigeon pea genotype IPAB 18-21 and Pusa Arhar-16 showed resistance against pulse beetle, *Callosobruchus chinensis.*
- *Mi-vit 2*, a vitellogenin gene of *M. incognita* was identified as the target gene for host delivered RNAi. A putative susceptibility (S) gene associated with heavy metal isoprenylated plant protein (HIPP27) was characterized from the model plant *A. thaliana*.
- An improved protocol for RNAi as well as a stringent bioinformatic pipeline were developed and 21 G-protein coupled receptors (GPCRs) were identified in entomo-pathogenic *Heterorhabditis bacteriophora*. Several receptor candidates were *de novo* characterized from *G. mellonella* using *Bt* toxin as the ligand for *in vivo* toxicity assays.
- *Bacillus subtilis* (OL716087), *B. cereus* (OL716088), *B. megatherium* (OM816754) and nonpathogenic *Pseudomonas stutzeri* (OL716089) were identified as nematode-antagonistic bacterial isolates. *Meloidogyne hapla* infestation of the weed *Parthenium hysterophorus* was reported for the first time.
- A series of twenty 2-indazol-1-yl-chromen-4-one derivatives and two prenylated chalcones showing good antifungal activity against *Sclerotium rolfsii* and *Fusarium oxysporum* were synthesized. The imidazolyl chalcones (IC), IC-8, IC-10 and pyrazoles (P) P-2, P-11 and P-25, with potent antifungal and nematicidal activity were identified. The aphicidal activity of oil/methanolic extract of piperine from *Piper longum* was demonstrated.
- An analytical method was developed for quantitatively estimating sulfamethoxazole using LC-MS/MS. A cost-effective anthocyanin purification technology involving ion-exchange resin was evaluated. A robust method has been developed for the quantification of 103 pesticides in mango fruit drinks using LC-ESI-MS/MS. The adsorptive removal of sulfamethoxazole (SMXZ) was found effective in removing antibiotics from wastewater. The incorporation of organic amendments reduced the leaching potential of Trichlosan.

School of Basic Sciences

Significant progress was made in the identification of donors, physiological processes, and genes involved in abiotic stress tolerance, input use efficiency and yield.

- Through genome editing, exogenous DNA-free SDN1 type mutants of the DROUGHT AND SALT TOLERANCE (DST) gene in the rice variety MTU1010 were developed and are currently being evaluated in the national field trials. "CRISP-PTG-Assembler", a Windows-based desktop application (Category: Bioinformatics Software) was developed to hasten the process of primer designing with accuracy and can design PTG constructs for all plant species.
- Genome-wide association studies using 192 diverse rice germplasms for resistance starch (RS) content showed the presence of marker-trait association in chromosome 5 in *RICE STARCH REGULATOR1* gene which encodes a transcription factor regulating the expression of Group 1 starch biosynthetic genes. Considering the need for high resistant starch (RS) - low glycemic alternatives,

three different retrogradation strategies (i) Freeze-thaw (ii) Autoclave (iii) Microwave (Mw) were optimized for enhancing RS III in rice and pearl millet, with 3rd cycle of Mw treatment showing highest increase of RS.

- Breeder-friendly marker for the *waxy1* (*wx1*) gene in maize was developed to differentiate the dominant (*Wx1*) and recessive (*wx1*) alleles.
- Photosynthetic pigments in developing green grain in thermotolerant genotype maintained a higher level of photosynthetic pigments, zeaxanthin, Fv/Fm, Y(II) and non-photochemical quenching (NPQ), antioxidant enzyme activities, expression of violaxanthin de-epoxidase, PEPC and Rubisco genes, yield and its components.
- The use of the Ca^{+2} chelator EGTA confirmed the involvement of Ca^{+2} in the regulation of transcription of NPFs and NRTs and nitrate uptake in wheat.
- Early-sown wheat genotypes (290) were phenotyped for high night temperature tolerance at the seedling stage, and early vigor was identified as a promising trait linked to the Phosphatidyl glycerophosphate-phosphatase PTPMT2-like gene.
- Three drought-tolerant lentil genotypes (IC560051, IC560032, IC560246) were identified based on variability in root traits in relation to drought tolerance at seedling and reproductive stages, which can be utilized as donors in lentil breeding.
- In vegetable science, studies were carried out on doubled haploid production in capsicum (*Capsicum annuum* L.) hybrids and onion, mapping of QTLs/genes for heat tolerance in hot pepper, identification of QTLs for dietary minerals content in cauliflower, molecular mapping of downy mildew and ToLCNDV resistance in cucumber and muskmelon, identification of putative candidate genes associated with gynoecious sex expression in bitter gourd and development of genomic resources in onion and garlic.
- Lipid-induced digestive resistance was optimized where complexation of dietary starch (rice and pearl millet) with mustard oil and desi ghee was found to be superior in terms of low *in vitro* glycemic response along with superior *in-vitro* glucose diffusion retardation index (GDRI).
- Plant protein blends were developed from steam-infused peanut and chickpea protein isolates and non-steam-infused brown rice protein isolates as an excellent protein source in daily diet.
- In *Drosophila* genetics, the transcript localization of *DWnt4* studied by RNA *in situ* hybridization in novel *DWnt4* mutant allele segment showed a polarity-like pattern in embryos at stage 10. The MARCM clones of $DWnt4^{AL7}$ have been generated in the terminal filaments of the developing ovaries.
- Farm Irrigation Scheduling using Open-source Multi-sensor Satellite Data showed GBM and RF machine learning (ML) algorithms with selected covariates using Boruta performed the best in capturing profile soil moisture. Landsat remote sensing was more accurate in estimating soil moisture profiles than Sentinel-2.
- Cubist model was the best predict developed for predicting severity of yellow rust in wheat and chickpea wilt using visible and thermal imaging coupled with ML algorithms. Fabrication and development of a nano biosensor for nitrate detection in soil with a sensitivity of 9.01×10^{-4} Ω^{-1} $(mg/L)^{-1}$ using electrochemical impedance spectroscopy (EIS) technique.
- A high-resolution *kharif* season composite agricultural drought index for India was developed with 1 km grid size using meteorological and remote sensing indices at 16-day intervals. Bilingual, bi-weekly agromet advisory bulletins were prepared based on past, real-time and weather forecast data and disseminated through print and electronic media to different stakeholders of the NCR region.

School of Social Sciences

Studies were conducted on assessing government schemes and technologies, climate change adaptation, agri-preneurship and farmer-led innovations and nutrition and health security.

- A study on e-NAM, an innovative approach to agricultural marketing, showed that 55% of the principal markets were linked in e-NAM with a participation of 14% of the total cultivators. The total e-NAM trade value was about 2% of the agriculture gross value added (AgGVA).
- Technology dissemination through 300 episodes of 'Pusa Samachar', a weekly programme in Hindi and other languages aired weekly has been well received by the farmers with a total viewership of 1.4 million views. Over 15,000 farmers' inquiries were addressed through the 'Pusa WhatsApp Salah' (9560297502) service.
- Two Farmer Producer Companies (FPCs) (Grofree Producer Company Limited Tigipur, New Delhi and Dauji Phool Utpadak Producer Company Limited Fatehpur, Biloch, Faridabad) were established with 100 members each.
- Through ATIC a 'Single Window Delivery System'. Farm advisory services were provided to 24,650 farmers and other stakeholders during the year. Pusa seeds of worth INR 15,80,124/- and farm publications worth INR 6,760/- were sold to the farmers. IARI has established *Pusa Krishi Haat* within the campus to facilitate the market linkages of farm entrepreneurs.

The Graduate School

The 61st Convocation of the Graduate School of the Indian Agricultural Research Institute (IARI) held on February 24, 2023 was graced by Sh. Jagdeep Dhankar, Hon'ble Vice President of India as the Chief Guest. During this Convocation, 403 students (222 M.Sc./M. Tech. and 181 Ph.D.) from India and other countries received their Post Graduate and Doctoral degrees.

- In order to expand the scope of academic collaboration across ICAR research institutes, the Academic Council of IARI approved the collaboration across 16 regional ICAR hub clusters in its 418th meeting. The Governing Body, ICAR, approved the sun-planet-satellite model-based system of academic collaboration. Out of a total of 1197 seats, a total of 1104 students were admitted for the academic session 2023-24 in IARI, New Delhi, and the 16 hubs. A tele-education facility was established at the ICAR-IARI, New Delhi to facilitate online teaching.
- IARI played a key role in establishing the Afghan National University of Agricultural Sciences and Technology (ANASTU), Kandahar, Afghanistan, and the 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 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.
- During 2023, 38 students (19 girls and 19 boys students) were trained for a duration of one to three months in International Universities/Institutes in the USA, UK, Europe, Auralia, Taiwan, Mexico and the Philippines.
- In addition, nine students (7 girls and 2 boys) underwent 10-day study tour to National Chung Hsing University, College of Agriculture and Natural Resources, Taichung, Taiwan.

Research Publications and Extension Activities

The scientists of the institute published 799 research papers with international impact factors in scientific peer-reviewed journals.

- Forty-eight national and international training courses and other capacity-building programs were conducted to benefit farmers, academicians, researchers, extension workers, and other professionals.
- Pusa *Krishi Vigyan Mela*-2023 was organized at the IARI *mela* ground from March 2-4, 2023, with the theme of "*Nutritional, Food and Environmental Security through Millets*".

- More than one lakh visitors from different parts of the country, including farmers, farm women, extension workers, entrepreneurs, students and others, visited the mela.
- Seeds of high-yielding varieties of basmati rice, mungbean, bajra, pigeon pea, and vegetable kits were sold through the Pusa Seed Sale Counter, earning revenue of INR 2.20 crores.
- The institute's outreach programmes, namely, Mera Gaon Mera Gaurav (MGMG), Scheduled Caste Sub Plan (SCSP), Tribal Sub Plan (TSP), and North-Eastern Hill region (NEH), are helping to enhance farmers' incomes through technological interventions.
- Under MGMG, 1498 field interventions were made, benefiting 22864 farmers, while under the SCSP programme, 69029 SC farmers covering 28 districts of six states were benefitted. Under TSP, small agricultural equipments were provided to more than 1000 tribal farmers. Under the NEH, 3000 beneficiaries were given small equipment, and demonstrations on cereals, pulses, oilseeds and vegetables were conducted over 2500 ha area.

Through a comprehensive approach spanning research, education, and extension efforts, IARI is dedicated to move towards Viksit Bharat.

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 3386: It is a bread wheat variety released for timely sown irrigation conditions of NWPZ. Its average yield is 62.5 q/ha. It possesses resistance to yellow and brown rust and moderate resistance against leaf blight, powdery mildew, Karnal bunt and flag smut.

Field view of HD 3386

HD 3388: It is a bread wheat variety released for timely sown irrigated conditions of NEPZ. Its average yield is 52.0 q/ha. It is resistant to yellow and brown rust, and highly resistant against Karnal bunt and powdery mildew. It is tolerant to terminal heat and has an excellent chapati quality score (8.0).

Field view of HD 3388

HD 3390: It is a bread wheat variety released for timely sown irrigated conditions of NCT of Delhi. Its average yield is 62.4 q/ha. It is highly resistant to all three rusts and carries the stripe rust resistance gene, *Yr10*. It possesses a good level of protein content (12%).

Field view of HD 3390

HD 3410: It is a bread wheat variety released for early sown irrigated conditions of Madhya Pradesh and NCT of Delhi. Its average yield is 70.4 q/ha under the NCT of Delhi and 65.9 q/ha under the MP state. It is highly resistant to multiple diseases, *viz.*, all three rusts, Karnal bunt, powdery mildew and foliar head blight.

Field view of HD 3410

HD 3437: It is an improved version of HD 2967 with a leaf rust resistance gene, *Lr34/Yr18* and stripe rust resistance gene, *Yr10*. It has been released for the NCT of Delhi with an average grain yield of 53.9 q/ha.

Field view of HD 3437

HD 3406 (Unnat HD 2967): It is a near-isogenic line (NIL) of popular wheat variety, HD 2967. It is released for timely sown irrigated conditions of the NWPZ. It is high yielding with an average yield of 54.7 q/ha. HD 3406 possesses *the LrTrk/Yr gene,* which provides resistance to both leaf and stripe rusts.

HD 3407 (Unnat HD 2932): It is a NIL of popular wheat variety, HD 2932. It is released for late sown irrigated condition of CZ. It is high yielding with an average yield of 46.7 q/ha. HD 3407 has three genes, *Lr19/Sr25* and *Lr24/Sr24* for both leaf and stem rusts, and *Yr10* for stripe rust resistance.

HD 3369: It is a bread wheat variety released for restricted irrigated conditions of NWPZ. Its average yield is 50.6 q/ha. It is resistant to yellow and brown rust and moderately resistant to leaf blight, powdery mildew, Karnal bunt and flag smut. HD 3369 has the best HMW sub-units combination for bread making with a *Glu-1* score of 8/10.

HD 3411: It is a bread wheat variety released for timely sown irrigated conditions of the NEPZ. Its average yield is 46.8 q/ha. It has resistance to yellow and brown rust and moderate resistance against leaf blight, powdery mildew, Karnal bunt and flag smut. HD 3411 has the best HMW sub-units combination for bread making with a *Glu-1* score of 10/10.

HI 1650 (Pusa Ojaswi): It is a bread wheat variety released for timely sown, irrigated conditions of the CZ. Its average yield is 57.2 q/ha. It is highly resistant to stem and leaf rust. It has high zinc (42.7 ppm) and iron (39.5 ppm) content.

HI 1653 (Pusa Jagrati): It is a bread wheat variety released for timely sown, restricted irrigated conditions of NWPZ. Its average yield is 51.1 q/ha. HI 1653 is immune to blast disease and highly resistant to stripe and leaf rusts.

HI 1654 (Pusa Aditi): It is a bread wheat variety released for timely sown, restricted irrigated conditions of NWPZ. Its average yield is 51.8 q/ha. HI 1654 has high resistance to blast disease, stripe, and leaf rust. It has excellent chapatti quality (7.5), bread quality (7.6) and perfect glu score of 10/10.

HI 1655 (Pusa Harsha): It is a bread wheat variety released for timely sown, restricted irrigated conditions of CZ. Its average yield is 38.8 q/ha. It shows high field resistance to leaf and stem rust and seedling resistance to all 23 pathotypes of stem rust. It has an excellent chapatti quality (8.4).

HI 8826 (Pusa Poshtik): It is a durum wheat variety released for timely sown, irrigated conditions of the PZ. Its average yield is 48.8 q/ha. It has a high level of field resistance to stem and leaf rust.

HI 8830 (Pusa Kirti): It is a durum wheat variety released for timely sown, restricted irrigated conditions of CZ. Its average yield is 40.4 q/ha. It has a high level of field resistance to stem and leaf rust.

1.1.1.2 Wheat genotypes contributed to AICRP trials

During the year under report, 65 genotypes contributed towards evaluation under AICRP trials in various production conditions of all the wheat-growing zones of the country as per details given below: AVT (HD 3471^{M*}, HD 3494^{M}, HI 1668*, HD 3428*, HD 3455, HD 3495^{M}, HD 3468, HD 3447, HD 3467, HP 1978, HD 3460, HI 1669*, HI1683, HI 1684, HI 8848 (D), HI 8849 (D), HI 8850 (D), HI 1674*, HI 1687, HI 8851 (D), HI 8852 (D), HD 3461, HD 3463) and NIVT (HD 3474, HD 3475, HD 3476, HD 3477, HP 1981, HD 3478, HD 3479, HD 3480, HP 1982, HI 1694, HI 1695, HW 3298-1, HD 3481, HD 3482, HD 3483, HD 3484, HP 1983, HI 1696, HI 1697, HI 1698, HI 1699, HI 8853 (D), HI 8854 (D), HI 8855 (D), HI 8858 (D), HD 3485, HD 3486, HD 3487, HD 3488, HI 1700, HI 1701, HI 1702, HI 8856 (D), HI 8857 (D), HS 700, HS 701, HS 702, HD 3493, HD 3489, HD 3490, HD 3491 and HD 3492) [*Final year entry, ^{M}: MABB entry]

1.1.1.3 Promising genotypes under IARI Common Varietal Trials (CVT)

A total of 170 promising genotypes superior for grain yield and disease resistance identified in station trials at Delhi, Indore, Pusa, Shimla and Wellington in previous crop seasons were evaluated in different CVTs under various production conditions.

1.1.1.4 Wheat genotypes developed through marker-assisted selection (MAS)

HD 3494: It is a NIL of wheat variety HD 2967, with resistance to leaf, stem and stripe rusts. It carries three genes *Lr19*/*Sr25*, *Lr24*/*Sr24* and *Yr10* with recurrent parent genome (RPG) recovery of 96.6%. The mean ACI recorded for stripe, leaf and stem rust are 0.6, 9.3 and 7.9, respectively. The average yield of HD 3494 was 61.5 q/ha in the station trial.

HD 3495: It is a NIL of wheat variety HD 3059, resistant to leaf, stem and stripe rusts. It carries stripe rust resistance gene *Yr15* with recurrent parent genome (RPG) recovery of 93.75%. The mean ACI recorded for stripe, leaf and stem rust are 1.9, 7.8 and 3.7 respectively. The average yield was found to be 50.4 q/ha in the station trial.

DL 23-16: Marker-assisted backcross breeding (MABB) integrated with rapid generation advancement (RGA) technique was used to improve wheat variety HD 3086 for leaf rust resistance using the *Lr52* gene.

1.1.1.5 Identification of lines for yellow rust resistance

To identify the novel *Yr* gene(s), a set of synthetic hexaploid wheat (SHW) was screened for yellow rust resistance. Among the lines evaluated, SHW87 was highly resistant to all five yellow rust pathotypes and has been selected for genetic analysis and mapping of resistance gene(s).

1.1.1.6 Pyramiding of leaf and stem rust resistance genes in bread wheat

Pyramiding/stacking of stem and leaf rust resistance genes, *Sr24*/*Lr24*, *Sr25*/*Lr19* and *Sr26* was attempted with recipient parents *viz*., Lok 1 using donor parents *viz*., Darfkite (*Sr24*/*Lr24* and *Sr26*) and Wheatear (*Sr25*/*Lr19*)). Genotypes with all three gene combinations were selected at BC_3F_4 generation.

1.1.1.7 Pyramiding of rust resistance genes

Pyramiding of stem and yellow rust resistance genes, *Sr26*, *Sr27*, *Yr10* and *Yr15* in six elite cultivars already carrying *Lr24*/*Sr24*, *Lr19*/*Sr25*, *Lr45* and *Lr47* targeting NWPZ and NEPZ is in BC_2F_4 stage.

1.1.1.8 Transfer of powdery mildew and rust resistance from rye into wheat using triticale as bridge species

A total of 112 genotypes derived from a cross 'TL2942 (*Triticale*)/HS562 (whreat)' were evaluated for powdery mildew resistance. A unique recombinant, 'T/W7-4' was identified as resistant to Shimla isolate to powdery mildew under seedling and adult plant stage.

1.1.1.9 Developing doubled haploids (DHs) in wheat

Among 29 doubled haploid lines, DH 4 and DH 19 showed seedling resistance to yellow rust and DH 23 to yellow and brown rusts.

1.1.1.10 Characterization of drought-tolerant mutant lines at the molecular level

Genomic regions for glaucousness and reduced awn were located on chromosomes 2B and 5A using bulked segregant analysis (BSA) in wheat mutants. The alternate dwarfing gene, *Rht18* positively impacted on yield and biomass in restricted moisture conditions due to increased coleoptile length and early establishment traits.

1.1.1.11 Genetic gain in grain yield

An effort was made to assess the genetic gain achieved through indigenous breeding efforts for optimum conditions during the last 16 years. The absolute genetic gain realized was found to be 91.8 kg/ha/per annum with a relative genetic gain of around 0.9%, which is equal to or better than many international breeding programs.

1.1.1.12 Study on lodging resistance

A set of 138 solid stem lines carrying different rust resistance genes such as *Lr19/Sr25*, *Lr24/Sr24*, *Lr47*, *Yr10* and *Sr36/Pm6* were screened and identified among the advanced breeding lines. The solid stem trait was confirmed using marker, *gdm247*.

1.1.1.13 Development of 'A' lines

T. timopheevi-derived CMS introgression in the background of HW 3094, DBW 39, HD 2967, and HD 3086 is in BC_3F_3 stage.

1.1.1.14 Introgression of blast resistance

Ae. Ventricosa-derived translocation, 2NS carrying *L37/Sr38/Yr17+*, a source of resistance to wheat blast caused by *Magnaporthe oryzae* Triticum pathotype has been transferred into popular cultivars, HD 2733, HD 2967, DBW 39, K 0307, HD 2824, HD 3118 and HD 2985. The materials are in BC_2F_6 stage.

1.1.1.15 Introgression of *Sr36/Pm6*

Triticum timopheevii-derived gene complex, *Sr36/Pm6*, conferring resistance to stem and powdery mildew, has been transferred to a dicoccum (highly susceptible to powdery mildew) variety HW 1098. The material is in BC_2F_3 stage.

1.1.1.16 Characterization of elite wheat germplasm for rust resistance genes

Twenty-three elite wheat genotypes were characterized for race specific (*Lr19/Sr25*, *Lr24/Sr24*, *Lr26/Yr9*, *Yr10*) and non-race specific (*Lr34/Yr18/Pm38/Sr57*) rust resistance genes using different molecular markers. Nine genotypes were confirmed for non-race specific gene complex *Lr34/Yr18/Pm38*/Sr57 with molecular marker *csLV34*. Among 23 genotypes, five possessed *Lr19/Sr25* and *Yr10* gene combinations.

1.1.2 Oat

1.1.2.1 Variety released

JWGO-01: It has been developed and released as the first grain oat variety in India and notified for the state of Madhya Pradesh for timely sown irrigated conditions.

1.1.3 Rice

1.1.3.1 Varieties released

Pusa Narendra KN 1: It is a high-yielding, semi-dwarf, and non-lodging *Kalanamak* rice variety with an average yield of 36.0 q/ha across three years of testing in the state of GI area in Uttar Pradesh. This variety has been released for Uttar Pradesh.

Field view of Pusa Narendra KN 1

Pusa CRD KN 2: It is a high yielding, semi-dwarf and non-lodging *Kalanamak* rice variety with an average yield of 31.6 q/ha during three years of testing in the GI area of the Uttar Pradesh. This variety has been released for Uttar Pradesh.

Field view of Pusa CRD KN 2

Pusa JRH 56: It is a high-yielding, short-duration, long-slender grain aromatic rice hybrid with a seed-to-seed maturity of 125 days and an average yield of 61.5 q/ha. Pusa JRH 56 is the first two-line hybrid developed by the

Field view of Pusa JRH 56

public sector institution in India. It has been released for the state of Madhya Pradesh.

1.1.3.2 Varieties identified

Pusa 2090: It is a high-yielding mid-early duration rice variety with a seed-to-seed maturity of 125-130 days and an average yield of 88.4 q/ha. It exhibited 22.3% yield superiority over Pusa 44, the most popular non-Basmati variety grown in this region. It has a semi-dwarf, non-lodging, and non-shattering habit with a very sturdy stem. Owing to its early maturity, it can help the timely harvest of paddy crops in the NCT of the Delhi area, which can help to provide sufficient time for after-harvest operations. It has been identified for the NCT of Delhi.

Field view of Pusa 2090

Pusa 1824: It is a high-yielding, medium-duration rice variety with a seed-to-seed maturity of 120-125 days and an average yield of 95.09 q/ha. It exhibited 31.5% yield superiority over Pusa 44. It has semi-dwarf non-lodging and non-shattering habit with very high culm strength. Owing to its early maturity, it can help in the timely harvest of paddy crops in the NCT of Delhi area, which can help to provide sufficient time for

Field view of Pusa 1824

after-harvest operations. It has been identified for the NCT of Delhi.

1.1.3.3 Entries in AICRP trials

A total of 28 genotypes were nominated in different stages of testing in the AICRP trials during *kharif* 2023. This includes seven entries promoted from respective trials conducted in *kharif* 2023 and 21 new entries. Entries in AVT-II (Pusa 3057-9-69-37-160-9-185-1 and Pusa 3057-9-69-37-160-9-185-1), AVT-I (Pusa 2091-26, Pusa 5358-3-1-1-1-1-1, Pusa 5417-15-11-9-54-17, Pusa 5417-15-11-9-50-27, Pusa 2070-22-1, Pusa 3136-12-10-46-14, Pusa 3136-49-2-105-19 and Pusa 3039-16-4-2-5-1-1-) and NIVT (Pusa 3067-16-10-5, Pusa 3067-16-10-6, Pusa 3076-12-1-2-9, Pusa 3083-17-8-3-13-1-17, Pusa 5567-21-1, Pusa 2095-23, Pusa 2096-26, Pusa 2086-36-11-12-1, Pusa 2087-40-19-4-1, Pusa 5567-3-1-4-3, Pusa 2084-38-1-4-1, 2085-36-9-5-7, Pusa 5544-16-4-2-1-1-3, Pusa 2082-40-3-19-1, Pusa 2082-40-26-6-4, Pusa 2083-40-16-10-4, Pusa 5377-4-1-1-2-2-1, Pusa 2088-40-17-2-3, Pusa 5483-47-6-1-1-2-1-4, Pusa 5477-28-30-2-1-1-3-3, Pusa 2088-38-9-1-3, Pusa 2088-40-19-4-1, Pusa RH66, Pusa RH 67 and Pusa RH 68) were evaluated in AICRP trials.

1.1.4 Maize

1.1.4.1 Hybrid released

PJHM 2: It is a medium-maturing maize hybrid released for Madhya Pradesh. It has an average grain yield of 81.6 q/ha with a potential of 114.0 q/ha under the *kharif* season. It is resistant to polysora rust and moderately resistant to charcoal and bacterial stalk rot.

Ear and grain characteristics of PJHM 2

1.1.4.2 Hybrids identified

APH 4: It is a QPM + provitamin-A rich hybrid identified for release in the NWPZ, PZ and CWZ. It possesses high provitamin-A (6.70 ppm), lysine (3.47%) and tryptophan (0.78%). It produces an average yield of 70.5 q/ha with a potential of 112.1 q/ha.

APTQH 5: It is a QPM + provitamin-A + vitamin-E rich hybrid identified for release in the NWPZ, NEPZ, PZ and CWZ. It possesses high provitamin-A (6.22 ppm), vitamin-E (α-tocopherol: (21.6 ppm), lysine (4.93%) and tryptophan (1.01%). It produces an average yield of 70.3 q/ha with a potential of 110.5 q/ha.

ABSH 4-2: It is a CMS-C-based male sterile baby corn hybrid identified for release in the NEPZ, PZ, and CWZ. It produces a dehusked baby corn yield of 22.7 q/ha with a potential of 32.6 q/ha.

APCH 2: It is a popcorn hybrid identified for release in NWPZ and PZ. It has 97.8% popping with an expansion volume of 18. It produces 46.0 q/ha of grain yield with a potential of 71.5 q/ha.

APCH 3: It is a popcorn hybrid identified for release in PZ. It has 96.7% popping with an expansion volume of 19. It produces 45.1 q/ha of grain yield with a potential of 72.9 q/ha.

AFH 7: It is a forage maize hybrid identified for release in NWZ. It has 9.2% crude protein, 41.9% acid detergent fibre, 62.5% neutral detergent fibre and 56.4% dry matter digestibility. The green fodder yield is 413.1 q/ha, with a dry matter yield of 90.3 q/ha.

AH 8181: It is a single cross-field corn hybrid identified for *rabi* season in Madhya Pradesh. It produces an average yield of 82.0 q/ha.

Adoption of Pusa Baby Corn Hybrid-1 (AH 7043) by UAS Dharwad: The adoption proposal of PBCH-1 (AH-7043) for Zone 3 and Zone 8 of Karnataka was accepted by SLVEC. Earlier, PBCH-1 (AH-7043) has been released for Zone-I, Zone III and Zone IV.

1.1.4.3 Entries in AICRP trials

Promising entries were AVT-II (APQH4, APTQH1, ALPQH1, ALQH9, AQWH4, APSKH1, ABHS27 and AH-8323), AVT-I (APH6, AQWH5, APQWH8, APTSKH1, APCH-4, AHD-2008, AHD-2077 and AHD-8751) and NIVT (APH7, APH8, APQH1, APQH5, APQH7, AH-4727, AH-4668, AH-4717, AH-4723, AH-4724, AH-4725, AH-4726, AH-4152, AH-4673, AH-4722, AH-4158, AH-467,2 AHD-2006, AHD-2050, AHD-2109, AHD-2130, AHD-2065, AH-8194, AHD-8722, AH-8245, AH-4762, AH-4782 AH-4000 and AH-4001).

1.1.4.4 Signing of Memorandum of Understanding (MoU)

MoU for bioethanol production from maize: To popularize IARI-bred maize hybrids for their utilization in bioethanol and DDGS production, the ICAR-IARI, New Delhi and Uttar Pradesh Distillers' Association (UPDA), New Delhi have signed a MoU.

Signing of MoU between IARI and UPDA

1.1.4.5 Commercialization of biofortified maize hybrids

Eight private seed companies have signed nine MoUs for seed production and sale of four IARI-bred double-biofortified maize hybrids.

1.1.4.6 Breeding for doubled haploids

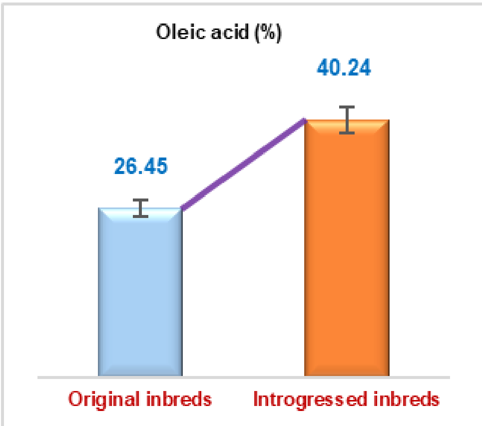
Development of new haploid inducer lines with intense anthocyanin colouration: F_2 segregants with *mtl*, *dmp* and *R1-nj* genes having a high intensity of anthocyanin pigmentation were developed. The newly developed HI inbreds with high colour intensity provided as high as 11.6% haploid induction.

1.1.4.7 Nutritional quality enhancement

Effect of *opaque2* and *opaque16* genes during kernel development: A decreasing trend of amino acid accumulation in *o2*-based (lysine: 0.561%, 0.476%, 0.392%, tryptophan: 0.284%, 0.163%, 0.082%), *o16*-based (lysine: 0.558%, 0.464%, 0.371%, tryptophan: 0.272%, 0.152%, 0.078%) and *o2o16*-based (lysine: 0.782%, 0.632%, 0.508%, tryptophan: 0.361%, 0.248%, 0.139%) was observed at 15, 30 and 45 DAP, respectively.

Genetic variation for folate content in diverse maize inbreds: Evaluation of 236 genotypes of maize revealed that average folate was 66.9 µg/100 g with a range of 6.5-185.0 µg/g. The exotic genotypes exhibited a higher mean folate (70.4 µg/100 g) over the indigenous genotypes (63.5 µg/100 g).

Enhancement of kernel oil content with better oil composition: The favourable alleles of *dgat1-2* and *fatb* genes were introgressed into four elite multi-nutrients rich maize inbreds (PMI-PV5-PVE, PMI-PV6-PVE, PMI-PV7-PVE and PMI-PV8-PVE). Kernel oil content increased from 5.07% in original inbreds to 6.93% in introgressed inbreds with an increased oleic acid from 26.45 to 40.24% and decreased palmitic acid from 20.46 to 14.27%.



Enhancement of oleic acid in introgressed lines

Development of new low phytic acid inbreds: Inbreds possessing *lpa1* and *lpa2* genes have been developed separately in seven genetic backgrounds (HKI323, HKI1105, HKI1128, HKI161, HKI163, HKI193-1 and HKI193-2). Crosses were made among the isogenic lines differing for *lpa* genes. Segregants homozygous for *lpa1* and *lpa2* genes possessed low phytate (1.70 mg/g) compared to 2.68 mg/g in original wild-type inbreds.

1.1.4.8 Breeding for specialty corn

Development of hybrids for higher bioethanol production: Traditional hybrids provide 370-380 litres of bioethanol from one tonne of maize grains. Lab analysis suggested that IARI-bred biofortified maize hybrids had estimates of 420-430 liters of bioethanol from one tonne of grains. Further, traditional maize possesses 62-64% extractable starch in grains. Seven hybrids possessing with 69-70% extractable starch were also developed.

Introgression of the ae1 gene for lowering GI: The parental lines of multi-nutrient-rich maize hybrids (QPM + provitamin A + vitamin-E) were crossed with donors with the *ae1* gene. The BC_2F_3 progenies with homozygosity at *ae1*, *crtRB1*, *lcyE*, *vte4* and *opaque2* loci have been selected. The introgressed progeny possessed >50% amylose compared to 30-35% in the original lines.

Development of silkless baby corn: HM4 - a popular baby corn hybrid was targeted for introgression of *sk1*, *ts1* and *ts2* genes for converting into silkless version. Progenies with a combination of *sk1sk1+ts2ts2* and *sk-1sk1+ts1ts1* have been developed in the genetic back-grounds of HKI 1105 and HKI 323, respectively.

1.1.4.9 Breeding for plant architecture

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

Variation of leaf angle in maize inbreds

Lowering the leaf angle for high-density planting: The parents of three released hybrids were crossed with *lg1*-donor. BC_2F_3 progenies homozygous for *ligu-leless1* (*lg1*) gene showed <10° leaf angle with the stem. These newly derived inbreds would be important in en-hancing plant density from ~84,000/ha to >1,20,000/ha.

1.1.4.10 Breeding for improvement in field corn

Identification of mutants for kernel size: The genotype (AI 544: 21.2 g) treated with an electron beam was characterized for seed size and other kernel-related traits. The test weight varied from 22-42.8 g. The following top 10 variants *viz*., M544-20 (42.8 g), M544-19 (41.7 g), M544-18 (41.1 g), M544-17 (36.8 g), M544-56 (36.3 g), M544-16 (35.9 g), M544-15 (35.1 g), M544-55 (33.8 g), M544-14 (32.0 g) and M544-13 (31.7 g) were selected.

Development of a base population for genomic selection: A total of 544 maize inbred lines with diverse origins were characterized for DUS and various morpho-phenological traits. These sets of inbreds would be used for genomic selection for yield and contributing traits.

Variation in grain filling period among field corn genotypes: Grain filling attributes were studied in 24 inbreds and 10 hybrids along with their parents. Total grain filling duration ranged from 20-38 days with inbreds showing 20-29 days and hybrids 25-38 days. Kernel and ear filling rates varied from 9.1-13.4 days and 5.2-9.1 days, respectively.

1.1.4.11 Breeding for abiotic stress tolerance

Screening under excess soil moisture (ESM) conditions: A set of 70 experimental hybrids and two checks (Pusa HQPM7 Improved and Pusa HQPM1 Improved) were evaluated under ESM conditions. DL1 × DL6, DL1 × DL13, DL1 × DL14, DL8 × DLDL7, DL32 × DLDL5, DL32 × DL11, DL 33 × DL 4 and AH4142 were promising under ESM.

1.1.4.12 Breeding for biotic stress tolerance

Development and evaluation of single cross hybrids: Of the 100 hybrids screened against turcicum leaf blight (TLB) under artificial epiphytotics, 15 were highly resistant, 40 moderately resistant and 35 moderately susceptible hybrids were categorized. AHD 2077, AHD 8722, AHD 8452, AHD 2037, H 2016 and H 2088 with a grain yield of >10 t/ha were resistant to TLB with a disease score of <3.0 (0-9 scale).

Identification biotic stress tolerant genotypes: Inbreds *viz*., PDI 751, CDM 1345, C 82, PDI 3003 and TSM 1 were resistant to TLB, while C 82, DIM 204, PDI 3003 and PDI 751 were resistant to maydis leaf blight (MLB) and PDI 21, D 2287, PDI 3004, PDI 3005 and PDI 751 were resistant to curvularia leaf spot (CLS). These inbreds possessed >3.5 t/ha of grain yield.

Identification of inbreds with tolerance to fall armyworm (FAW) infestation: The pre-screened inbreds against FAW, such as CDM-1330, DDM-2309, PDI 639, and C79, were tolerant in second-year screening as well. Further, an experiment with no-choice and multiple-choice test revealed AI 541, AI 542 and PDM 24 as tolerant to FAW. Besides, repeated screening of biofortified inbreds revealed MGU-FAW-161, MGU-FAW-195 and MGU-FAW-203 as tolerant to FAW infestation.

1.2 MILLETS

1.2.1 Pearl millet

1.2.1.1 Identification of hybrid

Pusa 1801: It is a dual-purpose pearl millet hybrid identified for release by NCT of Delhi. It has an average yield of 42.0 q/ha and yielded an average of 184.3 q/ha of dry fodder. It has high grain iron (70 ppm) and zinc (57 ppm) contents. This hybrid possesses a high degree of resistance against downy mildew, foliar blast, rust, smut and ergot.

Field view of Pusa 1801

1.2.1.2 Nominations in AICRP trials

A total of 17 entries were nominated to AICRP trial during *kharif* 2023. Pusa Hybrid Bajra 2301 was nominated to Initial Hybrid Trial (IHT) and Pusa Hybrid Bajra 2302 was nominated to Initial Hybrid Trial (Medium). Further, Pusa Composite 732, Pusa Composite 733 and Pusa Composite 734 were nominated for Initial Population Trial (IPT). Five biofortified restorer lines *viz*., PPMI 1273, PPMI 1274, PPMI 1275, PPMI 1315 and PPMI 1316 were nominated to CRP Biofortification Parental Line Trial (CRB-PLT). Three restorer lines, *viz*., PPMI 1310, PPMI 1311, and PPMI 1312 were nominated for the PMPHY-2 trial. Two entries, *viz*., PPMI 1313 and PPMI 1314 were nominated to PMPHY-7 for screening genotypes for heat stress tolerance at the seedling stage. Two hybrids, Pusa 1803 and Pusa 2101 were also nominated to forage trials.

1.2.1.3 Genetics of biochemical and yield contributing traits

Generation mean analysis revealed the predominance of additive and dominant effects besides additive × additive, additive × dominant and dominant × dominant interaction for the inheritance of grain iron and zinc in pearl millet, both additive and dominant components were present for amylose and starch. Governed additive components with large interaction effects on oil and protein. Phytic acid and total phenolic showed both additive and dominant gene action. In case of plant height, spike length, spike girth, 1000-seed weight and seed yield per spike, both additive and non-additive genes effects were significant.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Varieties released

Pusa JG 16 (BGM 10221): It is an MABB-derived drought-tolerant introgression line released for cultivation in central Indian states. It is an improvement over JG 16 and has a yield advantage of 16% over the recurrent parent. The grain protein content is 21.9%. It produces an average yield of 21.2 q/ha under drought conditions. It flowers in 56 days and the crop duration is about 111 days. It can fit well in the double cropping systems. It is resistant to *Fusarium* wilt and stunt virus, moderately resistant to dry root and collar rot and tolerant to pod borer.

Grain characteristics of Pusa JG 16

Pusa Chickpea 3057 (BG 3057): It is a kabuli variety released for commercial cultivation in NCT of Delhi. Its average grain yield is 20.0 q/ha and it matures in 130-135 days. It is highly resistant to *Fusarium* wilt and collar rot and moderately resistant to dry root rot, *Ascochyta* blight and *Botrytis* grey mould. It is a large seeded variety with 100-seed weight of 30-35 g. It has 24-25% seed protein.

Grain characteristics of Pusa Chickpea 3057

Pusa Chickpea 10217 (Pusa Vijay): It is released for cultivation in Uttar Pradesh. It is a drought-tolerant, high-yielding variety. Its average yield is 19.0 q/ha with a potential yield of 24.0 q/ha. It yielded 21.0 q/ha in the Bundelkhand region. It is an early flowering (65 days) and early maturing variety (128 days). Its average 100-seed weight is 18.5 g and highly resistant to *Fusarium* wilt.

Grain characteristics of Pusa Chickpea 10217

1.3.1.2 Promising entries in AICRP trials

Altogether, 14 promising chickpea entries were tested in different AICRP trials during *rabi* 2022-23. BG 4037 has been promoted to AVT-2 (mechanical harvesting) in NWPZ. BG 4040 has been promoted to AVT-1 (late sown) in NWPZ. In addition, eight desi entries (BG 4047, BG 4048, BG 4049, BG 4050, BG 4053, BG 4054, BGD 7023 and BGD 7041) and two large seeded kabuli types (BG4051 and BG4052) were nominated for multi-location testing in five different IVTs during 2022-23.

1.3.1.3 Characterization of recombinant inbred lines (RILs) for grain yield

Promising RILs of BG 362 × FLIP 07-183C were evaluated under restricted irrigation conditions. Four lodging resistant RILs (LRRIL-149, 308, 348 and 368) were found significantly superior to parents and checks in their yield potential. The highest yielding and lodging resistant RIL produced 3424 kg/ha of grain yield compared to wheat variety HD 2967 (4044 kg/ha). It was compared with wheat to evaluate the profitability of two competing winter crops under similar conditions.

1.3.1.4 Selection and evaluation of RILs differing in stem growth habit and flowering time

Promising RILs of BG 362 (late) × BGD 132 (early) and BGD 72 (indeterminate) × BG 3078-1 (semi-determinate) were evaluated under restricted irrigation conditions. DT-RIL136 (semi-determinate, early), DT-RIL159 (indeterminate, early) and DT-RIL179 (semi-determinate, early) were the highest yielders producing 3445, 3385 and 3508 kg/ha of grain yield, respectively. BG 3078-1, a semi-determinate and early genotype produced the highest grain yield of 3784 kg/ha.

1.3.1.5 Development and evaluation of input use efficient and determinate plant architecture

A set of 14 lines were evaluated under limited irrigation conditions. Two semi-determinate (SDT) lines (BG 201724-1 and BG 201724-2) were found promising for grain yield.

1.3.1.6 Identification of rust-resistant pre-breeding and mutant lines

Fifty pre-breeding lines were screened against rust disease under artificial epiphytotic conditions. A *Cicer pinnatifidum* accession, ILWC0, showed a resistance reaction.

1.3.1.7 Development of genotypes tolerant to dry root rot

SSD 718-42, SSD718-40 and SSD 718-4 showed higher grain yield and wilt incidence (<10%). Of the 167 RILs screened against DRR, 29 were resistant, 40 were moderately resistant, 51 were susceptible and 46 lines were highly susceptible.

1.3.1.8 Development of genotypes resistant to *Fusarium* wilt, cold tolerance and lodging resistance

High-yielding chickpea genotypes resistant to *Fusarium* wilt (BG 4031), cold tolerant (BG 9976) and lodging resistant (BG 201601-149) have been developed.

1.3.1.9 Identification of stable heat-tolerant chickpea lines

Genotype rankings based on the Multivariate Stability Trait Index (MSTI) using multi-trait genotype-ideotype distance index (MGIDI) led to the identification of IG 5999, IG 5875, IG 5851, IG 5868, IG 5993 and ILC 5588 as the stable genotypes.

1.3.1.10 Screening of germplasm against wilt disease

A set of 625 germplasm lines were screened against *Fusarium* wilt in sick pots. Of these, 162 lines were highly resistant, while 146 were moderately resistant. Genotypes such as ICC 7853, ICC 7893, ICC 8070, ICC 8097 and ICC 8185 were the most promising lines with high degree of resistance to *Fusarium* wilt.

1.3.1.11 Genetics of double podding

Genetic analysis of F_2 and F_3 of BGD112 (single pod) × BGD112m (double pod); T39-1 (single pod) × T39-1m (double pod); and BGD112 m (double pod) × T39-1m (double pod), revealed that double podding was governed by a single recessive gene.

1.3.2 Pigeonpea

1.3.2.1 Hybrid released

Pusa Arhar Hybrid 5 (Pusa Arhar Yamuna): It is a CGMS-based hybrid released for the NCT of Delhi. It is moderately resistant to SMD, resistant to *Phytophthora* stem blight and had low incidence of *Macrophomina* blight and *Alternaria* leaf spot disease. It provides an

Field view of PAH 5

average grain yield of 23.4 q/ha with a potential yield of 25.5 q/ha.

1.3.2.2 Nominations in AICRP trials

Pusa Arhar 21-60 is in AVT-1 (Early NWPZ). Two lines *viz.*, Pusa Arhar 23-5 and Pusa Arhar 23-4 were in IVT (Early) at NWPZ. Three lines are in IVT (Late) for NEPZ. One hybrid, PAH 22 is in the IHT Early trial for NWPZ. Further, two hybrids, PAH 23 and PAH 24 were in the CRPHT Multi-location trial.

1.3.2.3 Breeding for high-density planting and mechanized cultivation

Pusa Arhar 23-4 (semi-dwarf determinate compact extra early), Pusa Arhar Dwarf 22-1 (dwarf determinate early) and Arhar Dwarf 22-3 (semi-dwarf determinate early) were developed and found suitable for spacing of 30×20, 67.5×30 and 45×20 cm, respectively. These genotypes were also suitable for mechanized cultivation.

1.3.2.4 MAGIC population

Eight different and diverse parents (from mono culm, highly branched, spreading to erect type) were selected to develop the MAGIC population which is presently in F_6 generation.

1.3.2.5 Broadening of the genetic base of pigeonpea

F_2 generation of eight crosses involving diverse lines *viz.*, advanced generation lines and inter-specific derivatives (involving crosses of *Cajanus cajan* with *C. scarabaeoides*, *C. platycarpus* and *C. cajanifoleus*), Pusa Arhar 16 and Pusa 992 were evaluated and advanced.

1.3.3 Mungbean and lentil

1.3.3.1 Varieties released

Mungbean

PMS 8: It is suitable for moderate salt-affected conditions with an average yield of 5.6 q/ha. It shows resistance to MYMV, *Cercospora* leaf spots (CLS), *Anthracnose*, web blight and urdbean leaf crinkles (ULCV). It has been released for the NCT of Delhi.

Field view of PMS 8

PMD 9: It is an early maturing high yielding variety with an average yield of 10.8 q/ha. It showed resistance to MYMV, *Cercospora* leaf spot (CLS), *Anthracnose*, web blight and urdbean leaf crinkles (ULCV). It has been released for the NCT of Delhi.

Field view of PMD 9

PMD 10: It is an early maturing, high-yielding variety with an average yield of 11.1 q/ha. It showed resistance to MYMV, *Cercospora* leaf spot (CLS), *Anthracnose*, web

Field view of PMD 10

blight and urdbean leaf crinkles (ULCV). It has been released for the NCT of Delhi.

Lentil

PSL 19: It is a high-yielding lentil variety tolerant to moderate salt stress conditions (ECe 5.1 to 6.7 dS/m). It has been released for cultivation in the NCT of Delhi. It produces an average yield of 14.5 q/ha under salt-stress conditions. It shows field resistance against wilt, rust and *Ascochyta* blight.

Pods view of PSL 19

PSL 17: It is a high-yielding green-seeded variety suitable for moderate salt-affected soils with an average yield of 12.9 q/ha. It showed resistance to wilt, rust, *Aschochyta* spp., pod borer and aphids. It has been released for the NCT of Delhi.

Field view of PSL 17

1.3.3.2 Lentil entries in AICRP trials

The following entries were in NIVT (PLR 23-1, PLR 23-2, PLS23-1, PAL 25, PLL 23-1 and PAL12) and AVT-I (PLS22-2, PSL 24 and PLRF 22-1 and PLRF 22-2).

1.3.3.3 Mungbean entries in AICRP trials

Following entries were in NIVT (Pusa M 23-31, Pusa M 23-32, Pusa M 23-41 and Pusa M 23-42; *rabi*: Pusa 23-111 and Pusa 23-112), AVT-I (Pusa 2371, PMD 15, Pusa M 2331, Pusa M 2332, Pusa M 2341, PMS 9 and PMS 13) and AVT-II (Pusa M 2271, Pusa M 2031, Pusa M 2032, Pusa 2231, Pusa 2241, Pusa 2341 and Pusa 2371).

1.3.3.4 Characterization of a RIL for seed parameters in lentil

A set of 188 RILs [L830 (20.9 g/1000 seeds) × L4602 (42.1 g/1000 seeds)] were evaluated for seed size. BSA identified a marker (PBALC449) differentiating the parents and small seed size bulk only. The small seed size trait was strongly regulated by the locus near PBLAC449 (chromosome-3), whereas the large seed size trait was governed by more than one locus. Candidate genes like ubiquitin carboxyl-terminal hydrolase, E3 ubiquitin ligase, TIFY-like protein, and hexosyltransferase having a role in seed size determination were identified.

1.3.3.5 MYMIV resistance in mungbean

A set of 132 diverse mungbean genotypes were evaluated for various phenotypic traits. The GBS assay identified 31,953 high-quality SNPs on all 11 chromosomes. The candidate genes for flowering time (E3 ubiquitin protein ligase DRIP2, AT2G30580), MYMIV resistance (30S ribosomal protein S31, chloroplastic, AT2G21290), SPAD value (E3 ubiquitin protein ligase RIE1, AT2G01735), leaf area (nifU-like protein 1, chloroplastic, AT4G01940) and trichomes (LOB domain-containing protein 21 AT3G11090), were identified.

1.3.3.6 Genetic variation for phosphorus use efficiency in *Vigna* species

A set of 327 accessions of 18 *Vigna* species were examined for phosphorus uptake (PupE) and utilization (PutiE) efficiency under hydroponic conditions. Seven mungbean genotypes (IC 251950, IC 585931, V1002532AG, IC 371653, IC 331615, V1001400AG, and V1000532BG) were promising for both PupE and PutiE. Further, mungbean genotypes *viz*., KPS 1546, IC 277060, IC 697141, IC 343440, and Pusa 0831 were identified as better performers based on the stress tolerance index under phosphorus stress.

1.3.3.7 Analysis of root system architectural (RSA) traits

The present study used eight genotypes of each mungbean and urdbean for comparative analysis of RSA traits. KM 12-29 followed by PUSA 9072 among the mungbean genotypes, and LBG 623 followed by PU 11-14 among the urdbean genotypes showed higher values of RSA traits. The order of distribution of root diameter in mungbean & urdbean was 0-0.5 >0.5-1.0 > 1.0-1.5 >1.5-2.0 >2.0 mm.

1.4 OILSEED CROPS

1.4.1 Mustard

1.4.1.1 Variety released

Pusa Mustard 34: It is a low erucic acid Indian mustard variety released for cultivation in Zone-II (Jammu, Punjab, Haryana, Delhi and Northern Rajasthan). The average seed yield of the variety is 26.1 q/ha and matures 147 days after sowing. It has brown seed coat colour.

1.4.1.2 Varieties identified

Pusa Double Zero Mustard 35 (PDZ-14): It is a double zero [low erucic acid (<0.92%) in seed oil and low glucosinolates (<30 ppm) in the seed meal] mustard variety identified for release in Zone-III. It has yellow seed coat colour. Its average seed yield is 21.5 q/ha with an average oil content of 42.1%.

Pusa Double Zero Mustard 36 (PDZ-15): It is a double zero [low erucic acid (<0.46%) in seed oil and low glucosinolates (19.28 ppm) in the seed meal] mustard variety. It has been identified for release in Zone-III and possesses yellow seed coat colour. Its average seed yield is 20.5 q/ha with an average oil content of 41.8%.

1.4.1.3 Entries in AICRP trials

A total of 19 Indian mustard entries *viz*., NPJ 252, NPJ 253, NPJ 257, NPJ 258, Pusa MH 126, NPJ 265, NPJ 259, NPJ 260, NPJ 261, NPJ 262, NPJ 263, NPJ 264, PDZ-18(00), PDZ-19(00), LES 66(0), LES 67(0), PQMH 1, Pusa Mustard Hybrid 103 and Pusa Mustard Hybrid 111 were tested in different AICRP trials. NPJ 252 and NPJ 253 were promoted to AVT-II, while, NPJ 261 and NPJ 262 were promoted to AVT-I.

1.4.1.4 Elite genotypes evaluated in Station Trials (MSTs)

A total of 82 genotypes superior for seed yield and oil content were evaluated in five trials *viz*., MST Early Sown (14 entries), MST timely sown irrigated (16 entries), MST timely sown rainfed (18 entries), MST quality mustard (16 entries) and MST late sown (18 entries) along with the checks.

1.4.1.5 Promising hybrids evaluated in station trials

A total of 204 hybrids were evaluated in four station trials *viz*., MSTH-1 Early Sown (10 entries), MSTH-TS-2 (39 entries), MSTH-TS -3 (75 entries), MSTH-4 (80 entries). Besides, 25 hybrid entries contributed towards testing under CRPHT Project trials *viz*., CRP MLT-1 (5 hybrids), CRP MLT-2 (10 hybrids) and CRP MLT-3 (10 hybrids).

1.4.1.6 Evaluation and advancement of breeding material for varietal development

Short duration genotypes: A total of 11 F_6 progenies were bulked and 215 single plants were selected (F_6: 1; F_5: 28; F_4: 32, F_3: 60 and F_2: 95) under early sown condition. Whereas 51 progenies (F7: 12 & F6: 39) were bulked and 428 single plants (F5: 86, F4:101, F3:127 and F2:114) were selected from the late sown condition.

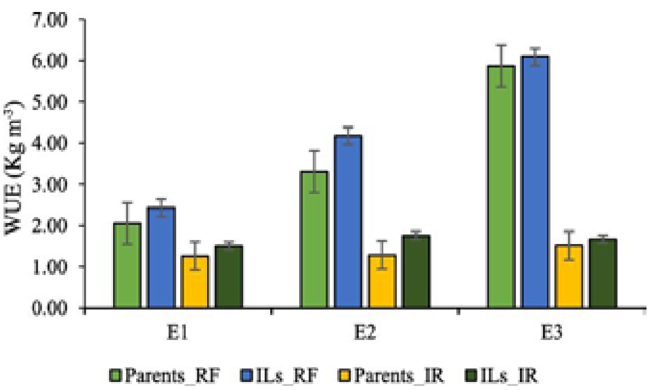
Genotypes for timely sown condition: A total of 561 (F_1=50; MCF_1=76; F_2=158; MCF_2=28; F_3=110; MCF_3=47; F_4= 48; MCF_5=14, F_5=26; and F_6=4) single plants/ progenies were selected and 30 entries were bulked for inclusion in station trials.

Genotypes for quality: A total of 16 and 14 entries were bulked from F_6 and F_7 generations, respectively, for the ‘0’ trait. Similarly, 20 and 24 entries were bulked each from F_6 and F_7 generations, respectively, for ‘00’ trait.

Single plants were selected for 0/00 traits in F_2 (189), BC_1F_3 (121), F_3 (110), F_4 (119) and F_5 (49) generations.

1.4.1.7 Development of *B. carinata* derived *B. juncea* introgression lines and their utilization

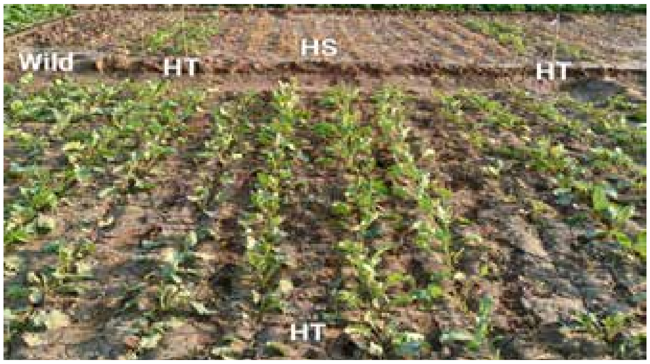
A set of *B. carinata* derived *B. juncea* introgression lines (ILs) was used to identify heterotic genomic segments and potential genes *viz*., PUB10, glutathione-S transferase, TT4, SGT, FLA3, AP2/ERF, SANT4, MYB, and UDP-glucosyl transferase 73B3 that were previously reported to regulate yield-related traits. The heterozygosity of the *FLA3* gene significantly improved siliqua length and seeds per siliqua in IL hybrids of Pusa Mustard 30. Since *B. carinata* is highly tolerant to drought stress, these lines were further deployed to identify QTLs conferring drought tolerance. A total of 29 additive QTLs were identified for drought tolerance; 17 (58.6% of total QTLs detected) were contributed by *B. carinata.* Eight QTL hotspots, containing two or more QTLs, governing seed yield contributing traits, water use efficiency, and drought tolerance under moisture deficit stress conditions were identified.



WUE in *B. carinata* derived *B. juncea* introgression lines along with their parents under rainfed (RF) and irrigated (IR) conditions [Environment, E1 = 2018–19 (Delhi); E2 = 2020–21 (Delhi); E3 = 2020–21 (Bharatpur)]

1.4.1.8 Development of herbicide-tolerant mustard genotypes

EMS-mutated plants of mustard variety, Pusa Mustard 30, were identified to be relatively tolerant to imazethapyr in the M1 generation. Further, 56 M2 progenies were raised and sprayed with weedicide and 31 progenies were identified to be tolerant. Genomic DNA was isolated from four of these progenies and the Acetolactate Synthase (ALS) gene was amplified, cloned, and sequenced. A point mutation in the *ALS* gene was identified.



Herbicide-tolerant M_2 progenies in the genetic background of Pusa Mustard 30 (Wild), HT=Herbicide tolerant, HS= Herbicide susceptible

1.4.2 Soybean

1.4.2.1 Variety identified

DS 9421: It is a Kunitz Trypsin Inhibitor (KTI) free soybean variety developed through MAS. It has been identified for release in the NCT of Delhi. This is the first-ever specialty soybean variety developed in North India through MABB. DS 9421 has resistance against major diseases such as Yellow Mosaic India Virus (YMV), Soybean Mosaic Virus (SMV) and Bud Blight (BB) and is moderately resistant to stem fly (*Ophiomyia phaseoli*). It matures in about 113 days (110-117 days). It has high protein (36.9%) and oil content (23.7%).

Plant and pod characteristics of DS 9421

1.4.2.2 Entries in AICRP trials

The following entries were in NIVT *viz*. DS 1550, DS3105, DS 1550, DS 1547, DS 1547E, DS1550E, DS 1510, DS 1529, DS 1527 and DS3163.

1.4.2.3 Development of herbicide-tolerant soybean

To develop herbicide-tolerant soybean varieties, seven Indian soybean varieties *viz*., JS9560, JS335, JS20234, JS2069, JS2098, JS2029, and DS9712 were crossed with an herbicide-tolerant American variety, S14-9017GT. The plants of various combinations are in different backcross generations. In the case of the JS9560-based population, plants homozygous for the EPSPS gene have been identified.

1.4.2.4 Identification of genotypes with higher pods/plant and low oil content

A set of 290 inter-specific RILs were field evaluated for the different seed characters and yield parameters. A line (IS-1) containing more than 900 pods/plant was identified. Besides, RIL nos. 15-2-1, 15-2-3, 7-23-3, 7-34-1,9-12-3, 7-2-4, and 19-33-3 that contained >150 pods/plant were selected. RILs with lower oil were 7-25-4 (2.9%), 34-9-3 (3.3%), 7-33-2 (4.2%), 31-1-3 (4.6%), 14-3-5 (4.6%), 7-1-4 (5.1%), 13-40-4 (5.3%), 13-37-2 (5.8%) and 4-32-1 (9.1%).

Plants of RIL No. 15-2-3 (left side), and 15-2-1 (right side) having more than 150 pods/plant

1.4.2.5 Evaluation of lipoxygenase and Kunitz trypsin inhibitor free lines

Thirty-three MAS-derived lines, free from off-flavor producing lipoxygenase allele, *Lox2*, and Kunitz Trypsin Inhibitor producing, *KTI* allele, were field evaluated for various morphological traits including yield and yield contributing characters. Two lines with desirable traits and yield have been identified, and included in station trails 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

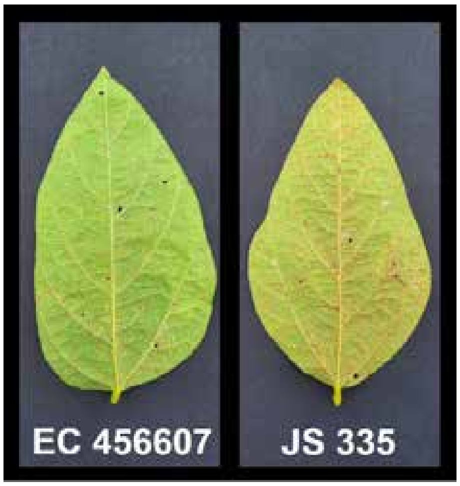
To eliminate the off-flavor from the vegetable soybean the null allele of the *Lox2* gene was transferred from a donor genotype to the vegetable soybean genotype, Swarna Vasundhara, through MAS. Progenies are in BC_2F_2 generation.

1.4.2.7 Breeding for rust resistance

Screening for pod borer tolerance: Soybean germplasm lines (IC 10755, UGM47, UPSL 303, UPSL 784, DS 2005, Pusa 1213 and SL958) were screened for third consecutive year for tolerance to pink pod borer. These lines recorded <10% pod damage. The tolerant lines were used in crossing program to introgress pod borer tolerance to elite cultivars JS 335 and DSb 34.

Identification of super early soybean lines: A set of 50 germplasm lines were evaluated for earliness phenology. Seven lines (EC 1037564, IC 993181, IC 993192, IC 993196, EC 993229, EC 1037788 and EC 1037882) with days to maturity of 60-65 days were identified. The super early line, IC 993181 was used in crossing programme to introgress earliness to elite cultivars DSb 23 and DSb 34.

Screening for rust resistance and development of mapping population: EC 456607 was identified as rust resistant germplasm line under natural epiphytotic condition. This line exhibited a reddish brown (RB) lesion with no or less sporulation compared to the susceptible line, JS 335, which produced a tan-coloured (TAN) lesion with profuse sporulation. Crosses were developed between JS 335 and EC 456607 and advanced to the F_2 population for the genetic study of soybean rust resistance.



Reaction of soybean lines against soybean rust

1.4.2.8 Water logging tolerance

A set of 50 soybean germplasm lines were evaluated for tolerance to pre-germination waterlogging tolerance. GP 394 (EC 472119), EC 471920, EC 471972, GP 441 and GP 197 were identified as highly promising for tolerance up to eight days of complete submergence.

1.5 SEED SCIENCE AND TECHNOLOGY

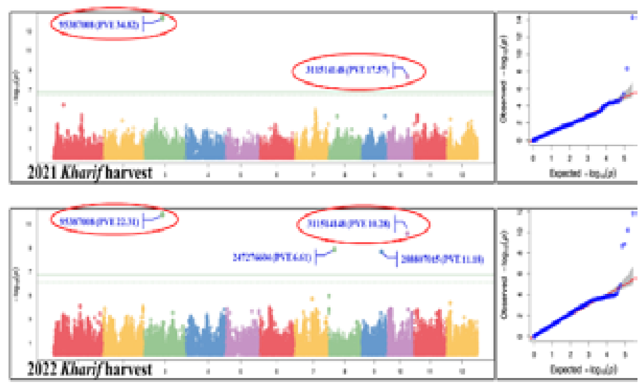
1.5.1 Studies on seed quality traits

1.5.1.1 Seed physical parameters

- A new method consisting of whole plant images using deep learning algorithms was studied to identify basmati rice varieties from traditional rice varieties. The ripening stage was identified as the most suitable for whole plant images, and VGG16, a deep learning algorithm, was found the best with an accuracy of 73%.
- Multi-spectral imaging was followed using 'VideometerLab4' to measure seed size, shape, and colour attributes in around 1100 rice germplasm lines. A correlation test was run between the color code values of each genotype and 19 color bands, which exhibited a strong negative correlation in color bands 2, 3, 4, 5, 6, 7, and 8 with a coefficient of -0.71.

1.5.1.2 Germination and vigour

- Rice varieties of different maturity groups were harvested at physiological maturity, and seed germination and vigor were recorded. Forty-four varieties were clustered into five groups based on all 20 seed vigour parameters. Cluster 1, with the highest seed vigor value, consisted of 21 varieties, most of which belong to the early maturity group. Cluster 4 consisted of three very late maturity group varieties and the lowest seed vigour value.
- The candidate genes (LOC_Os03g28090, LOC_Os10g33940, LOC_Os08g08860 and LOC_Os09g30150) having a major role in the early coleoptile emergence stage were identified in rice.



Manhattan and QQ plots showing candidate genes for early coleoptile emergence in rice

1.5.1.3 Seed dormancy

Mung bean: The genome-wide association (GWAS) mapping of 138 mung bean genotypes for seed dormancy identified seven MTAs for dormancy index at 130 days after harvest (DAH) and four MTAs at 175 DAH; 12 MTAs for DSDS50 and 1 MTA for intensity of dormancy on different chromosomes. Four infrared treatments for breaking the dormancy *viz.*, 1000 W for 90 sec, 1500 W for 60 sec, 1500 W for 90 sec and 2000 W for 60 sec resulted in higher germination and seed vigour.

Buckwheat: The buckwheat seeds were treated with different concentrations of GA_3, KNO_3, and H_2O_2. Untreated seeds had germination of 21% which was enhanced to 69% by seed treatment with 0.4% KNO_3. The seedling length was enhanced by 55% by 200 ppm GA_3 seed treatment. There was a 305% enhancement in seed vigour in 20 mM H_2O_2-treated seeds.

Cucumber: Parthenocarpic, gynoecious and monoecious lines of cucumber were studied for their seed dormancy behaviour in *kharif* and spring-summer. The duration of dormancy ranged from 0-4 months and was higher in seeds produced in *kharif* than in the spring-summer season.

1.5.1.4 Seed Storability/longevity

Onion: The 16 days of accelerated ageing (AA) reduced germination from 82 to 0.66%. The correlation analysis revealed that fatty acid methyl esters, $C_{18:2}$ (n-6)-linoleic acid (r= 0.59, 0.97), $C_{24:0}$-lignoceric acid (r = 0.66, 0.74) and negative correlation of $C_{15:0}$-pentadecanoic acid (r= -0.49, -0.80), $C_{18:3}$ (n-6)-g-linolenic acid (-0.72, -0.88) and $C_{20:3}$n3-cis-11,14,17-eicosatrienoic acid (r=-0.63, -0.72) had significant positive correlation with germination.

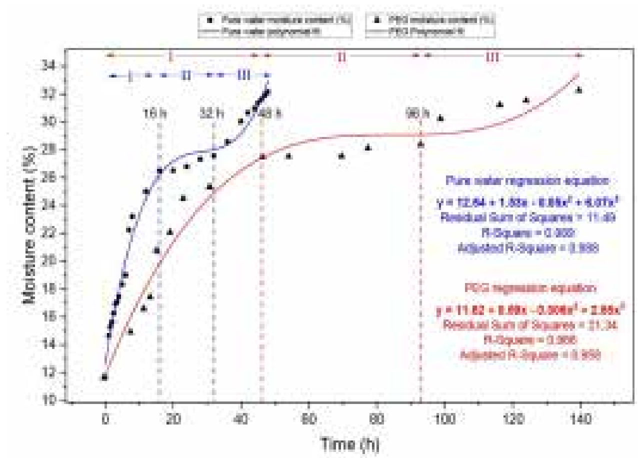
Rice: In a storage study, seeds of different seed lots at low ERH (33%) showed varied responses to different oxygen levels and storage temperatures. Among the seed lots, FR 13A was most tolerant to aging with average seed germination of 70% after 1553 days of storage. Cypress with 27% average seed viability was the most sensitive during storage. Among the different oxygen levels, seeds of different seed lots exposed to hypoxia for 1553 days showed higher seed germination of 81%. In contrast, seeds under normoxia (21% oxygen) and hyperoxia (99% oxygen) showed significantly lower germination of 53% and 28%, respectively.

Soybean: GWAS carried out in seeds of 270 soybean genotypes subjected to AA conditions identified one significant SNP on chromosome 1 and two significant SNPs on chromosomes 16 and 20. In seeds stored under ambient conditions, five significant SNPs on chromosomes 16, 12, 13, and 5 were related to seed germination, and three significant SNPs on chromosomes 13, 12, and 16 were identified that regulated normal seedlings.

1.5.2 Studies on seed priming

1.5.2.1 Seed priming standardization

Rice: The priming technique was standardized using IR64 rice variety. The moisture content curves at ψ = 0 and -1.2 MPa were fitted with third-order linear polynomial to identify different imbibition phases. The -1.2 MPa water potential, with phase II of imbibition and low dry back temperature (26° C) enhanced the seed vigour in terms of seedling growth, speed of germination and uniformity of germination.



Water uptake pattern showing triphasic imbibition at 0 and -1.2 MPa water potential in rice

Lentil: Priming protocol was standardized in lentil variety, IPL 316. Among different treatments, higher seed germination was observed when seeds were soaked with humic acid at the concentration of 600 ppm for 18 h (100%), whereas humic acid @ 800 ppm for 15 h soaking showed significantly low germination (87%), seed vigour index I (1891) and seed vigour index II (1.10).

1.5.2.2 Nano-priming

The tomato seeds treated with ZnO @ 7.5 ppm showed significantly higher chlorophyll 'a', 'b' and total content (7.35, 15.58 and 22.93 µmol m^{-2}), higher peroxidase and lower catalase activity. The ZnO @15 ppm showed a high vigour index-I (1398.9) over control. KNO_3 treatment resulted in significantly lower seedling length (9.7 cm) and higher fresh weight (0.236 g) and SOD activity over the control.

1.5.3 Seed production technology

1.5.3.1 Mustard

To study the temperature effect on flowering behavior, seed production, and oil content, 22 Indian mustard varieties were sown in the last week of September, October, and November. Seedling emergence was influenced by both high and low temperatures during sowing time. The high temperature at the reproductive stage reduced the seed filling, seed weight, yield, and oil content drastically. All the varieties showed higher seed yield per plant when sown at higher temperature/ early sowing time.

1.5.3.2 Tomato

Tomato fruits were harvested at three stages *viz*., pink, light red and red ripe and seeds were extracted at 25^0 C using four methods. The percent moisture content (MC) was significantly lower (5.76%) in seeds harvested from light red fruits than others. The percent MC was significantly higher (6.42%) in seeds extracted with 10% sodium carbonate ($NaCO_3$) for 24 hrs than the rest three. Significantly higher germination (%) and seedling vigor index-II were observed in red ripe fruits than in the pink and light red stages.

1.5.3.3 Cucumber

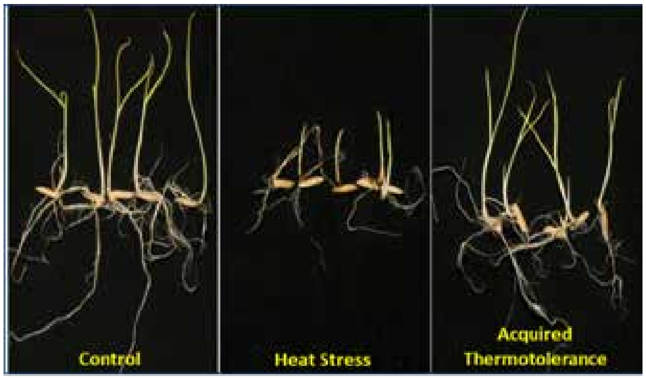
The hybrid seed production technology was developed for the gynoecious cucumber (Pusa Cucumber Gynoecious Hybrid-18) with 3:1 row ratio, pollination up to 10 AM and by leaving 3-4 fruits/ vine. In the case of parthenocarpic cucumber (Pusa Parthenocarpic Cucumber Hybrid – 1), a 1:1 row ratio, 8-10 early planting of seed parent and leaving two fruits per vine was found the best for enhancing the seed yield.

Seed production of Pusa Cucumber Gynoecious Hybrid-18 in net-house

1.5.4 Effect of abiotic stress on seed quality and yield

1.5.4.1 Thermotolerance

The basal thermotolerance (BT) of 57^o C for 30 minutes for imbibed seed, 48^oC for 30 minutes for the radicle emergence stage and seven-day-old seedlings showed significant variation between tolerant and sensitive genotypes. The seeds/ seedlings subjected to mild acclimation temperatures could completely tolerate the severe heat stress equal to BT after 2 h (SAT) and 2 days (LAT). The short and long acquired thermotolerances (SAT and LAT) were validated in four heat-sensitive and four heat-tolerant genotypes.



Rice seedlings under control, heat stress and acquired thermotolerance condition

1.5.4.2 Cold tolerance

A set of 110 maize lines were screened for early seed vigour traits for improved emergence under sub-optimum temperatures. Variations among lines was observed in seed germination, speed of germination, germination index, mean germination time (MGT), and vigor indices. Lines with early vigour traits performed better under 15 and 20°C for all the seed physiological traits.

1.5.4.3 Salinity tolerance

Lentil: In lentil, a total of 241 RILs were screened for germination traits under ambient control conditions and 100 mM salinity stress at 20°C. Significant variations in seed germination parameters were observed with a lower (78%) average germination in salinity stress compared to the control condition (88%). Under salinity stress condition, the seedling vigor index-I (SVI-I) and SVI-II decreased by 59 and 70%, respectively.

Wheat: The effect of salinity stress was investigated in 11 wheat varieties including a salt tolerant genotype (KRL 210) and 10 prominent varieties *viz*. HDCSW 18, HD 3117, HD 3226, HD 3249, HD 3271, DBW 187, HD 3171, HD 3118, HD 2967 and HD 3086. Seedlings were grown in pots at different salinity levels (4 dS/m and 6 dS/m) including control treatment. Both the salinity levels significantly reduced seed quality traits, seedling emergence, spike length, and number of seeds per spike.

Soybean: A set of 73 soybean genotypes comprising 26 yellow released varieties and 11 yellow germplasm lines, 25 genotypes with black seed coat colour, five genotypes with green seed coat colour and six genotypes with brown seed coat colour were screened for tolerance to different salinity levels (0, 3, 6 and 9 dS/m) using standardized petri plate method. Based on early seedling vigour and salt tolerance index values, the genotypes were categorized into highly tolerant and susceptible. Jasmonic acid and paclobutrazol treatments were identified as suitable mitigation agents.

1.5.5 Seed health

1.5.5.1 Fungal pathogens

Trichoderma asperellum was a better bioagent than *Psedumonas fluorescens* for inhibiting the growth of *Fusarium oxysporum* and *Rhizoctonia bataticola*. Among the organic amendments, *Kunab jal* significantly reduced the growth of both pathogens. However, maximum radial growth inhibition of both pathogens was caused by Carboxin 37.5% WS + Thiram 37.5% WS.

1.5.5.2 Viral pathogens

Soybean genotypes under the initial varietal trials (IVT) were screened against viral diseases by subjecting the leaf samples to DAC-ELISA for testing against six seed borne and one non-seed-borne virus using polyclonal antibodies of bean pod mottle virus (BPMV), soybean mosaic virus (SMV), soybean vein necrosis virus (SVNV), tobacco ring spot virus (TRSV), groundnut bud necrosis virus (GBNV), soybean yellow mottle mosaic virus (SYMMV) and tobacco streak virus (TSV). Among the 52 IVT lines tested, TRSV was predominantly observed followed by BPMV in the leaf samples with blisters and bumping symptoms.

2. HORTICULTURAL SCIENCES

The Indian horticulture sector has a significant impact on the nation's economy. Beyond ensuring the country's nutritional security, it offers alternative employment opportunities in rural areas, diversifies farming activities and boosts farmers' income. The School of Horticultual Sciences, established in 2013, focuses on enhancing genetic resources, genetic improvement, cost-effective production technologies, efficient input management, postharvest procedures and the value addition of horticultural crops. Various improved varieties in different horticultural crops have been developed. Additionally, valuable genetic stocks with resistance or tolerance to various abiotic and biotic stresses have been created. Noteworthy contributions have emerged through integrating modern biotechnological tools with traditional knowledge, leading to increased productivity in horticultural crops.

2.1 VEGETABLE CROPS

Varieties released by Delhi State Seed Sub Committee: A total of five varieties and two hybrids of vegetable crops comprising of tomato (Pusa Prasanskrit), cherry tomato (Pusa Cocktail Tomato), Indian bean (Pusa Sem-6), broccoli (Pusa Purple Broccoli 1), okra (Pusa Lal Bhindi-1), cauliflower (Pusa Cauliflower Hybrid-102) and cucumber (Pusa Parthenocarpic Cucumber Hybrid-1) were released by DSSSC for NCT, Delhi and presented for notification to CVRC.

Varieties identified by IARI variety identification committee: One variety of brinjal (Pusa Chhota Baingan-1) and one of bitter gourd (Pusa Protected Bittergourd-2) were identified by the Institute identification committee and presented for release by SVRC for NCT Delhi.

2.1.1 Solanaceous crops

2.1.1.1 Tomato

Entries in AICRP-VC trials: One tomato entry promising for ToLCD resistance was promoted to the AICRP (VC) ToLCV resistance AVT-I trial and two entries in AVT-II trials. One entry was nominated to 2023/TOLCV/IET. Two entries were nominated to 2023/ TOLCV/Indeterminate/VAR/IET under Tomato/ TOLCV/Indeterminate/Varietal trial. Two entries were nominated to 2023/Processing tomato/IET under tomato processing trials.

Breeding for protected cultivation: Tomato genotypes (37) along with four commercial checks (GS600, NS4266, Himsohna and US-2853) were evaluated under protected conditions. Maximum yield was recorded in hybrid Pusa Rakshit (17.5 q) in 100 sq. m area. Four promising tomato hybrids, namely, DTPH 3, DTPH 7, DTPH 9 and DTPH 19 were identified for protected conditions having fruit weight in the range of 95 to 120 g and TSS 4 to 5.50 ^{o}Brix.

Dwarf and early maturing tomato selection: At ICAR-IARI Regional Station, Pune, a dwarf (65 cm) and early maturing (flowers 30 days after planting) tomato

Fruit view of Seln-25

selection 'Seln-25' was identified which produces high yield of large sized fruits (85 g) with lesser number of seeds.

2.1.1.2 Brinjal

Promising hybrids identified for yield: Seventeen F_1 hybrids were evaluated amongst which round fruited DBHR 501 and DBHR 566, yielded 40.3 and 37.9 t/ha, respectively. Long-fruited DBHL 432 (38.05 t/ha) and DBHL 521 (36.12 t/ha) were found promising. Other hybrids, DBHL 25, DBHL 221, DBHR 4070 and DBHR 112407 were advanced to AVT-I of AICRP (VC) trial.

2.1.1.3 Chilli

Entries in AICRP-VC trials: Five chilli genotypes entered AICRP trials including DChV-92 for AVT II, DChV-274 for AVT I, DChV-42 for IET (Chilli varietal trial) and DCapV-81 & DCapV-24 for IET (Capsicum varietal trial).

Varietal trials: A station trial of 37 new promising breeding lines was conducted, and these were evaluated for yield and yield attributing traits at IARI, New Delhi, along with national check-LCA-620 and Kashi Anmol. Eight lines *viz.*, DChBL-22(2), DChBL-73(B), DChBL-24, DChBL-22(1), DChBL-72(A) and DChBL-53(A) were found promising in comparison to the check Kashi Anmol and LCA 620.

Hybrid trials: Thirty-five chilli hybrids were evaluated during summer 2023 for yield traits as well as heat tolerance along with private sector hybrids of this zone NS 1701, NS 1101 and Eagle. Five hybrids *viz.*, DChH 11, DChH 25, DChH 8, DChH 28 and DChH 32 outperformed the check NS 1701.

Screening of germplasm against chilli leaf curl disease: Nine accessions *viz.*, EC769427, EC772795, EC771555, EC692283, EC773729, EC771550, EC772775 and EC771556-2 of *Capsicum annuum*, EC787119 (*C. frutescens*), EC772732 (*C. chinense*) and EC790590 (*C. tovari*) were found resistant against *ChiLCD* under both natural and artificial epiphytotic conditions.

Chilli selection: Seln-BLG-1: At ICAR- IARI Regional Station, Pune, Seln-BLG-1 was identified from a local collection from Assam (Assam Black) having upward fruit with dark purple pigmentation. The yield was approximately 15 t/ha which is five times more than Assam Black (3.17 t/ha). The line also possesses tolerance to leaf curl and is moderately resistant to thrips.

Seln-BLG-1

2.1.1.4 Capsicum

Evaluation of coloured capsicum for protected conditions: At ICAR- IARI Regional Station, Katrain, six capsicum genotypes along with two checks were evaluated for yield contributing traits. KTGC-17 (Green) (30.65 t/ha) followed by KTOC-1 (Orange)

KTGC-17

KTOC-1

KTRC-12

KTYC-8

Promising genotypes of coloured capsicum

(29.63 t/ha), KTRC-12 (Red) (28.83 t/ha) and KTYC-8 (Yellow) (27.89 t/ha) performed better over the check cultivars *viz*., Pusa Capsicum-1 (Green) (24.73 t/ha) and California Wonder (Green) (21.80 t/ha).

Hybrids evaluation: At ICAR- IARI Regional Station, Katrain, 36 hybrids of capsicum with check cultivar (Asha) were evaluated for yield and contributing traits. KTRC-5 × KTYC-17 (34.20 t/ha), KTRC-6 × KTRC-9 (31.40 t/ha) and KTGC-9 × KTOC-3 (30.64 t/ha) performed better over the check cultivar Asha (26.50 t/ha).

Entries contributed in AICRP (VC) trials: In capsicum, two open-pollinated genotypes (KTGC-4 and KTGC-9) were contributed to IET. Two open-pollinated genotypes (KTRC-13 and KTRC-14) were advanced to AVT-I, and two entries (KTOC-1 and KTYC-17) were advanced to AVT-II.

2.1.2 Cole crops

2.1.2.1 Cauliflower

New promising hybrids: CMS-based F_1 hybrids (236) of early group cauliflower were evaluated during September – November maturity period. The most promising new F_1 hybrids were DCEH 4108, DCEH 1863, DCEH 2307 and DCEH 7108 for September maturity (>15 t/ha), DCEH 98157, DCEH 98307, DCEH 7301 and DCEH 981521 for October maturity (>20 t/ha) and DCEH 2371, DCEH 7301, DCEH 6709 and DCEH 722 for November maturity (>25 t/ha). In the mid-early group, out of 10 CMS-based F_1 hybrids, the promising hybrids (>30 t/ha) were DCMEH 907, DCMEH 961, DCMEH 8405, and DCMEH 902 from mid-November to mid-December. Further, four F_1 hybrids (DCEH 4198, DCEH 2171, DCEH 7567, DECH 31503, DCEH 7523 of early group; DCEH 1093 and DCEH 2225 of mid-early group; DCMH 8404, DCEH 8202, DCMLH 84161 DCMH 8476 of mid group) were advanced in AICRP(VC).

2.1.2.2 Cabbage

Red cabbage: KTCBR-5: It is an open-pollinated variety of red cabbage identified for zone-I (HP, J&K and Uttarakhand). It has 10-12 non-wrapping waxy and purplish leaves; plant height is 15-20 cm, the head is round in shape and purple, very compact, and covered with an outer leaf. It matures in 80-85 days after transplanting and has good field staying capacity (20-25 days) after head formation. The anthocyanin concentration in the edible portion is 13.58 mg/100 g, giving an average yield of 21.2 t/ha in zone-I.

KTCBR-5

Evaluation of CMS-based F_1 hybrids: Sixty-seven CMS-based F_1 hybrids were evaluated against five commercial checks. The promising hybrid

9A × EC-686718

2A × EC-90

9A × EC-686718 2A × EC-90

Promising CMS-based F_1 hybrids of White Cabbage

combinations over the best standard check for yield were 9A × EC-686718 (54.21 t/ha), 2A × EC-90 (52.65 t/ha) and 8A × EC-686718 (52.34 t/ha), showing a increase of 13.0, 9.8 and 9.1%, respectively over the best check Pusa Hybrid-82.

Evaluation of F_1 hybrids of Red Cabbage: Twenty-five CMS system-based red cabbage F_1 hybrids were evaluated against three checks. Hybrids RCGA × KR (44.8 t/ha), PMA × PoARC (43.8 t/ha), ZHA × RRM (41.5 t/ha), ZHA × KRG (39.5 t/ha) and ZHA × RCGRC-1 (38.6 t/ha) recorded significantly higher marketable yields over the best check Red Sky (26.0 t/ha) with an increase of 72.1, 68.3, 59.4, 51.8 and 48.3%, respectively.

RCGA × KR PMA × PoARC

ZHA × RRM Red Sky

Promising CMS based F_1 hybrids of Red Cabbage

Entries contributed in AICRP (VC) trials: Two open-pollinated varieties of red cabbage (KTCBR-1 and KTCBR-2) and two hybrids of white cabbage (KTCBH-210 and KTCBH-519) were contributed to IET. Four CMS-based hybrids (KTCBH-213, KTCBH-513, KTCBH-230 and KTCBH-630) were advanced to AVT-I, and 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-II.

2.1.2.3 Snowball cauliflower

Pusa Purple Cauliflower-1: This is the first true purple cauliflower variety developed by Indian public sector. It is suitable for growing in NCR Delhi under mid (November maturity) and late (December onwards maturity) conditions. Its average marketable curd weight is 765 g and average curd yield is 32.12 t/ha under NCR. The crop matures in 85-90 days after transplanting. It is a biofortified variety with 43.70 mg/100 g of anthocyanin in the edible part. It has been released by the Delhi State Seed Sub Committee and notified by the CVRC in 2023.

Pusa Purple Cauliflower-1

Evaluation of CMS and inbred parental lines-based hybrids: Sixty F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI Regional Station, Katrain, during the winter season of 2022-23. Amongst all, eight hybrids performed better than both check cultivars *viz.*, 'Pusa Snowball Hybrid-1 (PSBH-1)' and 'Himdev' with a heterosis range of 2.34 - 30.93 and 11.86 - 43.11%, respectively.

KTCF-62A1×KTCF-40B | KTCF-56A1×KTCF-10B | KTCF-60A3× KTCF- 38B | PSBH-1 (Check-1) | Himdev (Check-2)

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

Evaluation of CMS and DH parental lines-based hybrids: Forty CMS and DH parental lines-based F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI, Regional Station, Katrain, during winter 2022-23. Among all, 5 hybrids performed better than the check cultivar 'Pusa Snowball Hybrid-2 (PSBH-2)' with a heterosis range of 1.79 - 18.72%.

KTCF-69A1× KTCF-DH-4B | KTCF-68A2× KTCF-DH-2B | KTCF-65A2× KTCF-DH-2B

KTCF-74A2× KTCF-DH-3B | PSBH-2 (Check)

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

Screening and evaluation of cauliflower germplasm for off-season cultivation: During the spring-summer

KTCF-33

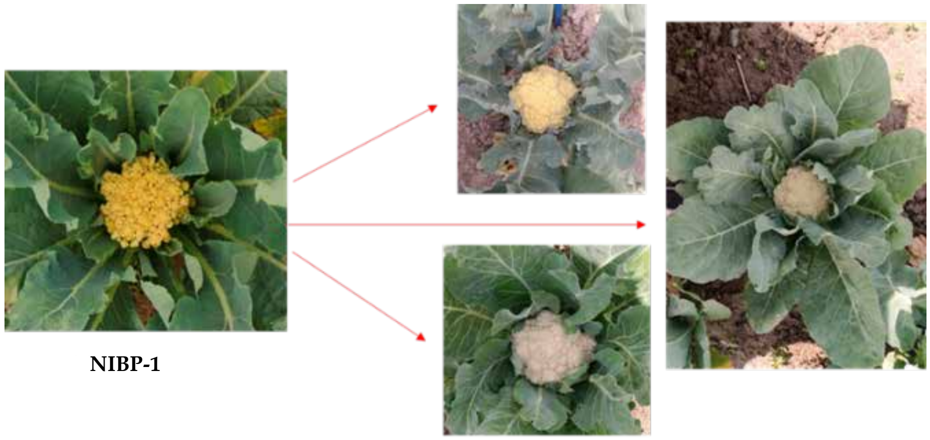
KTCFH-515

KTCFH-534

Screening and evaluation of cauliflower germplasm for off-season cultivation

season of 2022-23, 50 genotypes and 30 hybrids of cauliflower were evaluated for yield and other horticultural traits. Among all, KTCF-33, KTCF-26, KTCF-46, KTCFH-534, KTCFH-515 and KTCFH-5137 formed good quality curds under high temperature conditions.

Diversification of male sterile cytoplasm in snowball cauliflower: During winter 2022-2023, developed BC_2 population of *Erucastrum canariense* male sterile cytoplasm was introgressed into different genotypes of snowball cauliflower.



NIBP-1

BC_2 Genotypes with *Erucastrum canariense* male sterile cytoplasm

Cauliflower with introgressed *Erucastrum canariense* male sterile cytoplasm (BC_2)

Evaluation of promising snowball cauliflower hybrids in multi-location yield trials: Twelve promising F_1 hybrids were evaluated along with three check cultivars at three locations *viz*., Katrain, New Delhi and Solan during winter 2022-23. The tested hybrids revealed a heterosis range of -3.86 - 31.77, -2.02 - 34.30 and -0.73 - 36.06% over the three check cultivars, however, 10 hybrids were found superior over all the check cultivars and were found suitable for harvesting during 4th week of December to 4th week of February.

2020/KTCFH-17(KTCFH-534)

2022/KTCFH-6841 2022/KTCFH-264

Promising cauliflower hybrids in multilocation yield trials

Entries contributed in AICRP (VC) trials: Two open-pollinated genotypes (KTCF-53 and KTCF-84) and two CMS-based hybrids (KTCFH-544 and KTCFH-6841) of mid-late season cauliflower along with two CMS-based hybrids (KTCFH-264 and KTCFH-5137) of late-season cauliflower were contributed in AICRP (VC) IET. 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 advanced to AVT-I. Besides, 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-II under AICRP (VC).

2.1.2.4 Broccoli

Evaluation of CMS-based F_1 broccoli hybrids: Sixty broccoli hybrids were evaluated for yield and horticultural traits against three private-sector hybrids. Hybrid 19KTSA × VCH recorded highest head yield

19KTSA × VCH VCHA × 1913-32

19B-31A × V-Pl-5-1

SMDA × V-Pl-5-1

Promising CMS-based F_1 hybrids of broccoli

(26.2 t/ha) followed by VCHA × 1913-32 (25.7 t/ha), 19B-31A × V-Pl-5-1 (25.3 t/ha), SMDA × V-Pl-5-1 (24.4 t/ha) and SMDA × V-Pl-4-1 (23.9 t/ha) which were significantly higher than best check Lucky F1 (15.8 t/ha) with an increase of 65.8, 62.6, 60.1, 54.4 and 51.2%, respectively.

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

Tropical broccoli: A new tropicalized genotype DC-Brocco-13 (18.5 t/ha) outperformed the check varieties Palam Samridhi (15.4 t/ha) and Pusa KTS-1 (13.5 t/ha). In tropicalized broccoli, eight promising progenies ($F_{2:4}$) were evaluated in July sowing and heading was observed in October month in three lines. DC-Brocco-13 yielded a maximum (16.5 t/ha), followed by DC-Brocco-51 (14.8 t/ha) and DC-Brocco-33 (12.4 t/ha) during December maturity. These genotypes had medium-size heads (350-400 g), medium bud size, and proper seed setting under Delhi conditions. Two CMS lines, namely DC-Brocco-PS-64A (BC7) (*Ogura*) and DC-Brocco-15A (BC6) (*Can*) were maintained.

2.1.3 Cucurbitaceous crops

2.1.3.1 Cucumber

Entries in AICRP-VC trials: The hybrids DGCH 148, DGCH 143, IMPUCH 148 and IMPUCH 13-01 are under different stages of AICRP (VC) trials. Two gynoecious parthenocarpic F_1 hybrids, DPaCH-07 and DPaCH-04, entered the AICRP (VC) trials.

Promising genotypes for open field and protected cultivation: Tropical gynoecious lines, IMPU-1, IMPU-2, IMPB, DGC-102 and DGC-103 showed stable performance at an average day temperature of 40-45° C. Out of 32 selections evaluated, DC-39 and DC-43 showed consistently good performance for fruit size and quality traits and yielded 18.3 and 17.4 t/ha, respectively. Out of 51 F_1 hybrids evaluated, gynoecious hybrids DGCH-148 and DGCH-143 yielded 25.8 and 27.2 t/ha, respectively. During *kharif* season 2023, 157 lines were screened for downy mildew resistance and DC-77 (17.8 t/ha) and DC-70 (16.5 t/ha) showed highly resistant disease reaction and had high yield, earliness and other desirable traits. Out of 20 F_1 hybrids evaluated, DCH-16 (19.5 t/ha) and DCH-19 (1.8.9 t/ha) were promising with high yield and tolerance to downy mildew disease.

2.1.3.2 Muskmelon

Entries in AICRP-VC trials: Two muskmelon hybrids DMH-18, DMH-23 and two varieties DMM- 154 and DMM-159 were evaluated in IET and promoted to AVT-I. Two new varieties DMM 207 and DMM 228 were entered in IET varietal trials of AICRP.

Promising hybrids and varieties for open field and protected conditions: Speciality melon (*C. melo* var. *inodorus*) DHM 162 (5.3 t/1000 m^2), DHM 226 (5.2 t/1000 m^2) and DHM 159 (5.1 t/1000 m^2) were promising for protected cultivation. Speciality melon hybrids DMH 112 yielded a maximum (5.8 t/1000 m^2) followed by DMH 119 (5.5 t/1000 m^2) and DMH 139

DMH-112

(5.5 t/1000 m^2) under the net house. Hybrid DMH 112 was evaluated as Pusa Muskmelon Hybrid-3 in DIHAR, Leh and yield potential under open field conditions with mulch was up to 65 t/ha with TSS in the range of 17 to 18^o B.

2.1.3.3 Watermelon

Genetics of new source of resistance to watermelon bud necrosis virus: Inheritance pattern of WBNV resistance in novel source of DWM-45 (*Citrullus lanatus* var. *citroid*) was found to be governed by a single dominant gene.

Watermelon bud necrosis virus (WBNV) under insect-proof glasshouse conditions

2.1.3.4 Bitter gourd

Promising hybrids: Two hybrids DBGH-4812 and DBGH-482 were promoted to AVT-I and two hybrids DBGH-4 and DBGH-2163 to AVT-II trials of AICRP (VC). For earliness and yield traits, best performing hybrids DBGH-2123 (29.5 t/ha), DBGH-21100 (28.0 t/ha) and DBGH-431(27.66 t/ha) entered in IET trials of AICRP (VC).

Promising genotypes identified for earliness and yield: Bitter gourd genotypes DBGS-21-06, DBGS-162, DBGS-48-00 and DBG-100-0 produced higher yield of 27.65, 26.34, 24.11 and 23.09 t/ha under open field conditions. Two genotypes, namely, DBGS-21-06 and DBG-100-0 showed earliness in flowering and fruiting.

Promising selections for protected cultivation: Two advanced lines with predominantly gynoecious sex (DBGS-21-06 and DBGS-57) were found superior for earliness and yield traits under polyhouse and net house conditions.

Genetics of ToLCNDV: It was confirmed that resistance to tomato leaf curl New Delhi virus (ToLCNDV) in bitter gourd is governed by recessive genes utilizing three F_2 segregating populations.

2.1.3.5 Bottle gourd

Promising genotypes identified for yield and mineral content: Twenty-one F_1 hybrids were evaluated for yield-related characteristics and mineral contents. Small round fruited hybrid DBOGH 12 was identified as promising with an average yield of 30.6 t/ha and fruit weight of 580 g. The hybrids DBOGH 6 was found promising for Ca (9.22 mg/g DW) and Na content (1.40 mg/g DW), DBOGH 16 for Mg (12.29 mg/g DW) and Mn (87.67 µg/g DW) content and DBOGH 5 for Fe (231.75 µg/g DW) and Cu (15.43 µg/g DW) content. The hybrid DBOGH 12 entered in IET trials of AICRP, VC in 2023.

DBOGH 12

2.1.3.6 Sponge gourd

Entries in AICRP-VC trials: One promising entry each were promoted to AICRP (VC) (2021/Sponge gourd/Var/AVT-II) and (2021/Sponge gourd/hyb/AVT-II) trial.

Screening for leaf curl disease resistance: A total of 20 accessions of sponge gourd were evaluated for tomato leaf curl New Delhi virus (ToLCNDV) under field conditions during *kharif* 2023 and genotypes VRSL-3, VRSL-14, VRSL-17 and VRSL-18 were found to be resistant.

Hybrids evaluation: Out of 40 hybrids evaluated in spring-summer 2023, DSGH 204 (15.2 t/ha) and DSGH

205 (14.9 t/ha) were found promising for yield. Out of 38 hybrids evaluated in *Kharif* 2023, two hybrids DSGH 201 and DSGH 206 showed superior performance in terms of yield (15.5 t/ha) with field resistance to sponge gourd leaf curl disease.

2.1.3.7 Ridge gourd

Germplasm evaluation: A total of 25 accessions were evaluated and two accessions DRG-74 and DRG-30 showed superior performance with an average yield of more than 16.0 t/ha.

Screening for leaf curl disease resistance: A total of 37 accessions of ridge gourd were evaluated for tomato leaf curl New Delhi virus (ToLCNDV) in field conditions in *kharif* 2023 and four genotypes VRRGL-2-38, VRRGL-3-3, VRRGL-3-12, VRRGL-3-17 were found to be resistant.

2.1.3.8 Pumpkin

Evaluation of breeding lines for yield and quality: Fifty-two genotypes/ breeding lines were evaluated for yield and related traits. Five genotypes, DPU-150, DPU-136, DPU-S-4, DPU-129 and DPU-165 were found promising. The fruits of DPU-150 and DPU-S-4 were spherical with light ribs and orange and thick flesh. The fruits of DPU-136, DPU-129 and DPU-165 were flattish round with orange and thick flesh.

Screening for resistance to squash leaf curl China virus: Upon challenge inoculation by whitefly, out of 52 genotypes/ advanced breeding lines, DPU-41 and DPU-43 showed resistance against SLCCV.

First report of pumpkin yellows virus (PuYV), a new polerovirus species associated with pumpkin in India: The occurrence of a new species of Polerovirus, named tentatively as PuYV exhibiting severe chlorosis, bleaching and yellowing symptoms has been reported in India.

Evaluation of hybrids for yield and quality: The best performing promising F_1 hybrids based on fruit yield, shape and flesh colour were DPUH-15-36 (average fruit weight 2.50 kg, flesh thickness 3.0 cm), DPUH-15-02 (average fruit weight 2.58 kg, flesh thickness 3.2 cm), DPUH-36-02 (average fruit weight 2.40 kg, flesh thickness 3.5 cm) and DPUH-101-15 (fruit weight- 1.95 kg, flesh thickness- 3.0 cm).

Identification of unique genotype: Pumpkin DPU-84 has a lemon yellow flower color, which can be used as a morphological marker. Fruits of DPU-84 are flattish round with an average weight of 5.4 kg and yellow-orange thick flesh.

DPUH-15-36

2.1.4 Malvaceae crop

2.1.4.1 Okra

Evaluation for yield and virus resistance: Five hybrids, namely, DOH-1, DOH-6, DOV-7, DOV-9 and DOH-10 were highly resistant to YVMV and ELCV. DOV-9 recorded maximum yield (273 q/ha) followed by DOV-7 (267q/ha), DOV-10 (260 q/ha) and DOH-6 (258 q/ha). Two hybrids DOV-9 and Pusa Okra Hybrid-1 recorded fruiting at shorter internodes (<4 cm) with >26 fruits/plant. DOV-7 was found earliest in flowering (34 DAS), DOV-9 and DOV-69 recorded fruiting at shorter internodes (<3.5 cm) with dwarf growth habit. DOV-88 and DOV-89 had shorter fruits (<6 cm) with export quality. Out of 10 red okra genotypes, Pusa Lal Bhindi-1 recorded a fruit yield of 150 q/ha, 10% higher than Kashi Lalima (Check). Maximum anthocyanin was recorded in Pusa Lal Bhindi-1 (130 µg/g) followed by Kashi Lalima (65 µg/g).

Screening for viral disease: Okra hybrid and varieties (120) from the public and private sectors were screened for okra enation leaf curl virus under natural epiphytotic conditions during the rainy season of 2023. Most of genotypes/hybrids were susceptible to okra enation leaf curl virus, however, DOV-92, DOV-69, Hina -302, Aardhya, H-7 and crosses that involve these parents were found resistant to okra enation leaf curl virus.

2.1.5 Root crops

2.1.5.1 Carrot

Evaluation of breeding lines for yield and quality: Sixty-two genotypes/ breeding lines were assessed for quantitative and quality traits during a normal season. Based on the quality (root shape, surface, external & internal colour and external appearance), promising high yielding genotypes identified were DCat-11, DCat-13, DCat-20 PR, DCat-30, DCat-85, DCat-91, DCat-96, DCat-98 and DCat-105.

Evaluation of hybrids for yield and quality: The promising high yielding F_1 hybrids with red colour were DCatH-31, DCatH-531, DCatH-016, DCatH-018 and DCatH-013, whereas in orange root colour category DCatH-34 was found promising. The promising hybrids for micronutrients were DCatH711 for potassium (194.29 mg/100g fw), DCatH536 for calcium (62.45 mg/100g fw), DCatH785 for magnesium (28.78 mg/100g fw), DCatH71 for iron (18.92 µg/g fw), DCatH9888 for zinc (4.16 µg/g fw), DCatH76 for copper (1.22 µg/g fw) and DCatH5316 for manganese (6.49 µg/g fw) contents.

DCatH-31

Entries in AICRP-VC trials: Two hybrids DCatH-73 & DCatH-13 were advanced to AVT-I and two hybrids DCatH-7 & DCatH-19 were advanced to AVT-II in AICRP-VC tropical carrot hybrid trial for evaluation in different zones.

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

2.1.5.2 Radish

Promising genotype- Selection-14: The petiole and root skin of Selection-14 are pink in colour. It reaches marketable maturity 50-52 days after sowing during *rabi* season. The roots are 7-8 cm long, 3.4 cm in diameter, with an average root weight of 75 g. The average root yield is 18-20 t/ha.

2.1.6 Bulb crops

2.1.6.1 Onion and garlic

Breeding for superior onion varieties/hybrids during *kharif* season: During *kharif* season, eight elite lines (POS20K, POS21K, POS22K, POS23K, POS24K, POS25, POS26, POS27K) were evaluated. Two lines, POS20K (red) and POS24K (white), outperformed their check varieties. Further, it was observed that storage loss in *kharif* entries ranged from 15.5% (POS21K) to 32.7% (POS27K). Storage loss in POS20K was 28.1% and in POS24K, it was 23.4%.

Evaluation of *kharif* onion genotypes for green onion: Thirty genotypes were evaluated for leaf yield related traits and storage life. Green onion yield varied from 2.3-6.16 t/1000 m^2. Moderate heritability was observed for number of leaves (38.56%) and yield (36.38%), while leaf length and plant height exhibited low heritability values. Pusa Riddhi and PKO-1964 exhibited better postharvest life with PLW <5% till 3 days.

Breeding onion for *rabi* season: Fifty-eight onion germplasm lines were evaluated in *rabi* season. POS22K (42.8 t/ha), POS25K (32.6 t/ha), RO1769, W353 and POS21K (30.4) yielded higher than the check variety Bhima Shakti (30.3 t/ha).

Evaluation of long-day red onion germplasm: In long-day onion, 5 inbred lines with red colour were evaluated for different horticultural traits along with check cultivar Brown Spanish. All the five genotypes *viz*., KTON-21 (46.97 t/ha), KTON-27 (43.74 t/ha), KTON-8 (43.69 t/ha), KTON-20 (41.35 t/ha) and KTON-64 (38.92 t/ha) were found superior compared to Brown Spanish (31.27 t/ha).

KTON-21

KTON-27

KTON-8

KTON-20

Promising genotypes of long-day red onion

Entries contributed in AINRPOG trials: Two open pollinated genotypes *viz*., KTON-51 and KTON-66 of long-day onion were advanced to AVT-I under AINRPOG.

2.1.7 Leguminous crops

2.1.7.1 Garden pea

Entries in AICRP-VC trials: Three new entries GP 1812, GP 2002 and GP 2101 in early maturity and one entry GP 1804 were in IET varietal trial of AICRP. Two entries GP 1802 and GP 1504 were promoted to AVT-I and AVT-II, respectively.

New genetic material for high yield and disease resistance: Twenty-eight bulks derived from F_6 generations breeding materials against three checks (Pusa Shree, VRP 6 & Arkel) were evaluated and 8 lines were identified having early maturity and 10 with medium maturity. The promising genotypes in early group were GP 1501 (10.6 t/ha), GP 1502 (10.5t/ha), GP 1504 (10.20 t/ha) and GP 1802 (11.8 t/ha), GP 1803 (11.5 t/ha) were in medium maturity group. Genotypes having a high degree of powdery mildew resistance were GP 1503, GP 1505 and GP 1804.

2.1.7.2 Other legumes

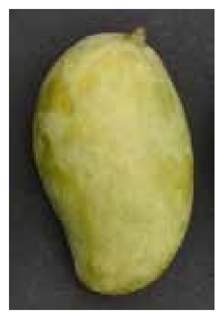
Sixty-nine advanced cowpea breeding lines were evaluated. CP 63 and 66 were promising for yield and better resistance to viral diseases. Thirty-nine Indian bean genotypes were evaluated and three most promising lines were DB 34, DB, 26, DB 41 and DB 28. One genotype DB 30 was identified for higher degree of resistance against common mosaic disease.

2.2 FRUIT CROPS

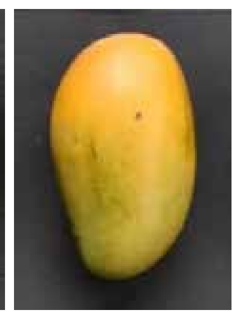
2.2.1 Mango

Evaluation of hybrids: Mango hybrids (88 nos.) were evaluated for 11 physico-chemical traits. The maximum fruit weight was observed in hybrid H-20-2 (402.0 g) and the maximum total soluble solids (TSS) was observed in the hybrid H-1-13 (25.06 °Brix). Mango

H-14-2



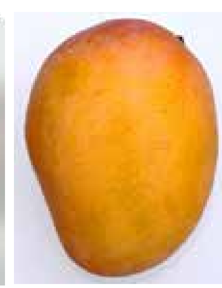
H-1-11



H-1-5

H-20-2

H-18-4



H-16-2

hybrids *viz*., NH-17-1, NH-18-4, NH 20-2, NH-19- 2, H-12-5, and H-3-2 had attractive red coloration on fruit shoulder and bore more than 200 g fruit weight with TSS ranging between 19.5 to 21.5 °Brix.

DNA bar code of mango hybrids: Polymorphic hyper-variable mango SSRs data of 24 IARI mango hybrids considering the allelic variations of polymorphic markers were translated into DNA.

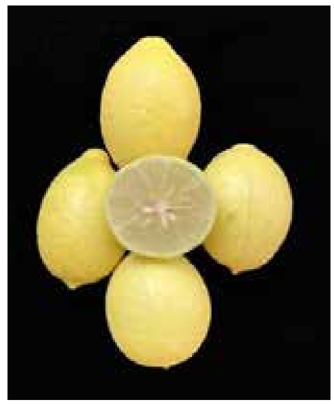
DNA Barcode of 24 mango hybrids based on 89 HMSSRs (Unique alleles- purple colour)

High-resolution mapping of QTLs for fruit colour and firmness: A high-resolution genetic linkage map was constructed using 4,613 SNPs markers distributed on 20 linkage groups. This is the first report on genetic recombination map based on bi-parental progeny population of Amrapali/ Sensation. The map covered a total genetic distance of 2,982.75 cM with an average distance of 0.68 cM between markers. The length of LGs ranged from 85.78 to 218.28 cM, with a mean size of 149.14 cM. Chromaticity coordinates observed on shoulder, middle, and bottom portions of mango fruits revealed that expression of *a** indicative of red color on the shoulder was associated with Chr 3 housing four QTLs (49.18 – 129.83 cM; LOD- 5.13 – 8.08). Two more QTLs on Chr 18 (79.42 and 83.20 cM) explained 19.9 to 25.2% phenotypic variations for *b** of fruit bottom (LOD 4.14-5.56). QTLs governing the brightness (L^*) of fruit were located on Chr 2, 3, 4, 10, 15, and 17. Peel firmness observed at shoulder and bottom of mango fruit was associated with SNPs located on Chr 11 and 20.

2.2.2 Citrus

Evaluation of acid and sweet citrus scion hybrids: Sixteen acid citrus genotypes (12 hybrids and 4 OP seedlings) were evaluated. The fruits of ACSH-7-13 tended to show the thinnest peel (1.23 mm) with higher juice (44.98%), TSS (9.5 °B) and acidity (6.14%). Hybrids ACSH-6-17 and ACSH-7-18 produced low-seeded fruits (8.2-9.0 seeds/fruit). A total of 85 sweet citrus scion hybrids were evaluated. Hybrid SCSH-8-11 was highly juicy (63.28%) followed by SCSH-5-6 (52.45%) which had very high TSS (14.17 °B) content.

ACSH-7-13



SCSH-5-6

Characterization of colchiploids of *Kinnow* mandarin and Mosambi: Fruit weight was found higher in colchiploids and the increased rind thickness can be considered a reliable marker for polyploidy in *Kinnow* and Mosambi. Two colchiploids of *Kinnow* (L5P12 & L5P13) and two of Mosambi (L6P10 & L7P7) exhibited stability for early maturity, less seeds and higher fruit weight continuously for three years. A chimeric branch was identified in 2^{nd} generation colchiploids of Mosambi sweet orange with different fruit morphological characteristics.

A chimeric Mosambi fruit

***In vitro* mutagenesis in *Kinnow* mandarin:** To induce solid mutants in *Kinnow* mandarin, the explants were subjected to irradiation doses of 20-160 Gy using direct somatic embryogenesis (DSE) and indirect somatic embryogenesis (ISE). Probit analysis showed high radiation sensitivity of the ISE system (LD50= 54.31 Gy) over the *in-ovulo* nucellus explant-based DSE (LD50= 65.75 Gy) system. In DSE system at the selected dose of 80 Gy, nearly 10% more embryogenesis and 57% more embryo production were noticed over ISE at 100 Gy. The DSE system had shorter days for germination and high plantlet recovery (4.35 and 2.0 folds, respectively). This is the first report on solid mutant induction through *in vitro* mutagenesis in citrus and modification of *in-ovulo* DSE protocol.

Collection and raising of promising citrus rootstocks: At ICAR- IARI Regional Station, Kalimpong, citrus species were collected from different parts of Darjeeling and Kalimpong districts for rootstock purposes.

2.2.3 Grape

Screening for powdery mildew resistance in grape: Forty-eight grape genotypes were evaluated for natural incidence of powdery mildew and artificial *in vitro* leaf inoculation (OIV455-1scores). *Vitis parviflora*, Male Hybrid and Pusa Navrang were rated as extremely resistant (DSI = 0.41, OIV455-1 score =8.83), highly resistant (DSI = 7.25, OIV455-1 score =8.33)and resistant (DSI = 23.5, OIV455-1 score = 7.67), respectively, while Pusa Trishar was rated as highly susceptible type (DSI = 0.88, OIV455-1 score =1.67).

2.2.4 Guava

Identification of promising guava hybrids: The hybrid 7A (GH-2017-7A), a white pulp coloured hybrid, with average fruit weight (150.33 g), seed weight (3.13 g), seed hardness (14.04 kg/cm^2), TSS (12.23 °Brix), titratable acidity (0.45%), ascorbic acid (169.6 mg/100g pulp), total phenolics (151.43 mg/ 100 g fruit fresh weight) and total flavonoids (62.53 µM TE/g fruit fresh weight). Another guava hybrid 8 F with deep pink pulp suitable for both table and processing purposes, having large fruit size (190-240 g), total soluble solids (12.50 to 13.6 °Brix), ascorbic acid (156.82-179.23 mg/100 g of pulp), titratable acidity (0.39-0.41%), and high total flavonoids (94.53-110.22 µM TE/g FW) were developed. It has yield potential of 37 to 42 t/ha.

GH-2017-7A

2.2.5 Papaya

Heterosis estimation: Heterosis was studied using 6 inbred lines, namely, Pusa Nanha (PN), Pune Selection 3 (PS 3), P-7-2, P7-9, P-9-5 and P-9-12. Most hybrids showed positive heterosis for stem diameter, days to flowering and days to fruit maturity. As regards the number of fruits per plant, heterosis in the desired direction was observed in most hybrids, and the better performing hybrids were PS3 x P-9-5, PS3 x P-7-9, P-9-5 x PS3 and P-9-5 x P-7-9. The hybrid combinations which exhibited the highest value of mid-parent heterosis in the positive direction for fruit yield were P-9-12 x P-7-2 (39.74%), P-9-5 x P-7-2 (34.49%), PN x P-7-2 (27.09%) and P-9-12 x P-7-9 (26.87%).

2.2.6 Pomegranate

Survey, collection and exploration of pomegranate germplasm: Three explorations were carried out in Western Himalayan region (Uttarakhand, Himachal Pradesh and Jammu Division of J&K) to collect wild pomegranate genotypes from the natural population. *In toto,* 221 wild and cultivated pomegranate accessions were collected out of which 177 genotypes were successfully multiplied and maintained under greenhouse conditions.

Characterization of pomegranate germplasm: Out of 177 genotypes, the final hardwood cutting success ranged between 8.33-83.33% for the indigenous and exotic pomegranate collections, respectively. The fruit weight ranged between 25.5 to 800 g, titratable acidity between 0.26 to 7.33% and TSS between 12.97 to 18.63 °Brix amongst the collected pomegranate genotypes. A variant of 'Bhagwa' with swollen and closed calyx and an intense red rind type 'Kandhari' was also collected.

Variability among collected wild and cultivated pomegranate genotypes

2.2.7 Temperate fruit

Surveyed Shimla and Kinnaur districts of H.P. and collected different species of *Malus* and genotypes to explore their suitability as rootstocks. A total of 8 germplasms of wild apples were collected from different locations in *Ribba* and *Rarang* Panchayat. Besides, elite walnut (1), apricot (1), peach (1) genotypes were also collected. One branch of the 'Pusa Khor' variety of walnut showed cluster-bearing habit of more than 25 pistillate flowers and recorded 13 fruits set in this branch. Evaluation of different rootstocks (*Prunus japonica*, colt, wild peaches, Chuli, Behmi, Bitter Almond, Paja) for different stone fruits were studied with different spacings. *Prunus japonica* exhibited best result in high density planting at 1 m x 1.5 m spacing. Sitofix applied in kiwi fruit along with summer pruning increased fruit size by 38-66 g over the control. A foliar spray of NPK (5 g/L) gave better results for tree growth in young apple plants.

Temperate fruit crops germplasm conservation: Apple (95), pear (16), peaches and nectarine (14), prune and plum (8), apricot (24), strawberry (105), kiwi fruit (7), walnut (18), almond (8), persimmon (5) and cherry (16) have been conserved in the field gene bank.

Pusa Khor walnut

2.2.8 Production technologies of fruit crops

2.2.8.1 Mango

Evaluation of newly developed mango hybrids under INM schedule: INM treatments significantly affected plant height and canopy diameter in different mango cultivars. The maximum plant height (5.76 m), canopy diameter (N-S 3.42 m & E-W 3.66 m), fruit number (35.86), fruit weight (220.12 g) and yield (26.42 kg) were recorded with the application of NPK 75% + AMF (250 g) + *Azotobacter* (250 g).

2.2.8.2 Citrus

Rootstock mediated alteration in citrus scion cultivars under NaCl stress: Pusa Sharad grafted onto CM, X-639, CRH-47, NRCC-1 and NRCC-3 rootstocks exhibited least reduction in scion height, leaf area ratio, root-to-shoot ratio, total chlorophyll content, total carotenoid content, photosynthesis rate, stomatal conductance, internal CO_2 concentration, and transpiration rate compared to other rootstocks under salinity stress.

2.3 ORNAMENTAL CROPS

2.3.1 Rose

RH-2-2018 (BRRS-2): It belongs to the Floribunda group. It is a hybrid between cv. Bharat Ram and cv. Rose Sherbet. It produces pink purple-coloured medium sized blooms, fragrant flowers, less petal shedding, compact and prolonged flower anchorage. It is suitable for loose flower and garden display purposes.

RH-1-2021: It belongs to the floribunda group. It is a hybrid between cv. Anne Elizabeth and cv. Midas Touch. It produces yellow-coloured medium sized blooms. It is a floriferous variety and has recurrent flowering habits. It is highly suitable for garden display purposes.

RH-2-2018 (BRRS-2)

RH-1-2021

Mutagenesis to induce variability in rose: Semi hardwood cuttings of rose cv. 'Pusa Virangana' was treated with different doses of gamma rays (20, 30, 40, 50, 60, 70, 80, 90 and 100 Gy) to induce variability. The higher doses of gamma rays at 50 Gy and above exhibited 100% mortality of cuttings. Two mutants namely Mutant -1 (PVM-1) and Mutant -2 (PVM-2) were isolated from var. 'Push Virangana'.

2.3.2 Marigold

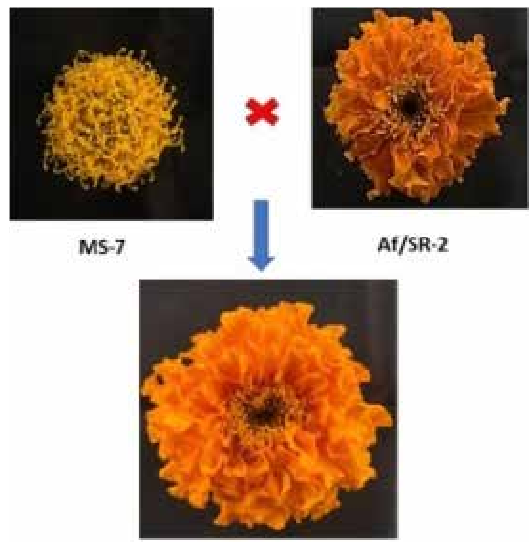
Af/SR- 15-1: It belongs to the African marigold group. The flowers are compact, medium and creamish white in colour (Yellow Group 2C). It flowers during October-November. It is suitable for landscaping purpose in pots/beds.

Fr./14-6: It belongs to the French marigold group. The flowers are compact, medium and brick red. It flowers during November-December. It is suitable for landscaping purpose in pots/beds.

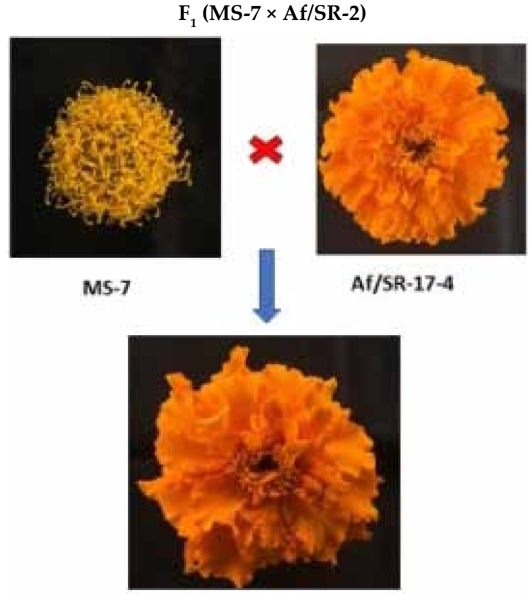
Af/SR- 15-1

Fr./14-6

Hybridization in marigold for flower yield related traits and carotenoids: A line × tester set of 15 parents involving three male sterile lines and 12 pollen parents



F_1 (MS-7 × Af/SR-2)



F_1 (MS-7 × Af/SR-17-4)

of African marigold (*Tagetes erecta* L.) and their 36 hybrids were analyzed for various flower yield related traits and carotenoid content. Hybrids MS-7 × Af/SR-17-4 and MS-7 × Af/SR-7 were best for higher lutein content, while hybrids MS-7 × Af/SR-2, MS-5 × Af/SR-17-4, MS-8 × Af/SR-1 recorded best for higher flower yield per plant.

***In vitro* application of salicylic acid to enhance thermo-tolerance in doubled haploids:** Anther derived doubled haploids (DH) were sub-cultured on MS basal medium supplemented with salicylic acid (0.2, 0.5 and 1.0 mM) along with control and were subjected to higher temperature treatments of 40, 42, 45^{o} C for 12 and 24 hrs. The survival rate of DH on MS basal medium supplemented with salicylic acid (1.0 mM) showed a higher survival percentage (79%) when subjected to higher temperatures of 40 and 42^{o} C for 12 and 24 hrs compared to the control.

2.3.3 Gladiolus

Pusa Sinduri: It was released by CVRC for Zone II, IV and VI (West Bengal, Punjab, New Delhi, and Rajasthan) on the recommendation of ICAR-DFR, Pune. It is a mid-season variety that flowers in 105 days and produces robust, compact, straight, long spikes with more florets per spike (18.66). It is a multi-color variety and florets are highly attractive for various purposes, such as cut flowers and garden displays.

Pusa Sinduri

Morphological evaluation of gladiolus hybrids: Twenty hybrids, including check variety were evaluated for different commercial traits. Early flowering *i.e.*, 83.7, 84.3, 85.0 and 87.7 days after planting was recorded in Chandni x Snow Princess, P-16-1 x Eurovision, Shweta x Regency and Berlew x Headywine hybrids, respectively. Maximum rachis length (71.66 cm), number of florets (20.0) was recorded in Vidushi as compared to remaining hybrids and check.

Brelew x Headywine

Smokey Lady x Headywine

Smokey Lady x Oscar

Vidushi mutant

Cross compatibility studies in gladiolus: Eleven varieties of gladiolus were crossed in diallel pattern and maximum capsule setting of 100% was found in crosses *viz*. Creamy Green × Pusa Red Valentine, Suchitra × Pusa Red Valentine, Chandini × Pusa Red Valentine, Pusa Mohini × Creamy Green, Pusa Mohini × Suchitra, Pusa Mohini × Pusa Red Valentine, Pusa Mohini × Shweta, Pusa Manmohak × Creamy Green, Pusa Manmohak × Suchitra, etc. Number of seeds per capsule was highest in crosses *viz*. Chandini × Shweta (96.80) followed by Chandini × Pusa Red Valentine (95.60) and Surya Kiran × Suchitra (86.60).

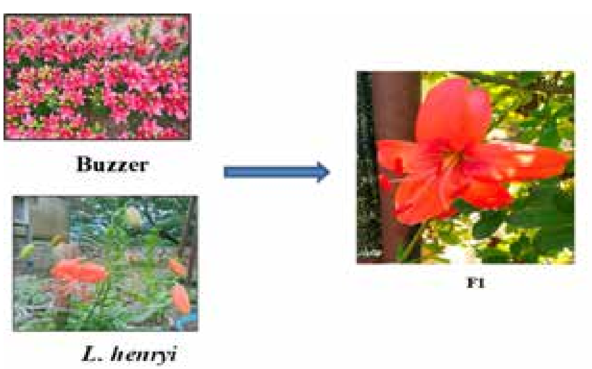
2.3.4 Chrysanthemum

Pusa Udai: It is an open-pollinated, promising variety of Lalpari. It has long stem and attractive green foliage suitable for open and polyhouse conditions, Possessing late blooming attributes under northern plains. The plant is of upright growth habit, very sturdy and branches do not droop down. This variety is suitable for potted purpose.

Pusa Udai

2.3.5 Lilium

Evaluation of Lilium hybrids: A total of 44 interploidy crosses were attempted with *Longiflorum* Asiatic x Asiatic hybrids. Swollen fruits with embryos were found only in 9 crosses. Maximum setting of 84% was found in Salmon Classic x Buzzer cross. Whereas, maximum number of embryos (630) were found in Fangio x Buzzer cross. Seed germination was maximum (25%) in *Lilium lancifolium* x Buzzer cross. Flowering was observed in cross Buzzer x *L. henryi*.



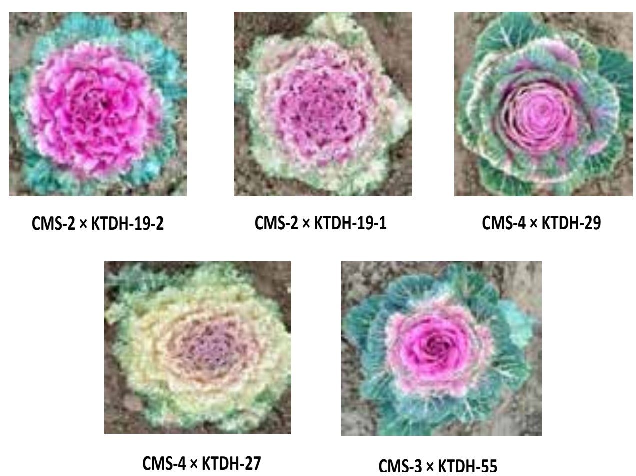
Flowering of F_1 hybrid

New Lilium germplasm line PKLH-14: A new seed propagated trumpet shaped male sterile line PKLH-14 was isolated from a cross between No.18 x cv. Jollanda. This line showed a significant difference for days to flowering and plant height over the female parent No.18.

PKLH-14 male sterile line

2.3.6 Ornamental Kale

Development of CMS-based hybrids in ornamental kale: In ornamental kale, 20 CMS and DH-based hybrids were evaluated. Seven hybrids performed better than the standard check Crane Rose with heterosis range for days to colour initiation -11.8 to 2.9% and days to head formation -9.1 to 6.0 per cent. Mean plant spread and height ranged from 27.20 -46.35 cm and 17.30– 32.77 cm with a heterosis range of -0.6-41.7 and -36.3 to 20.6%.



Best-performing CMS-based ornamental kale hybrids

Evaluation of advanced inbred lines in ornamental kale: A total of 58 inbred lines of ornamental kale were evaluated for different ornamental traits. Among them,

Ktok-1 Ktok-6 Ktok-13

Best performing kale lines

significantly early colour development was observed in Ktok-6 (30.33 days). Early head formation was recorded in Ktok-13 and Ktok-1 (60.33 days). The diameter of the central coloured portion was significantly higher in Ktok-6 (18.37 cm).

2.3.7 Antirrhinum

Evaluation of inbred lines: The developed inbred lines were evaluated for different ornamental traits. Among the inbred lines, KTANT-13, KTANT-14, KTANT-15 were found suitable for cut flower production and plant height varied from 112.14 to 122.54 cm. Maximum plant height was observed in KTANT-13 (122.54 cm) and minimum days to flowering in KTANT-14 (34.56 days). The maximum number of flowers per stem (32.24) was recorded in KTANT-13. Among the genotypes, KTANT-20, KTANT-21 and KTANT-22 were suitable for pot culture.

KTANT-13 KTANT-14 KTANT-15

KTANT-20 KTANT-21 KTANT-22

2.3.8 Evaluation of tree species for pollution tolerance

Two sites were selected as polluted and non-polluted to identify the best tree species based on APTI values. Based on APTI index *Ficus infectoria, Ficus religiosa and Pongamia pinnata* were found tolerant to polluted sites while *Azadirachta indica* and *Cassia fistula* were found intermediate tolerant. Tree species *Alstonia scholarish and Polyalthia longifolia* were sensitive.

2.3.9 Suitability of treated wastewater for turf grass irrigation

Among different turf grasses, Seashore paspalum (*Paspalum vaginatum*) exhibited the highest shoot fresh weight, shoot dry weight, shoot density, root fresh weight and root dry weight when irrigated with 50% treated wastewater followed by Bermuda grass (*Cynodon dactylon var. Tif dwarf - 419*) and Zoysia grass (*Zoysia japonica*).

2.3.10 Irrigation scheduling and nutrient management in gladiolus

Applications of seven irrigations at 15 days interval along with the application of *Azotobacter* + Bio-phosphorous + Bio-potash + Bio-iron + Bio-Zn each @ three liters per hectare as foliar spray at 30 and 60 days after planting was found best for growth, flowering, and corms related traits of gladiolus variety Pusa Shanti.

2.3.11 Packaging materials to improve the longevity of marigold loose flowers

Among the varieties, Pusa Narangi Gainda showed better storage life as compared to Pusa Basanti Gainda and Pusa Arpita. Among packaging materials, shrink wrap proved to be the better packaging material followed by HDPE under both ambient and low temperature conditions.

2.3.12 Standardisation of nutritional requirement of *Heliconia*

At ICAR- IARI Regional Station, Kalimpong, application of NPK 15:10:15 g/plant/year + FYM (500 g/plant) + vermi compost (50 g) + neem cake (50 g) improved plant height (132 cm), number of suckers (7.6), number of leaves (26.25) and area of leaves (485 cm^2) of *Heliconia* as compared to other treatments.

2.3.13 Height control of Easter Lily

At ICAR- IARI Regional Station, Kalimpong, higher dose of Paclobutrazol (160 mg L^{-1}) reduced plant height by 60%, induced earliness of flowering by 103 days, increased flower size (12.65 cm), number of bulbs (3.95), weight of bulbs (84.63 g), diameter of bulbs (4.25 cm) and number of daughter bulbs (2.65).

2.3.14 Post-harvest study in Lilium

Nanosilver @ 40 ppm pulse for 24 h or 20 ppm + 2% sucrose as vase solution extended the vase life and quality parameters of cut lilium flowers.

2.3.15 Effect of melatonin on growth and development of Lilium

A foliar spray of melatonin (200 μm L^{-1}) was found to be the best treatment for all growth and flowering related parameters and bulb multiplication in Lilium *cv.* Watch Up.

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

3.1.1.1 Germplasm registration

- **HS545 (INGR#23027):** It is developed from a cross 'HD 2819/HS 435. It has shown resistance against all the pathotypes of brown rust under the seedling resistance test (SRT). HS 545 has been validated for the presence of *Lr24/Sr24* using molecular marker *Sr24#12*.
- **HW 3654 (INGR#23082):** It has been registered and carries one major gene each for stem rust (*Sr36*), leaf rust (*Lr45*) and powdery mildew (*Pm6*) resistance, including adult plant rust resistance genes (*Sr2/Lr27/Sr30*).
- **HW 3655 (INGR#23083):** It carries one major gene each for stem rust (*Sr36*), leaf rust (Lr45) and powdery mildew (*Pm6*) resistance. Genes for adult plant rust resistance genes (*Sr2/Lr27/Sr30*) are also present.
- **Germplasm conservation:** More than 7000 wheat, barley, oats, Triticale lines, synthetics, CIMMYT advance lines, RIL's carrying different leaf, stem, yellow, head scab, blight resistance genes, PHS sources and 1900 wild spp were maintained 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* and *Lr68, Yr10 and Yr15* were maintained.

3.1.2 Barley

3.1.2.1 Germplasm registration

- **BHS479 (BBM 798) (INGR#23029):** The developed genetic stock is resistant to all the pathotypes of leaf rust at the seedling stage. It also possesses seedling resistance against all the pathotypes of stripe rust (except for race 24 showing moderately resistant response) and has adult plant resistance to leaf rust and stem rust.
- **BHS 480 (BBM 803) (INGR#23066):** The developed genetic stock is resistant to all the pathotypes of leaf rust at the seedling stage and to all pathotypes of stem rust except for race 11 at the seedling stage.

3.1.3 Rice

Pre-breeding - evaluation of wild rice accessions: A set of 100 different accessions of wild rice collections including *O. rufipogon, O. nivara* and *O. longistaminata* were evaluated for different traits. 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*).

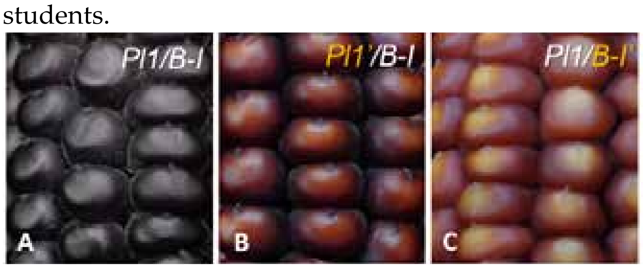
Evaluation of rice landraces for yield and other components: A set of 1513 rice landraces collected from different parts of the country were evaluated for yield and components such as number of tillers per plants, plant height, panicle length, days to 50% flowering, days to maturity, number of grains per panicle during *kharif* 2023.

Field evaluation of rice landraces

3.1.4 Maize

Identification of trait-specific field corn germplasm: A total of 15 newly identified inbred lines for specific traits such as high kernel row number, cob length and white endosperm were submitted to NBPGR with IC number (IC-0648502 to IC-0648516).

Development of novel genetic stocks: Inbreds with *Purple Plant1* (*Pl1*) and *Booster1* (*B1*) genes and their epialleles *viz*., *Purple Plant1'* (*Pl1'*) and *Booster1* (*B1'*) were developed to demonstrate the phenomenon of methylation and paramutation in maize kernel to the students.



A: MGU-Pl1/B1-101, B: MGU-Pl1'/B1-102, C: MGU-Pl1/B1'-103.

3.1.5 Mungben, urdbean and lentil

Registration of germplasm lines: Following germplasm lines were registered at NBPGR, New Delhi: lentil (L 4717 NM: INGR#23093), mungbean (PMR 1: INGR#23096) and urdbean (IC 519933: INGR#22149 and IC 5304912: INGR#22148).

3.1.6 Mustard

Maintenance of wild relatives: A total of 645 germplasm lines including *B. juncea* (397), *B. rapa* (26), *B. carinata* (170), *B. nigra* (7), *B. napus* (16), and 29 accessions of wild /related species were raised and maintained.

3.1.7 Genetic resources developed in vegetable crops

Cucumber: Two tropical gynoecious lines *viz*. IMPU-1 (INGR#23050) and IMPU-2 (INGR# 23051) developed through MABC were registered by ICAR-NBPGR, New Delhi.

Broccoli: A set of 14 DH lines, 28 germplasm and 8 CMS lines were purified, maintained and utilized in hybrid breeding programme.

Cabbage: A set of 96 germplasm of cabbage including 10 DH lines, 54 open pollinated (OP) genotypes and 32 CMS lines were purified, maintained and utilized in hybrid breeding programme.

Cauliflower: A total of 222 germplasm lines of white cauliflower (78 CMS, 100 OP, 20 EC lines, 14 DH lines and 5 genotypes each of orange and purple coloured cauliflower) were purified, maintained and utilized in hybrid breeding programme.

Capsicum: A set of 86 open pollinated genotypes of capsicum [green (39), yellow (27), red (15) and orange (5)] were purified and maintained.

Temperate carrot: A set of 115 genotypes of temperate carrot including 95 OP lines and 20 CMS lines were purified, maintained and utilized in hybrid breeding programme.

Onion: A set of 40 advanced breeding lines of long day onion (red, yellow and white) were purified and maintained.

Summer squash: Ten open pollinated genotypes of summer squash (green, orange, yellow and creamy white) were purified and maintained.

3.1.8 Genetic resources developed in flower crops

Temperate flowers: A set of 59 cultivars and five species of *Lilium*, 64 lines of ornamental kale, 58 lines of *Antirrhinum*, 22 species/varieties of *Iris*, 20 varieties of *Dahlia*, 25 varieties of *Alstroemeria*, 75 breeding lines of *Gladiolus* and 15 inbred lines of *Eustoma* were maintained and used for crop improvement programme.

Rose: Garden display varieties namely Amma, Girija, J. N. Biswas, Kalpana Chawla, Lady's Choice, Rupasi, Ahallya, Pink Shower, Priti, Red Vatertag, Sanyog, Eddy Mitchell, Headliner, Burgundy Ice and Baby Love were collected from secondary sources to enrich the existing germplasm.

Marigold: One new genotype of marigold namely var. Forest Fire was collected from secondary sources to enrich the existing germplasm.

Gladiolus: One variety 'Solan Mangla' was collected from secondary sources to enrich the existing germplasm.

Potted plants: Germplasm of indoor potted plants especially succulents like *Echeveria elegans*, Crassula, Porcelain Plant (*Graptoveria opalina*), Bunny Ear Cactus (*Opuntia microdysis*), *Mammilaria nejapensis*, *Haworthia sp*, *Pachyphytum oviferumn* were collected. Besides, germplasm of spider plant, swiss cheese plant, dumbcane, philodendron silver sword, philodendron imperial green and *Syngonium* 'Holly M' were also collected.

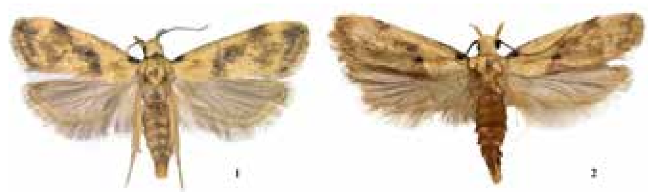
3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Insect biosystematics

Identification service and NPC augmentation: Three-hundred specimens belonging to different families of Coleoptera were identified including Elateridae, Scarabaeidae, Nitudilidae, Chrysomelidae, Anthicidae, Curculionidae, Dytiscidae, Hydrophilidae. Collections of Coleopterans were made from different locations of Delhi, Meghalaya, Arunachal Pradesh, Manipur and Nagaland. Approximately 1,000 specimens of various families were collected and augmented to National Pusa Collection.

Coleoptera: A new species similar to *Scymnus* (*Neopullus*) *nigroventralis* Chen et Ren 2014 from China was recorded from Nagaland, India, which differs in the elytral pattern, first abdominal ventrite color and male genitalia. A new record of the largest click beetle genus *Sinelater* (Coleoptera: Elateridae) and its single species *Sinelaterperroti* was reported from Arunachal Pradesh, India. The males can be easily distinguished from females based on the antennae, which are flabellate in males and pectinate in females. To date, this species is reported only from Vietnam, China, Bhutan, Tibet, Laos and Myanmar.

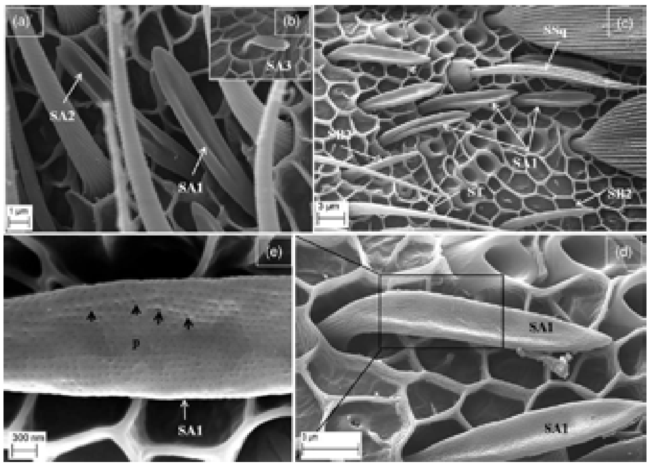
Lepidoptera: A new species and new record of the genus *Pexicopia* (Lepidoptera: Gelechiidae) from India: A new species, *Pexicopia tungabhadrai* sp. nov. (Lepidoptera: Gelechiidae) feeding on *Abutilon indicum* was described from Karnataka, India. This is the first report of the genus *Pexicopia* Common, 1958 from India.



Adults of *Pexicopia tungabhadrai* sp. nov. 1, Male (Holotype); 2, Female (Paratype).

Discovery of a new species and six new records of subfamily Olethreutinae (Lepidoptera: Tortricidae) from India: A new species of the genus *Theorica* Diakonoff, 1966 was reported for the first time from India. Described and annotated checklist from Karnataka, India, namely, *T. malnadense* Reddy and Shashank, sp. nov. Six species namely *Gatesclarkeanaidia* Diakonoff, 1973; *Endotheniastibara* Razowski and Wojtusiak, 2012; *Olethreutescerographa* (Meyrick, 1907b); *Tetramoeraisogramma* (Meyrick, 1908); *Fulcriferaboavistae* Razowski, 2015; and *Pammeneperistictis* Meyrick, 1912, are recorded for the first time from India.

Morphological characterization of the antennal sensilla of *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae): The antennae of both sexes of *M. vitrata* were filiform with the number of flagellar segments varying from 72 to 84. Nine major morphological types of sensilla were observed on male and female antennae. Sensilla cylindrica were observed only on male antennae, indicating sexual dimorphism. This study aims to provide some basic evidence for further studies on the mechanism of insect–plant chemical communication and future semiochemical based management strategies of the major legume pest *M. vitrata*.

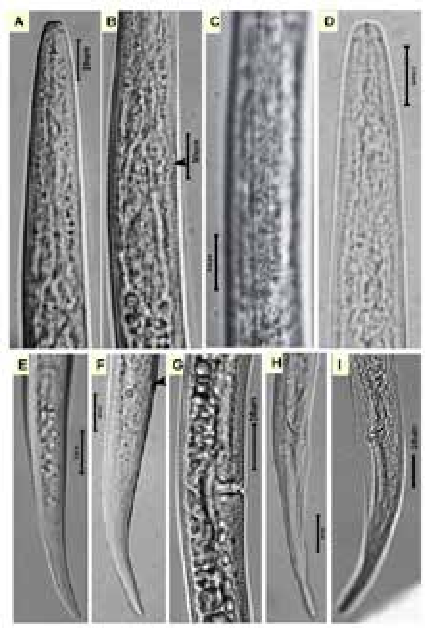


SEM images showing three subtypes of sensilla auricillica on male and female antennae of *M. vitrata*

3.2.2 Nematode biosystematics and identification services

Taxonomy and Biosystematics: Surveys of different crops cultivated under organic farming in Bulandshahr, Uttar Pradesh; Satna, Madhya Pradesh; and western Rajasthan were conducted to identify the nematode communities and entomopathogenic nematodes. Twenty-one nematode genera were encountered during the survey. Three isolates of *Steinernema* sp. and one of *Oscheius* sp. were identified. Soil and roots samples (49) from different crops were received from Kerala, Rajasthan, Bihar, Madhya Pradesh and Uttar Pradesh for nematode identification services. Lesion nematodes (*Pratylenchus* spp.) were identified and characterized from apple orchards in Kashmir, and citrus, wheat, chickpea crops at ICAR-IARI, New Delhi. A population of *P. hippeastri* was identified and characterized based on morphological, morphometrical, and molecular studies, which is the first report of *P. hippeastri* from apple orchards in India. *Ditylenchus rafiqi* n. sp. was recovered from the rhizosphere of pomegranate in New Delhi. Morphological, morphometrical and molecular characterization revealed that the new species was closely related to *D. acutus*, *D. gilanicus* and *D. medicaginis*. *D. rafiqi* n. sp. and forms an intermediate clade between the *D. triformis* and *D. dipsaci* groups.

During the course of survey, nematode associates to figs in North India were identified. Three species of *Schistonchussensulato* such as, *Ficophagus flagello racemosus, Ficophagus mucro benghalensis* and one *Ficophagus* n. sp. were identified on the basis of morphology and mophometric characters. A survey of guava orchards of Uttarakhand, Uttar Pradesh and Haryana was conducted to assess the spread of root-knot nematodes *Meloidogyne enterolobii*. First report of the root-knot nematode *Meloidogyne hapla* Chitwood, 1949 infecting kiwi fruit (*Actinidia chinensis*) in Bageshwar, Uttarakhand. A Recombinase Polymerase Assay for diagnosis of rice root-knot nematode *Meloidogyne graminicola* was developed.



Photomicrographs of *Ditylenchus rafiqi* sp. n.

3.3 Microbial genetic resources

Analysis of population dynamics and conservation of microbes associated with wheat: Population dynamics of culturable fungi and bacteria that harbour in rhizosphere and phyllosphere region of wheat and barley from different fields of Nilgiri hills were analysed.

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

The School of Crop and Natural Resource Management is entrusted with research towards conserving natural and man-made resources, enhancing resource/input-use efficiency, reducing environmental footprints, besides improving productivity and sustainability of the croping systems and farmers' income. Research is conducted on scale-appropriate integrated farming system models catering to the needs of farming communities, conservation agriculture, cropping system diversification, and sensor-aided precision nutrient management including nano-fertilizers for improving crop productivity, soil health, farm income and climate resilience. The school performs basic and applied research on quantity and quality of soil organic carbon, nutrient dynamics & management, alternate plant nutrient sources/systems using novel materials. Water body resources inventory and drought prediction for NCT of Delhi are updated from time to time. Machine learning models for reference evapotranspiration and IoT and sensor operated greenhouse vertical farming system are developed. The school is involved in development/fabrication of several low-cost and energy-efficient tools/ implements/ equipment for farming communities. Research is carried out towards improving quality and shelf-life of processed food products. In microbiology, various strains of cyanobacteria and P solubilizing bacteria are screened and characterized. GHGs emissions, global warming potential, climate change impacts, adaptation gains and GHGs mitigation are studied in various cropping systems.

4.1 AGRONOMY

4.1.1 Integrated farming system model for small farmers under irrigated situations in North India

The system comprising of crop + dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas unit + vermi-compost provided higher system productivity (61.5 t/ha), system production efficiency (168.5 kg/ha/day), gross returns (979.8 ×10^3 ₹/ha), water productivity (891.3 kg/ha-cm) and lowest water footprint (112.2 l/kg REY) compared to other systems under study. This system reduced GHGI by 78% over crop enterprise alone.

4.1.2 Integrated farming system model for sustainable livelihood of the marginal farm holders

Cropping system consisting of cowpea-marigold-vegetable mustard system led to higher sustainable

Different components of IFS model

livelihood index (SLI) with the pooled value of 119% followed by okra-cole crops- cowpea system (74.2%). The pooled SLI for RWCS and MWCS were -13.6% and -23.1%, respectively. IFS module with the integration of field crops, open field vegetable cultivation, protected vegetable cultivation, mushroom production, bee keeping and vermi-composting gave significantly higher productivity (83.40 t MEY/ha), net returns (774.9 x10^3 ₹/ha), profitability (2123 ₹/ha/day) and employment generation (788 man-days). The module (VP+ PVC+ FC+ AHS+ MP+ BK+ VC) was found superior in livelihood index, water productivity (6.74 kg/m^3), nutrient recycling (115.3 kg of N/ha, 34.5 kg of P/ha and 190.7 kg of K/ha), partial nutrients budget and human nutrition balance (achieved 100% supply with significant surplus in nutrition supply).

Agri-horti components under IFS model

4.1.3 Promising cropping systems under agri-horti systems in rainfed agriculture

The baby corn-chickpea cropping system provided significantly higher productivity (21.5-27.37%) compared to maize (cob)-chickpea, cowpea-chickpea and pearl millet-chickpea cropping systems. The ridge and furrow system with residue mulch and drip irrigation increased the system productivity by 21.8% compared to flatbed system. The lowest water footprint was recorded under the baby corn-chickpea (670.38 L/kg) and in ridge and furrow (759.03 L/kg). Baby corn-chickpea grown in the ridge and furrow with residue mulch and drip irrigation was recommended for higher productivity, water use efficiency, net returns, and benefit-cost ratio in the semi-arid rainfed conditions.

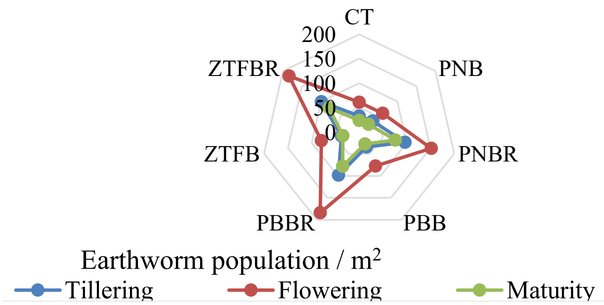
4.1.4 Bio-intensive resource-efficient cropping system

The temporal integration of maize + black gram (raised bed) + soybean (furrow)-chickpea (raised bed) + wheat (furrow) (3:2)-green gram (raised bed) + sunflower (furrow) (5:1) was found economically feasible and recorded higher production efficiency (175%). The greenhouse gases intensity was the lowest under maize-wheat cropping system.

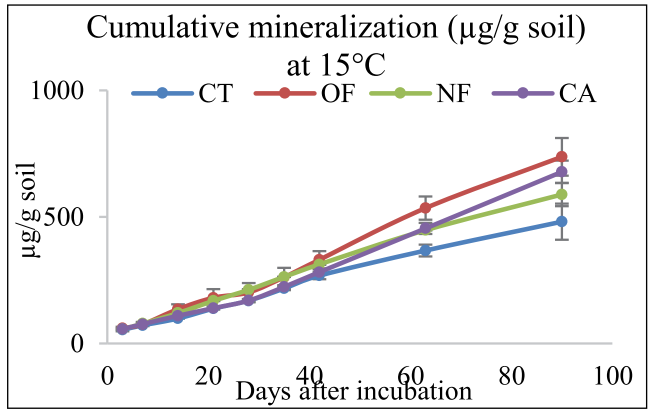
4.1.5 Conservation agriculture promotes earthworms abundance and ecosystem services

Among the crop establishment methods, zero till flat bed with residue (ZTFBR) resulted in the highest population and biomass of earthworm followed by permanent broad bed with residue (PBBR) and permanent narrow bed with residue (PNBR). The earthworm population and biomass were the lowest under conventional tillage (CT). Among the different stages of growth, the highest population and biomass of earthworms was observed at flowering stage followed by tillering and maturity.

Bio-intensive cropping system

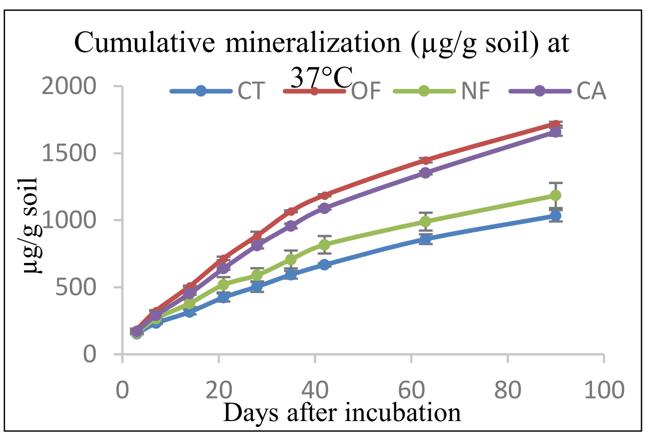


Earthworm population and biomass



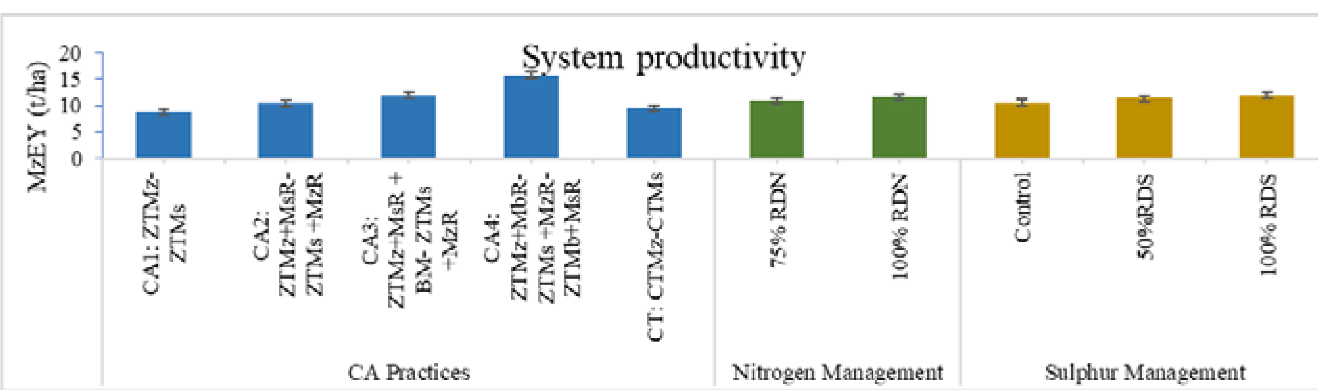
4.1.6 Temperature sensitivity of carbon in pigeon pea-wheat production systems

Mineralization kinetics and temperature sensitivity of carbon were evaluated in four pigeonpea-wheat production systems, such as conservation agriculture (CA), organic farming (OF), natural farming (NF) and conventional tillage (CT). The OF plots recorded the highest cumulative mineralization (C_{min}) (2082 µg/g soil) followed by CA plots at both 37º C and 15º C temperatures. Although the CT and NF systems provided the comparable C_{min}, the NF plots registered relatively higher C_{min}. The CA and OF plots provided similar temperature sensitivity, which was significantly higher than CT and NF.



4.1.7 Nitrogen and sulphur economy in conservation agriculture-based maize-mustard system

Nitrogen and sulphur economy was evaluated in a long-term CA-based maize-Indian mustard system. The CA-based practice ZTMz+MbR - ZTMs+MzR - ZTMb+MsR (CA4) provided the highest maize equivalent system productivity (15.72 t/ha), which was 79.5, 50.3 and 63.3% higher than ZTMz- ZTMs (CA1), ZTMz+MsR- ZTMs +MzR (CA2) and CTMz-CTMs (CT), respectively. No significant difference was found between 75 and 100% recommended dose of N (RDN). Further, the interaction effect between CA and N was non-significant between 100 and 75% RDN under all the residue retention treatments, *i.e.*, CA4, CA3 and CA2. Similarly, the effect of 100 and 50% recommended dose of S (RDS) on system productivity was significantly



higher over control (no sulphur application) across CA and CT treatments. The CA4 registered a net return of ₹ 182206 per ha, which was 97.9% higher than CT. Sulphur application resulted in significant impact on mustard economics, *i.e*. the application of 50 and 100% RDS recorded comparable net return but these two treatments resulted in 13.7 and 21.4% higher net return over control (no sulphur application), respectively.

4.1.8 Organic nutrient management in baby corn-chickpea cropping system

The ridge and furrow system with 3 t/ha residue mulch resulted in 21.8% increase in system productivity over conventional flatbed practice and provided the highest net returns (₹ 153,590/ha), B: C ratio (1.29), and economic efficiency (₹ 742/day/ha). Among the nutrient management practices, applying a 100% recommended dose of nitrogen (RDN) through leaf compost resulted in the highest system productivity (5.30 t/ha), which was 34.1% higher than the control. However, applying 75% RDN through leaf compost + 2 sprays of *jeevamrit* at 25 and 50, DAS resulted in the highest net returns (₹ 155,000/ha), B: C ratio (1.27), and economic efficiency (₹ 749/day/ha), followed by 100% RDN through leaf compost.

4.1.9 Nitrogen remobilization and grain yield in wheat genotypes under diverse water regimes

Wheat genotypes HD 2967, HD 3086, HD 3249, DBW 187, and HD 3226 under well-watered (WW) situation resulted in 36, 35, 38, 33, and 42% more grain yield compared to water deficit (WD) situation. Compared to the WD, the WW had 28, 30, and 28% greater root length, biomass, and root length density at flowering, while among the genotypes, HD 3249 had relatively greater root-traits. At flowering (Z_{61}) and maturity (Z_{89}), the genotypes under WW accumulated 30-46 and 30-53% higher shoot biomass over the WD, respectively. Furthermore, the shoot biomass remobilised for HD 2967, HD 3086, HD 3249, DBW 187, and HD 3226 under the WW was 32, 37, 39, 35, and 35% greater than the WD, respectively.

Root growth in different wheat varieties under well-watered and water deficit condition

4.1.10 Phosphorus management in maize-based systems under conservation agriculture

The maize + cowpea-wheat system provided 36% higher system productivity and 12 and 13.35% higher partial factor productivity of phosphorus (PFPP) in maize and wheat compared to the sole maize-wheat system, respectively. The application of 50% recommended dose of phosphorus (RDP) + phosphate solubilizing bacteria (PSB) increased agronomic efficiency by 49.21% in maize and 36.80% in wheat. In the sole maize-wheat system, there was lower soluble P compared to maize + cowpea-wheat system. But the Al-P, Fe-P, Ca-P and Residual-P (RES-P) under sole maize-wheat system were 9, 6, 8 and 10.5% higher than maize + cowpea-wheat system, respectively. The PSB increased soluble P and decreased Al-P, Fe-P, Ca-P, and RES-P and increased the organic P share by approximately 4.8% in the total P. The maize + cowpea-wheat (42.8%) had higher organic P than the sole maize-wheat system (39.5%).

4.1.11 Soy protein and Zn-coated slow-release fertilizer for enhancing rice production

The soy protein and zinc-coated fertilizer demonstrated a release rate of less than 60% within the initial 40 days, accompanied by a mere 5% leaching loss during the same period. Employing the soy protein and zinc-coated material at a rate of 100% of the recommended dose of nitrogen (RDN) through three split applications resulted in 8.83% increase in yield compared to the control.

4.1.12 Precision nutrient management protocols for rice-wheat system

The application of 50% N as basal + 25% N 10 DAT + 25% N 30 DAT + GreenSeeker guided N application + recommended P and K (NM_9) provided 14.4% higher grain yield compared to the state recommendation (NM_2) treatment. Meanwhile, the NM_3 treatment, based on soil test crop response-based NPK application, demonstrated the highest straw yield, exceeding the NM_2 treatment by 28.48%. Notably, the NM_3 treatment achieved the highest gross return, net return, and B: C ratio. Furthermore, the NM_3 treatment outperformed the NM_2 treatment in both grain and straw yield, which increased by 12 and 16.2%, respectively.

4.1.13 Conservation agriculture-based pearl millet-barley system for rainfed condition

Pearl millet and barley grown on ridges with residue mulch 3 t/ha produced the highest system productivity (6.67 t PEY/ha), 19.34% higher than CT. Maximum water use efficiency (8.43 kg/ha-mm) was recorded under ridge planting with residue mulch, followed by 8.28 kg/ha-mm under zero tillage with residue mulch. Growing crops in zero tillage with residue mulch fetched the highest net returns (₹ 83210 ha^{-1}) and B: C ratio (1.17).

4.1.14 NPK solubilizing microbial consortium for wheat

The seed treatment with Bio-NPK @ 2.5 g/kg seed was beneficial for wheat at all levels of NPK except control. Grain yield increased by 1.94, 1.29 and 6.42% under the application of 100% NPK (5.66 and 5.77 t/ha), 75% of NPK (5.41 and 5.48 t/ha) and 50% of NPK (4.51 and 4.80 t/ha), respectively compared to their respective NPK levels.

4.1.15 Effect of yellow gypsum on wheat yield in vertisols of Central India

Seven 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 demonstrated under 0, 30 and 45 kg S through yellow gypsum at 16 farmers' fields in three villages of Dewas district, Madhya Pradesh. Results showed that there was an improvement in wheat yields in all seven varieties in all the demonstrations due to the application of yellow gypsum at both doses. Wheat grain yields increased to the tune of 0.82 to 12.8% and 0.86 to 14.6% under the application of 30 and 45 kg S/ha, respectively, compared to the control.

4.2 SOIL MANAGEMENT

4.2.1 Soil aggregation and carbon accumulation in different land-use systems of Assam

Soil organic carbon dynamics was studied in different land use systems of Assam, which showed that forest and organic tea systems had significantly higher macro- and micro-aggregates associated carbon than inorganic tea plantation, rice-fallow system, and sugarcane system. Further, the study revealed that the upper Brahmaputra valley of the Assam region has higher C accumulation potential in different land use systems.

4.2.2 Soil carbon (C) stocks in long-term temperate plantation crops

The C stock was studied under apricot, apple, peach, walnut, almond, cherry, and plum plantations in Srinagar. Total carbon (TC) stock was the highest in apricot (46.70 Mg ha^{-1}) followed by walnut (46.44 Mg ha^{-1}) system in surface layer, whereas walnut plantation exhibited the maximum TC stock (66.81 Mg ha^{-1}) in subsurface soil.

4.2.3 Impact of conservation agriculture on humic acid (HA) quality and clay humus complexation

A long-term zero tillage without residue (ZT) and with residue (ZT+R) and conventional tillage (CT) in maize-wheat (M-W) and pigeonpea-wheat (P-W) systems were evaluated to characterize the HA by E4/E6 ratio and total acidity, and to specify the functional groups of clay humus complex. The ZT+R had a lower E4/E6 ratio and total acidity of extracted HA, showing a higher degree of humification and stability of HA carbon. The FTIR spectra of humic acid showed the numbers of functional groups were higher in CA-based treatments, and the peak areas reduced with depth, but the peak sharpness increased, which might be due to higher C stability. Besides, in 5-10 and 10-20 cm depth some functional groups in the region 1700-1715 cm^{-1} and 3200-3400 cm^{-1} present in ZT+R were absent in CT. Therefore, ZT+R has the potential to enrich organic carbon (C) quality in soil and can increase the aromaticity of HA, leading to carbon stabilization in soil.

4.2.4 Quantity and quality of soil organic carbon (SOC) under long-term fertilization and manuring

In a 50-year-old long-term experiment located at ICAR-IARI, New Delhi, the mean value of total SOC increased significantly across treatments in the span of 25 years from 1996-97 (6.49 g kg^{-1}) to 2021-22 (6.77 g kg^{-1}), implying C accumulation. The mean total SOC across the years under NPK, 150% NPK, and NPK+FYM were 19, 29, and 33% higher than the control. The SOC pools of higher lability increased significantly over the years under 150% NPK and NPK+FYM. The greatest sensitivity index (SI) values were reported for hot water extractable C (HWC) among all C fractions. The decline in HWC over a period of intensive cultivation without organic inputs forecast an early warning of the non-sustainability of that practice.

4.2.5 Inorganic carbon (C) sequestration through enhanced weathering

Surface soils were incubated with three graded doses of basalt rock dust (25, 50 and 75 Mg ha^{-1}) along with green manure (GM) (*Sesbania aculeata*) and farmyard manure (FYM), and cumulative SOC mineralization was measured at an interval of seven days up to 246 days. Results indicated a significant reduction in C emission from treatment GM 7.5 Mg ha^{-1} + FYM 10 Mg ha^{-1} + Basalt 5 Mg ha^{-1} compared with GM 7.5 Mg ha^{-1} + FYM 10 Mg ha^{-1}, indicating C sequestration potential of enhanced weathering of basalt.

4.2.6 Adsorption of dissolved organic carbon (DOC) by soil clay fraction

DOC was adsorbed on soil clay fraction (SCF) separated from Vertisol, Mollisol, Inceptisol and Alfisol. The highest DOC adsorption (on mass basis) was found in Vertisol-SCF followed by Mollisol-SCF.

4.2.7 Reversibility of non-exchangeable potassium release in major soil types of India

In a laboratory experiment, five soils *viz*., alkaline alluvial, acidic alluvial, calcareous alluvial, red, and black were leached 7, 15, 30, 45, 60, and 90 times with 0.1 N $BaCl_2$. Cumulative K released over 90 extractions followed the order black> red> alkaline alluvial> calcareous alluvial> acidic alluvial soil. There was a noticeable change in clay minerals, especially illite and mixed layer minerals, to different extents due to varied K-depletion in five soils. In association, the K-fixation capacity increased gradually with progressive K-depletion in all the soils. However, the increase in K-fixation capacity in different soils was only 0.09 to 0.29 mg kg^{-1} per unit (mg kg^{-1}) depletion in non-exchangeable K, indicating that the non-exchangeable K release is only partly (9-29%) reversible.

4.2.8 Soil quality under long-term rice-rice system in Alfisol of Assam

Thirty-two-year-old long-term rice-rice system in acidic Alfisol of Assam with eight treatments was assessed for 17 physical, chemical, and biological parameters for soil quality. Available Zn, available K, acid phosphatase activity and bulk density were selected as key indicators of soil quality. Integrated treatment with 50% NPK+25% green manure (GM)-N+25% farm yard manure (FYM)-N had the highest soil quality index followed by sole FYM application.

4.2.9 Lead (Pb) removal from aqueous solutions by modified clay products

The performance of phosphate-modified kaolinite was evaluated for removing Pb (II) from aqueous solutions under different experimental conditions. In terms of adsorption efficiency, the study demonstrated that the phosphate-bound kaolinite exhibited higher efficiency in removing lead compared to the raw kaolinite under controlled laboratory conditions and at various time points.

4.2.10 Isolation and screening of lead (Pb) bacteria resistant

Lead (Pb) concentration was estimated in lands near the industrial areas/ regions of Delhi, Jharkhand and Rajasthan. The concentration ranged from 16 to 784 mg kg^{-1}in Udaipur, Rajasthan, and 834 to 9326 mg kg^{-1} in the soils of Dhanbad, Jharkhand. A total of 309 isolates displaying distinct cultural and morphological characteristics were purified and subjected to further screening at varying Pb concentrations. Out of these, 120 isolates were identified for resistance to lead, having a concentration of 1000 mg kg^{-1}. These potential Pb-resistant bacteria can be used as bioremediation/ phytoremediation for the decontamination/ detoxification of lead-contaminated soil resources.

4.2.11 Impact of sludge application on soil health and metal uptake by baby-corn and spinach

Field experiments were undertaken to evaluate the effect of continuous sludge application for nine years on the buildup of heavy metals in soil and their uptake by field crops. Available Zn, Cu, Fe, Mn, Ni, Pb, and Cd contents in soil increased concomitantly with the increase in sludge application rate, the maximum content observed with sludge application at 30 Mg/ ha. Uptake of Zn, Cu, Fe, Mn, Ni, Cd and Pb in baby corn and spinach were significantly affected by sludge application rates. Nevertheless, the hazard quotient (HQ) was far below the permissible limit even with the application of sludge at 30 Mg ha^{-1}, indicating the safe consumption of the edible parts of the test crops. However, considering the build-up of heavy metals in soil, the application of sludge at the rate of 2.5 Mg ha^{-1} along with the recommended dose of NPK could be followed for growing crops.

4.2.12 Nutrient Management

4.2.12.1 Refinement in available boron (B) estimation

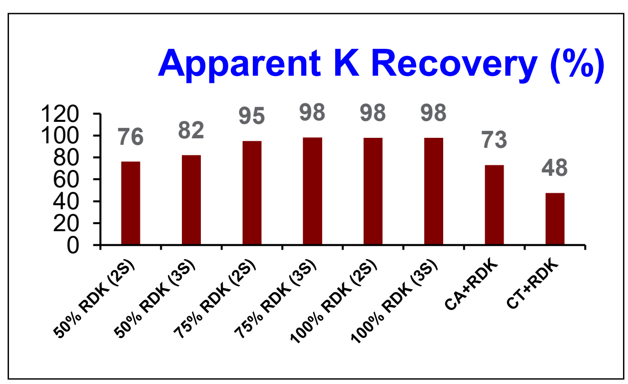
After assessing six different extractants, 0.1 M salicylic acid + 0.05 M mannitol + 0.01 M $CaCl_2$ was the most suitable extractant for the estimation of available B in both acid and alkaline soils.

4.2.12.2 Soil test-based crop recommendation (STCR) based equation for fertilizer recommendation in wheat

Front-line demonstrations were conducted on wheat crop in Rajpura village (Aligarh) during 2022-23 to demonstrate the performance of improved soil test-based fertilizer use for grain yield target of wheat in farmers' practice and state recommendation. Four demonstrations on wheat were conducted. Soil test-based fertilizer recommendations recorded the highest average grain yield (5.81 Mg ha-1) with a net profit of ₹ 46522 ha^{-1} compared to the recommended dose (4.90 Mg ha^{-1} and ₹ 29667 ha^{-1}), and farmers' practice (4.27 Mg ha^{-1} and ₹ 18497 ha^{-1}).

4.2.12.3 Effect of sub-surface fertigation on potassium (K) recovery

Potassium application in 2-3 splits through sub-surface fertigation in maize was found to increase the recovery efficiency of applied K to 98% against



Apparent K recovery as influenced by sub-surface fertigation; RDK: recommended dose of potassium; S: split application; CA: conservation agriculture; CT: conventional tillage

73% under normal application with conservation agriculture and 48% under normal application with conventional tillage.

4.2.12.4 Polymer-based novel fertilizer products for enhancing nitrogen-use efficiency

The application of 75% N through the nano clay bio-polymer composite (NCBPC) with 3% Dicyandiamide (DCD) as nitrification inhibitor resulted in statistically similar grain yield and biological yield as well as similar root morphology and chlorophyll content as that of 100% nitrogen supply through urea.

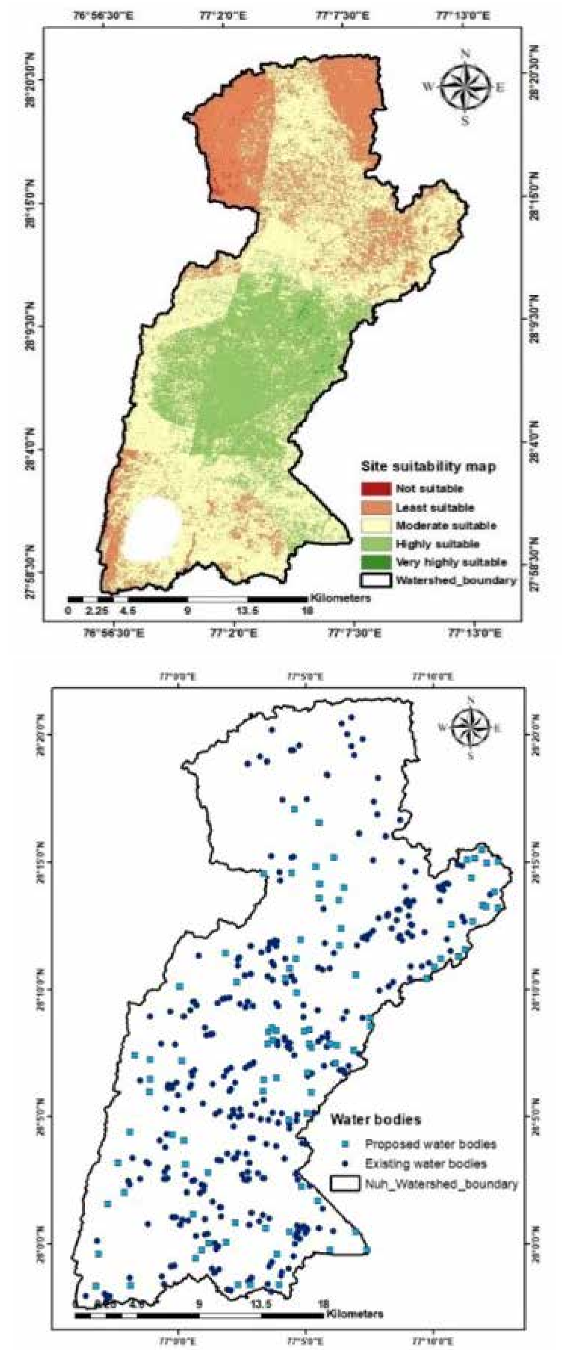
4.2.12.5 Recycling rice straw (RS) enhances the solubilization and plant acquisition of soil phosphorus (P)

The application of RS at 12 Mg ha^{-1} + PSM + 75% P enhanced the plant's available P by 21% over mineral fertilizer application during wheat growth. Application of RS (at 12 Mg ha^{-1}) +PSM+ 75% P resulted in a 45% greater wheat grain yield than control. It also improved root length, volume, and P uptake by 1.74, 2.40, and 1.61 times, respectively over control. Results indicated that P solubilization by Si and OAs significantly contributed to P availability in wheat rhizosphere. Hence, RS (at 12 Mg ha^{-1}) + PSM + 75% P of mineral P fertilizer could be recommended to the cultivators to save 25% P fertilizer without affecting yield.

4.3 WATER MANAGEMENT

4.3.1 Hydrologic zone-wise AHP based site suitability of water bodies in Nuh watershed, Mewat

After developing the protocol for pond revival in Mewat, Haryana, analysis was extended for Nuh watershed covering Nuh and Gurugram. A hydrologic zonation map was prepared, and a site suitability map was created through an Analytical Hierarchical process using thematic layers such as rainfall, soil, slope, land use/land cover (LULC), and distance to settlements. Based on the zonation map it was observed that the maximum number of 335 existing water bodies were in moderate to highly suitable areas. Areas with moderate to high runoff were selected as potential locations for proposed water harvesting structures which were then validated through ground truthing in Google Earth Pro. Out of the proposed water bodies, 86 could be



Site suitability and proposed water bodies in Nuh watershed

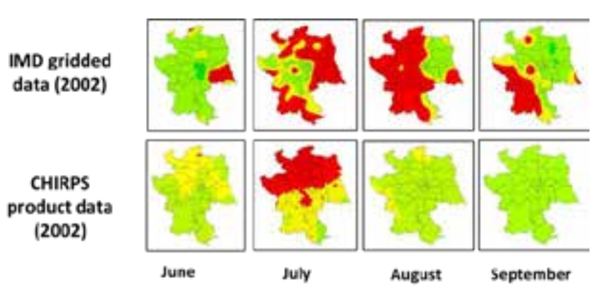
located under moderate, 49 water bodies under highly and two water bodies under very high suitable area.

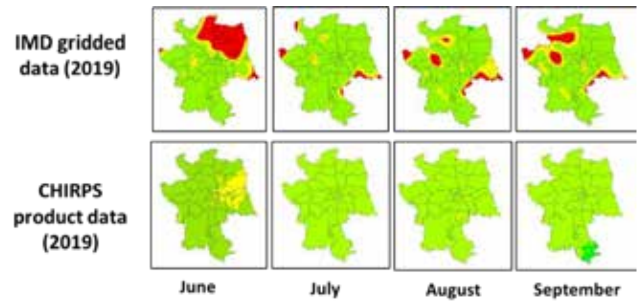
4.3.2 Resource inventory of water bodies in NCT of Delhi

Inventory of water bodies was performed in the NCT of Delhi after generating all thematic maps with two step methods using RS and ArcGIS tools. Sentinel-2A satellite imageries for the March and September months of the year 2022 were used for supervised classification for initially identifying water features in raster format followed by application of the query of NDWI ≥ 0 for calculated Normalised Difference Water Index (NDWI). The total potential locations of water bodies/ wetlands were individually verified in Google earth pro corresponding to respective spatial and temporal images. This showed 488 bodies in the NCT of Delhi.

4.3.3 Comparing IMD gridded data and CHIRPS products to assess drought over NCT Delhi

A study evaluated the satellite product over IMD gridded product for identifying meteorological drought over Delhi NCT. The precipitation data from satellite product (CHIRPS dataset) and IMD gridded data at 0.25º resolution for 33 years (1990 to 2022) was used in this study. Standardized precipitation index (SPI) was adopted to study the meteorological drought. The IMD gridded data observed 45% of the drought area under extreme and 26% of the area under severe drought conditions from July to September 2002, whereas CHIRPS data observed 29% of the area under extreme and 22% of the drought area under severe drought conditions. The analysis with drought years





showed that the IMD data product has better drought-capturing capability than CHIRPS data products over Delhi NCT.

4.3.4 Drip fertigation impacts on GHGs emission and crop productivity of tomato

Water applied under drip irrigated plots was 342 mm and 273 mm with 100 and 80% ETc, respectively, whereas under surface irrigation flooding, it was 480 mm. Surface irrigation emitted 19% more nitrous oxide than 100% ETc and 41% more than 80% ETc plots. No-fertilizer plots emitted 232% less nitrous oxide than 100% RDF and 135% less than 80% RDF plots. The treatment 100% ETc x 100% RDF (46.42 t/ha) showed the highest yield, followed by 80% ETc x 100% RDF (45.34 t/ha).

4.3.5 Developing monthly reference evapotranspiration machine learning models

Different machine learning models based on linear regression (LR), support vector machine (SVM), random forest (RF) and artificial neural networks (ANN) were applied for modeling monthly reference evapotranspiration (ETo) using minimal meteorological data for Jhansi, Banda and Hamirpur districts of Bundelkhand region. The results showed that the RF model performed better than the other models, and a combination of two input variables (Tmax and wind speed) and (Tmin and wind speed) could provide nearly identical results compared to taking all meteorological variables for ET_0 estimation.

4.3.6 Water footprint of wheat crop in North-Western plain agro-climatic zone

The green and blue water footprint of wheat was evaluated in North-Western Plains with 20 years of weather and yield data (2000-20) using the crop water requirement (CWR) model (FAO-CROPWAT 8.0). It revealed that blue crop water use ranged from 2526 m^3/ha to 3277 m^3/ha, while green crop water use varied from 514 m^3/ha to 950 m^3/ha. The blue water footprint ranged from 794 m^3/t to 997 m^3/t, and the green water footprint varied from 134 m^3/t to 310 m^3/t. On an average, the green and blue water footprints of wheat were found to be 227 and 771 m^3/t, respectively, contributing 23 and 77%, respectively, to the total water footprint of wheat.

4.3.7 Performance evaluation of biogas digestate filter systems for drip nutrigation

The Cascade Filter system of a biogas slurry nutrigation system provided higher effluent efficiency of 79.4%, and significant reductions in turbidity (198 NTU) and total solid content (51.2 g/L). It had an adequate slurry storage area of 61.8%, a low filtration rate of 5.1 L m^2 h^{-1} indicating better filtration efficiency.

Cascade filter system for drip nutrigation

4.3.8 Developing operation schedule for basin irrigation system using WinSRFR model

An operational guideline was developed using the WinSRFR model for designing a basin irrigation system as a ready reckoner for farmers to enhance irrigation application efficiency to more than 70%.

4.3.9 Nickel translocation in Ni-spiked waste water irrigated wheat amended with maize residue incorporation

The study showed that wheat yields varied from 3.13 to 4.87 t ha^{-1} and were maximum in plots incorporated with maize residue and irrigated with 2 mg l^{-1} nickel-spiked wastewater. Grain yields obtained with waste water irrigation containing 0, 2 and 5 mg l^{-1} of Ni were statistically equal, however, the grain yield reduced by 19 and 31% at 10 and 20 Ni mg l^{-1} compared to the yield obtained at 2 mg l^{-1} Ni spiking level. Wheat yields were not influenced by maize residue incorporation. Higher levels of Ni in wastewater irrigation resulted in a significant decrease in NPK accumulation but a significant increase in Ni accumulation in wheat. Incorporation of maize residue in soil showed a significant reduction of 21-26% in nickel uptake in wheat compared to no-residue incorporation.

4.3.10 Effect of nano urea on the productivity of wheat under irrigated condition

The spraying of nano or prilled urea with the recommended dose of N was adopted in this study. The highest grain yield (5.62 t/ha) was recorded with 100% N + water spray, which was at par with RDN + two sprays of nano urea, RDN + one spray of nano urea, RDN + two sprays of urea and 75% of RDN + two sprays of commercial urea. However, at lower levels, spray of commercial urea at the rate of 5% resulted in better results than nano-urea although leaf burning was noticed due to the spraying of 5% prilled urea.

4.4. PROTECTED CULTIVATION TECHNOLOGY

4.4.1 Water, nutrient and light interaction study for lettuce crop under greenhouse vertical farming

Different levels of irrigation (60, 80, 100% ET), nutrient and LED light conditions (DLI 8.64-11.5 mol m^{-2} d^{-1}) and (R: B ratio 2:1-4:1) were studied for water-use efficiency, photosynthetic and antioxidant activity of lettuce crop grown in vertical farming. The highest WUE (Pn/E) was observed under a DLI treatment of 11.5 mol m^{-2} d^{-1}. The WUE increased by 38.6% when the DLI increased from 8.64 to 11.5 mol m^{-2} d^{-1}. The photosynthetic rate decreased significantly from the top layer to the bottom layer by 70% for the control treatment. Increasing DLI from 8.64 to 11.5 mol m^{-2} d^{-1} increased the photosynthetic rate by 22%. Total phenolic content of 11.5 mol m^{-2} d^{-1} DLI was significantly higher compared to 14.4 mol m^{-2} d^{-1} and control whereas, vitamin C content was significantly higher in 14.4 mol m^{-2} d^{-1} compared to other treatments. DLI did not affect the antioxidant capacity of lettuce grown under artificial lights.

LED-operated greenhouse vertical farming for lettuce

4.4.2 Design and installation of IoT and sensor-based fertigation setup for greenhouse Capsicum

IoT and sensor-based fertigation setup was designed and installed inside the climate-controlled greenhouse for growing capsicum crops with automation. A fertigation control head with valves, filters, a pressure gauge, a water meter and a series of tanks were installed inside the greenhouse and connected with the fertigation controller.

IoT and sensor-based greenhouse capsicum

4.5 AGRICULTURAL ENGINEERING

4.5.1 Pusa electronic seed metering module (ESMM) for cultivators

The developed ESMM is a low-cost solution for farmers that can be retrofitted with the commonly available secondary tillage implement *i.e.*, cultivator. The hopper and metering system can be stored in a small bag, making it easy for transportation. The developed device can be powered with a tractor battery and can be easily lent to other farmers for sowing/ planting due to its compact and easy design.

4.5.2 Variable swath herbicide applicator (VarSHA)

A VarSHA robot has been developed to control the weeds by spraying herbicide with the robotic arms. The robot can change its swath (1.36 - 2.86 m) in real-

time during operation to match the crop geometry on the field. This feature of the robot makes it more useful than conventional machines like tractors and power tillers.

4.5.3 Tractor Auto-guidance system for critical farm operations

Finite element modeling was proposed to predict vertical vibrations (Z-axis) and frequencies at the different body segments of the seated small tractor operator. The maximum mean forces of the brake (172.8 N) and clutch (153.2 N) were used as the input parameters for the simulation study. The simulated results were validated with the field-measured vertical acceleration values at the operator's selected body segments. The results were compared with the international standards ISO 2631-1 (1985/1997) and ISO 5349-1 (2001) to assess the vibration characteristics at the different body segments of the operator.

4.5.4 Integrated seeder-cum-inoculum applicator for rice-residue management

An integrated seeder-cum-microbial inoculum applicator for in-situ residue management was developed. The machine carries out different operations like cutting, roto-tilling, inoculum application and seeding in one time. The machine is operated by a 50 hp tractor and has a fuel consumption of 6.2 l/h. The field capacity of the machine is 0.34 ha/h

4.5.5 Precision spraying system for microbial inoculum application

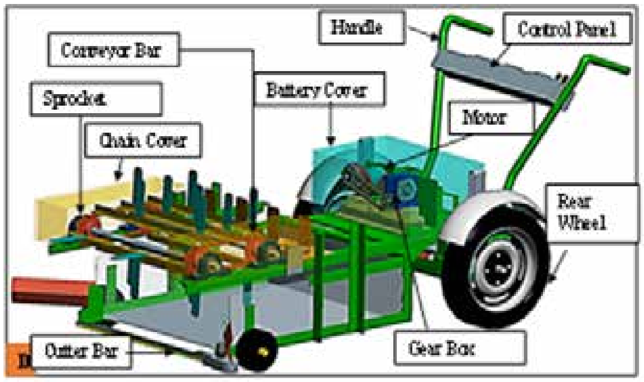
The flood nozzles at different operational parameters like operating pressure (1.5, 2.5 and 3.5 kg/cm^2), nozzle heights (50, 60 and 70 cm) and forward speeds (2.5 and 3 km/h) were evaluated for inoculum spraying. VMD and NMD were observed as 347–243 μm and 77.67–87.8 μm, respectively, whereas droplet density ranged from 252.5–403.9 droplets per square cm. The target-oriented microbial inoculum spraying with a flood fan nozzle accelerates the decomposition kinetics of rice residues.

4.5.6 Robotic pesticide applicator for greenhouse cultivation

A prime mover with a skid-type steering system for easy movement inside the greenhouse was designed. The estimated approximate weight of the mover is 70 kg. The major components of the robots are pneumatic tyres, hard plastic caster wheels, DC motor (Capacity: 350 W, RPM: 120), motor driver (Current and voltage), microcontroller (Atmega328), battery (12 V, capacity: 7 Ah and number: 4), ultrasonic sensor (Range: 2 m), transmitter and receiver (Range: 1 km), camera, display and video receiver (Range: 500 m).

4.5.7 Remotely-controlled harvester for cumin crop

A remote-controlled electronic harvester was designaned for the cumin crop. The harvester is equipped with a 250 W DC motor and can move at a maximun speed of 2.5 km/h. It has a reel to collect the crop in a hopper and a cutter bar is provided to cut the crop at a height of 5 to 15 cm. The harvester's field capacity and efficiency were 0.06 ha per hour and 61.36 percent, respectively.



4.5.8 Assessment of whole-body vibration and mitigation intervention in the tractor-trailer

During transportation, tractor drivers are exposed to vibration, which has significant occupational health problems. Two interventions were developed and attached between the 2 WD tractor and single axle trailer and vibrations were measured with and without interventions at no, half and full payload of the trailer at two terrains (asphalt road and farm terrain). With interventions, the measured vibrations in all three directions and total vibration values were reduced at all speeds and loads. The percentage vibration reduction in the x-axis was higher in all operating conditions, followed by the z-axis and y-axis directions. On asphalt roads, the maximum total vibration reduction was found at 22 km/h with intervention (I_2) as 16.86, 21.12 and 25.51% on no, half, and full payload trailers, respectively.

4.5.9 IoT-enabled devices for custom hiring services

Developed IoT-based custom hiring monitoring meter consisting of an auxiliary fuel tank, oval gear fuel flow sensor, designed PCB board, programming code in Arduino IDE, Cloud configuration setting and developed App based on Sketch programming in MIT App inventor. Sketch-based programming for mobile app development was included for data display design on mobile screens and its block programming code.

Conceptual layout of custom hiring monitoring meter

Fuel sensor and auxiliary plastic fuel tank mounted on the tractor

4.5.10 Attraction pattern studies using light chamber for trapping of white flies, thrips and leaf hoppers

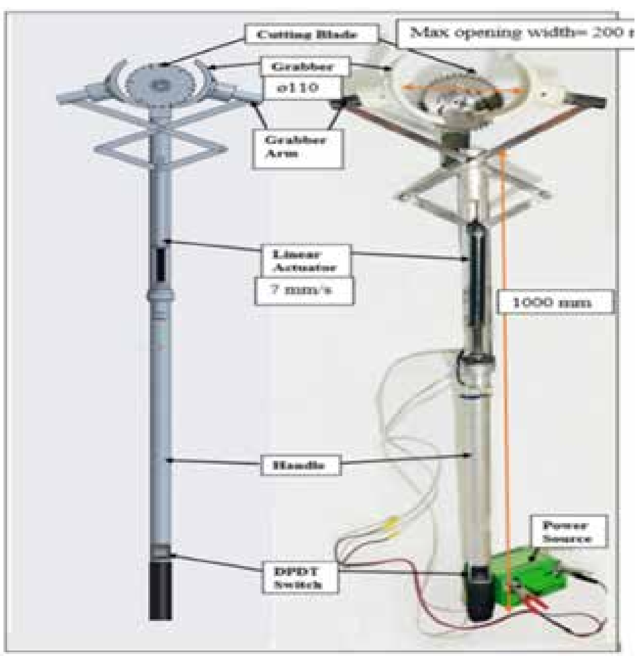
Attraction patterns of whitefly, thrips, and leaf hopper were analyzed using a light chamber to design a smart trap for safe and ecologically sustainable insect trapping. Additionally, the photo-tactic behavioral responses of targeted insects based on their response rate towards light colors were analyzed using L-shaped light chamber. The response rate towards yellow color light was higher for white flies and leaf hoppers and lesser for thrips, whereas the response rate of targeted insects for blue color light was higher for leaf hoppers and thrips and lesser for whiteflies. Similar types of color surfaces using acrylic sheets (yellow and blue) were evaluated in the field against different mounting trap heights. The field evaluation revealed that the trap height should be limited up to 110 cm for efficient insect attraction.

4.5.11 Developing disease severity detection device using spectral characteristics of diseased and healthy tomatoes

Laboratory and field experiments were conducted to assess the spectral characteristics of tomato plants under diseased and healthy conditions. For virus inoculation, 7–8 days old (2-3 fully expanded leaf stage) healthy tomato plant leaves were selected from the whole sample to receive the infection. Disease severity and symptom development were recorded at 48-hour intervals continuously for 30 days. Different machine learning models (SV and DT) were trained, tested and validated for disease severity classification in tomato.

4.5.12 Semi-automatic pineapple harvester

The prototype of a semi-automatic battery-operated pineapple harvester was fabricated for mechanical harvesting. The grabber was cylindrical based on the shape of a pineapple. The inner curved concave surface of the grabber unit was designed by using the maximum transverse diameter of 110 mm ±15 mm for proper holding and positioning of the pineapple fruit's body without disturbing the pineapple's crown. The cutting unit was designed based on the vertical diameter of the pineapple and stalk diameter.



Battery-operated pineappple harvester

4.5.13 Ergonomically compliant e-prime mover with suitable attachments for field and horticulture crops

A small electric 1 kW agri-prime mover was developed consisting of a C-type ladder chassis, 1500W three-phase BLDC motor, controller, power transmission unit, drive wheels, front cover of chassis, handle, accelerator, battery power pack of 48V and 33 Ah, and central hitch for attaching equipment as per operational need. The prime mover can save 1.14 kg CO_2 per h (15 kg CO_2/ha) with a three-time cultivator compared to a 2.25 kW petrol start and kerosene runs lightweight power tiller.

4.5.14 Infrared drum dryer processor

A drum-type dryer/processor was developed for drying fruits and vegetables. It consisted of a rotary drum (43x24 inch) made of galvanized iron supported

Drum dryer for fruits and vegetables

on a mild steel stand. A 12V geared DC motor was used as the driving unit and power transmission through chain and sprocket mechanism. It was fitted internally with 3 infrared bulbs along with a reflector. Internal flippers were provided for agitation of material and a 12x8 inch rectangular outlet was provided for unloading dried material.

4.5.15 Oil extraction technology from black cumin seed

An eco-friendly and cost-effective ohmic-assisted extraction technology (OAE) was developed from enzymatically hydrolyzed black cumin seeds. Different unit operations were involved in the extraction process and the process variables using response surface methodology (RSM) for maximizing oil yield were standardized. The goal-based multiple response optimization of the selected independent variables was done using RSM.

4.5.16 Solar-powered/battery-operated harvester for leafy vegetables

Solar powered/battery-operated harvester was designed and developed for leafy vegetables consisting of a cutting and conveying mechanism; adjustable reel (suitable for different crop heights) and propelling unit of the harvester (350 watt, 24 V DC motor). The selected leafy vegetables' engineering properties and crop geometry (spinach, fenugreek, and coriander) were determined. The harvester was operated by a 24 V- 350W DC motor.

4.5.17 Solar-powered on-farm cold storage system

A farm SunFridge was built at village Cullakpur, Delhi in which temperature and RH data was retrieved from the cloud at https://dashboard.hobolink.com/public/Farm%20SunFridge%20Cullakpur%20Delhi. The data from the farm Sunfridge at IARI, Pusa was also uploaded to the cloud and can be accessed at https://dashboard.hobolink.com/public/Farm%20SunFridge%20IARI%20PUSA%20Delhi. The modified Cullakpur SunFridge differs from the previous ones as it was built using prefabricated iron frames at the farm site.

4.6 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

4.6.1 Post-harvest ultraviolet-C treatment enhance shelf-life and quality of bitter gourd

Freshly harvested immature bitter gourd fruit were precooled to room temperature and exposed to UV-C treatment in a closed chamber [60 cm (W) × 100 cm (L) × 40 cm (H)] equipped with a germicidal tube (UV 25 W; 451.6 mm length; 28 mm diameter/ T8, Philips, Poland) emitting radiation at 253.4 nm wavelength for 40 minutes. Before its use, the UV chamber was stabilized for UV-C dose by keeping it on for 15 minutes. UV-C treatment for 40 minutes helped to maintain firmness, reduce weight loss and decay of stored bitter gourd fruit up to 16 days of storage at 10°C temperature and 85-95% relative humidity.

Comparative appearance of control (A) and UVC treated (B) bitter gourd on 16th day of storage.

4.6.2 Hot water-mediated pesticide residue reduction in apple

Pesticide residues in apple fruits were measured by LC-MS/MS after hot water treatment (HWT; 48, 50, 52 and 54°C) during cold storage. Increasing HWT temperature and duration yielded a significant reduction in residues (90-98%) in the processing factor. Azoxystrobin, and hexaconazole degraded at a lower rate than dithianon, difenoconazole, carbendazim and tebuconazole following first-order kinetics. Malathion and dimethoate dissipated completely upon HWT, while chlorpyriphos and thiacloprid dissipated at a lower rate. Thus, HWT of apple at 48°C/5 min and 50°C/2 mins yielded acceptable quality fruits and maximum reduction in fungicide residues.

4.6.3 Development of overripe banana-based puffed snacks

Overripe banana-based puffed snacks were developed via extrusion technology, and the concentration of dried overripe banana, water input rate, temperature, and screw speed were optimized. The process parameter comprising 26% banana flour with 200 rpm screw speed and 16% feed moisture was reformulated and validated. The developed snack is a source of dietary fiber with a sweet tinge of overripe banana flour and low-fat content. It can be categorized as a 'Fat-Free Snack' with 0.13 g fat per serving (RACC-20 g).

Overripe banana based puffed snack

4.6.4 Functionalization of pea pod powder for its inclusion in noodles and baked product

Pea pod powder was functionalized to be used as a major ingredient in instant noodles for partial replacement of refined flour. Extruded pea pod powder demonstrated increased disulfide bonding that contributed towards improvement of instant noodles. A 10% replacement of refined wheat flour with functionalized pea pod powder was optimized to ensure the end product's improved fiber and nutritional status without significantly affecting the sensory properties.

Noodles before pan frying

Fortified muffins incorporating pea pod powder were developed using response surface methodology. The optimized muffin formulation of 18% flour replacement with pea pod powder resulted in muffins rich in dietary fiber (13.78%) and protein (8.94%). Muffins remained free from microbial contamination in polypropylene packs up to 9 days of ambient storage (23±5°C) with good organoleptic acceptability.

Pea pod powder fortified muffins

4.6.5 Nano-cellulose-based edible coating on kale leaves

Nano-cellulose was extracted from rice husk following a chlorine-free method. Further, an edible coating was made out of the extracted nanocellulose. PLW of control and coated kale leaves was 5.18 and 5.38%, respectively, at the end of the 7 and 10th day of storage. Chlorophyll content of control and coated kale leaves varied from 55.04 to 5.14 SPAD unit and 55.06 to 28.74 at the end of storage. The respiration rate of control and coated kale leaves varied from 17.03 to 89.33 mL CO_2 kg^{-1} h^{-1} and 6.02 to 54.27 mL CO_2 kg^{-1} h^{-1}, respectively.

Nanocelluose base edible coated kale leaves

4.6.6 Preparation of gluten-free multi-millet pasta

Minor millets were used individually and in combination to prepare pasta which had low (<6% of FSSAI norms). The use of malted millets for pasta enhanced nutritive value and bioavailability and facilitated better functionality for pasta making process. The RVA profile differentiated the cooking profile of malted millets over other treatments. Higher firmness, expansion and lower leaching loss was recorded with malted grains. GRAS approved hydrocolloid mixture was used to improve texture and cooking quality. The developed pasta was found to be nutritionally superior to semolina pasta in terms of micronutrients (calcium, iron and zinc) and lower glycemic index (25-30.5) while being acceptable in cooking quality and taste. Further, moringa leaves and beetroot juice were used to enhance visual appeal besides improving antioxidant and nutritional values.

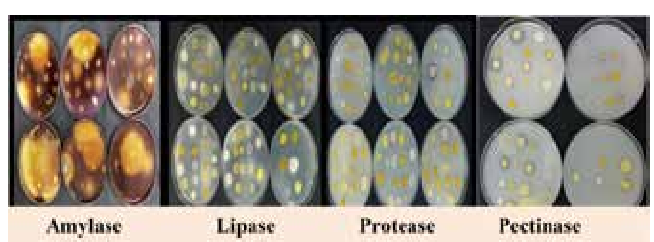
Moringa leaves incorporated pasta

Beetroot juice incorporated pasta

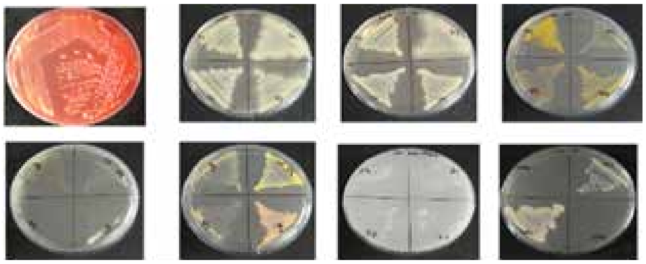
4.7 MICROBIOLOGY

4.7.1 Microbial strategies for abiotic stress tolerance

Drought tolerant cyanobacterial strains, *viz.* *Anabaena* sp. (SGR4, SGR7), *Nostoc* sp. (SGR1, SGR3, SGR12), *Neowestielliopsis* sp. (SGR8), *Calothrix* sp. (SGR5, SGR11), *Fischerella* sp. (SGR16), *Hapalosiphon* sp. (SGR2) were characterized for PGP traits e.g. ammonia release, IAA production, nitrogenase activity, EPS production at 10% PEG concentration. Cyanobacterial biofertilizer strains (*i.e. Nostoc muscorum, Anabaena variabilis, Aulosira fertilissima, Tolypothrix tenuis*) were evaluated for tolerance towards atrazine. It was observed that *Tolypothrix tenuis* was most tolerant while *Anabaena variabilis* was most sensitive. Pearl millet seed endophytic bacteria (124) from plants grown in diverse environmental conditions across three agro-climatic zones exhibited PGP traits: IAA, ammonia siderophore production, K, Zn and P solubilization and production of hydrolytic enzymes. More than 70% isolates could grow in presence of 30% PEG 6000 and best isolates evaluated through pot study led to enhanced plant biomass, chlorophyll content, RWC and MSI.



Potential of seed endophytic bacteria to exhibit PGP traits and produce hydrolytic enzymes



Isolation of nodule associated bacteria from lentil genotypes

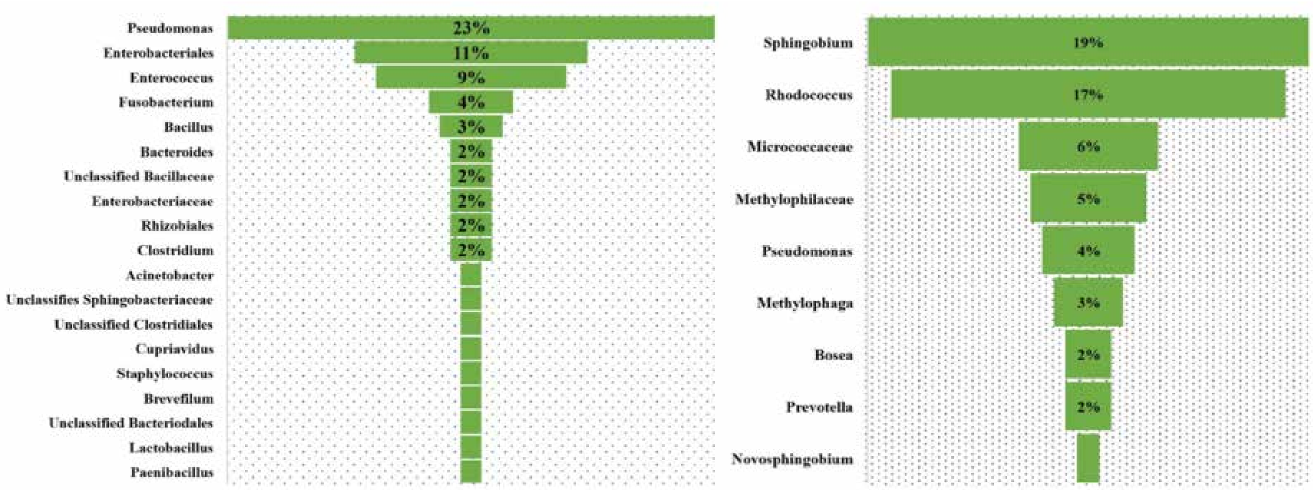
Nodule-associated bacteria (38) isolated from 6 different lentil genotypes with contrasting nodulation and drought tolerance were screened for their drought resilience by growth on media containing PEG. Actinobacterial isolates (40) purified from exo- and endo-rhizosphere of rice were screened for salt (NaCl) stress tolerance. Six potential isolates identified through 16S rRNA gene sequencing were *Kitasatospora* sp., *Streptomyces tritolerans*, *Streptomyces* sp., *S. mutabilis*, *S. tendae* and *S. mediolani*. Seed inoculation effect of these isolates evaluated using different *in plant* experiments under salt (150 mM NaCl) stress, showed significant improvement in seed germination, growth, root architecture, with increased free proline accumulation and total antioxidant content in the rice-leaves.

4.7.2 Nutrient management using microbes under changing climate

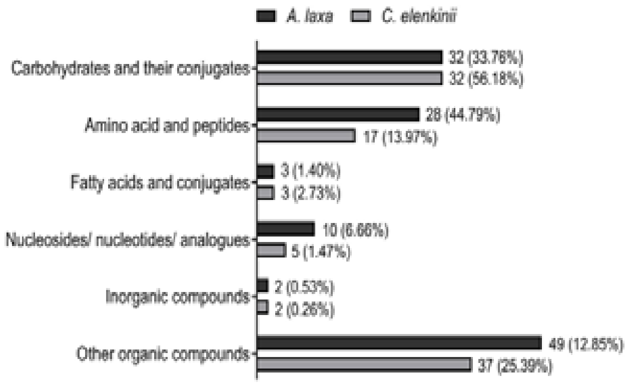
Arbuscular Mycorrhizal fungi (AMF) associated with genotypes of *Zea mays* L. in semi-arid field condition in alkaline (pH 8.5-9.2) and moderately alkaline (pH 7.5-8.5) soil were investigated and 10 species belonging to the genera *Acaulospora, Cetraspora, Entrophospora, Funneliformis, Glomus*, and *Rhizophagus* were found at higher diversity. Root colonization correlated positively with available N, organic C and with Zn, Mn with spore density.

Microbiome associated with the dominating AMF spores in wheat and maize was evaluated. Best P-solubilizers (30 of a total of 151) were screened for other PGP activities, and the three best isolates (G1, NSS22, OSS8S) were identified as *Pseudomonas aeruginosa*, *Bacillus licheniformis* and Bacillus hypnosis, respectively. Diversity analysis of bacteriome strictly associated with spores and hyphae of *Rhizophagus irregularis* using Illumina sequencing approach showed *Pseudomonas* as the dominant genus associated with spores and *Sphingobium* and *Rhodococcus* as dominating genera with hyphae.

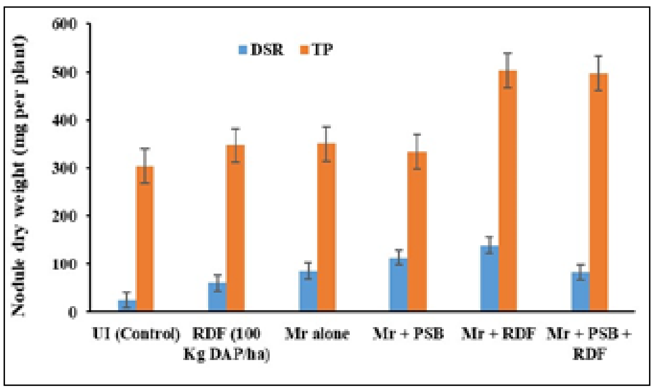
Untargeted metabolite GC-MS based profiling of two agriculturally beneficial cyanobacteria (*Anabaena laxa*, and *Calothrix elenkinii*) illustrated the presence of three chemical classes *i.e.* amino acid and peptides, nucleotides, nucleosides and analogues. In addition to other organic compounds, lactose was the most predominant metabolite. Pathway analysis showed that both *A. laxa*, and *C. elenkinii* were enriched in metabolites involved in aminoacyl-tRNA biosynthesis and amino acid metabolism pathways.



Relative abundance of bacterial genera associated with (a) spores and (b) and Hyphae



Metabolites identified of *A. laxa* and *C. elenkinii*

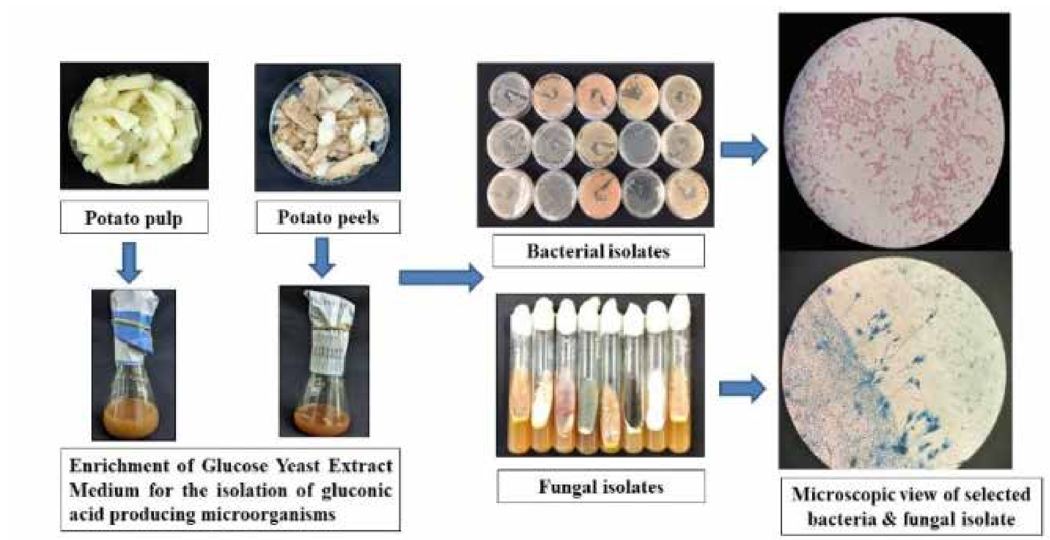


Interactive effect of microbial inoculation and rice cultivation systems on nodulation and growth of chickpea at flower initiation stage

The effect of inoculating native mesorhizobial population on growth and symbiotic response of chickpea (cv. BG 372) grown after rice in soils collected from transplanted rice (TP) and direct seeded rice (DSR) was evaluated. Combined inoculation recorded increase in nodulation in TP and DSR soil as well as better N and P uptake, and better synergy *w.r.t.* growth and yield of chickpea in TP soil.

4.7.3 Harnessing the potential of micro-organisms for conversion of farm waste to wealth

Efforts were made to improvise Pusa Decomposer for low temperature decomposition by qualitatively screening microbial isolates for cellulase, xylanase, silicase, laccase activity at 15°C. Among 14 psychrotolerant isolates, LTF 21 outperformed with respect all enzymatic activities. Field experiment to evaluate the effect of Pusa Decomposer on decomposition of paddy straw was carried out during winter (*rabi*) 2022-23 with four treatments. Urease, dehydrogenase and alkaline phosphatase activity increased with the use of Pusa Decomposer compared to control, corroborating with the rate of decomposition



Isolation and characterization of gluconic acid producing microorganisms from potato waste

of paddy straw. Both Pusa Decomposer forms (liquid and powder), were evaluated in farmers' fields in various villages of Haryana, Punjab and Delhi.

4.7.4 Value addition using microbes

Interaction between NaCl x light duration significantly affected carotenoid content in a promising cyanobacterial strain. For biomass production, low phosphate and nitrate concentration were favourable, however, for carotenoid content, low nitrate and high phosphate together with 25 mM NaCl, 3000 Lux light intensity for 24 h light duration and 40°C temperature led to maximum carotenoid content.

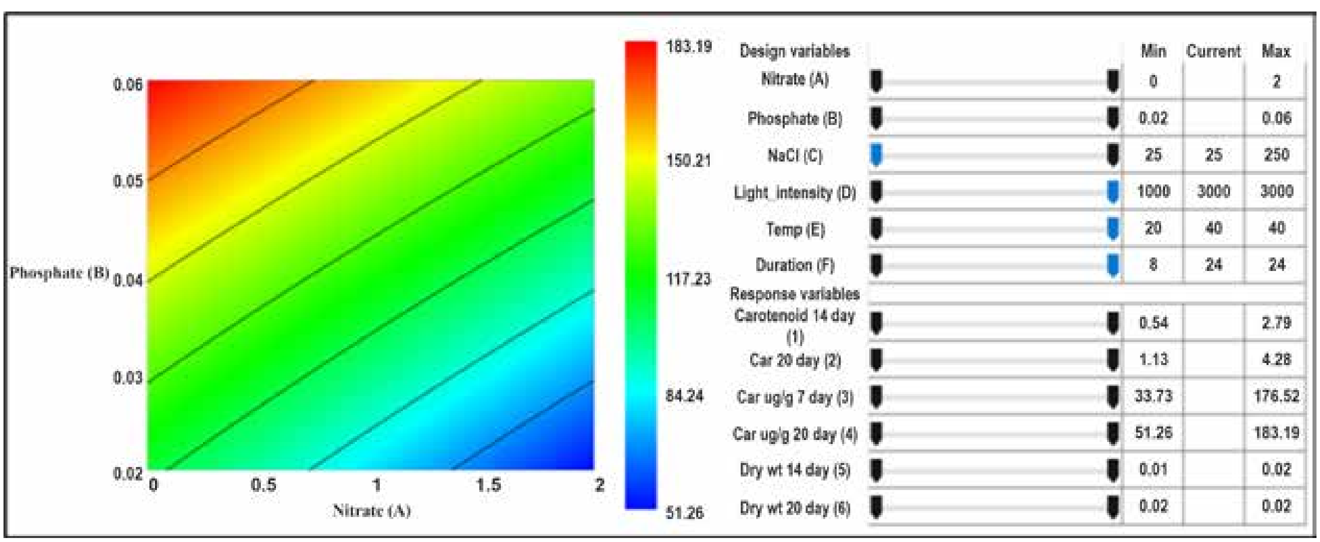
Oscillatoria sp. BTA-170 grown in a photobioreactor for 15 days, yielding 3.1 g/L of biomass was investigated for tray drying properties at different temperatures with constant air velocity of 0.6 m/s. To reduce the moisture content of biomass from 83.27% to <10%, drying time required 2, 12, and 30 h at 80, 60, and 40°C, respectively.

Screening and characterization of potential microorganism for gluconic acid production from diverse agri-horti residue (fruit waste, potato waste, paddy straw) was undertaken. Titrable acidity increased in all, but only 14 bacteria and 17 fungi were positive for acid production, while 9 bacteria and 18 fungi formed clear zone.

4.7.5 Novel bacteria-based bio-inoculants and delivery system for crop nutrient management

Based on PGP attributes and biocontrol activity against *P. infestans,* phyllospheric bacterial isolates were selected for pot evaluation in tomato and brinjal by seed and spray inoculation (at 3 stages). Significant improvement in vegetative parameters over control was recorded in Phytotron experiment, and based on compatibility studies a consortium of 5 isolates is being developed. The PGP potential of rhizobacteria associated with aquatic plants was investigated and a total of 60 bacterial colonies were purified. *In vitro* characterization showed solubilization of K, P and Zn, with majority of isolates producing IAA and ammonia. *In vitro* seed germination assay revealed the promise of inoculation on lettuce and tomato seedlings and with tomato crop in soilless medium.

The addition of phytohormones and phenolic compounds (*viz*., IAA, NAA, BAP, catechin, and coumarin) *in vitro* establishment of mycorrhiza in Ri T-DNA transformed carrot roots enhanced AM inoculum produced over control. Maximum AM fungal colonisation of 88.2% and root biomass increment were recorded with combination treatment of BAP+IAA+NAA and catechin than their treatments in solo.



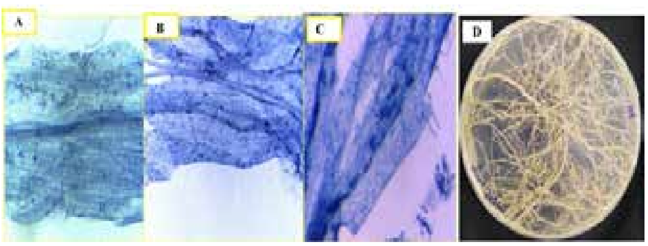
Contour plot illustrating Carotenoid content (μg g^{-1}) of a promising cyanobacterial strain after 28 days of growth

(a) (b) (c)

PGPR activity of bacteria isolated from aquatic plants (a) Solubilization of P, K, Zn, (b) seed Bioassay and (c) Effect of bacterial inoculation on the root growth of tomato in soil less medium

4.7.6 Novel consortium for climate resilience

The sugar utilization patterns of 30 methane-oxidizing bacteria and 4 cyanobacterial isolates were studied to develop a common growth medium. AMS and BG11 media (1:1), along with 0.2% of methanol was finalized as the optimized medium. Two cyanobacteria and 3 methane-oxidizing bacteria were selected for further investigation in rice cultivation to reduce methane emission.



Proportion of AM fungal colonization in Ri T-DNA transformed roots under the influence of (a) inoculated control, (b) catechin (85.4%), (c) BAP+IAA+NAA (88.2%); (d) Biostimulant assisted AMF-ROC dual culture 45 d old *in vitro*

4.7.7 Functional importance and translational applications of microbiomes for crop productivity

Differential expression analysis revealed significant changes in the expression patterns of N cycling genes with maximum differences observed between rhizospheres of acidic and alkaline soils. Seven nitrogen-fixing genes (*nifB, nifD, nifE, nifH, nifU, nfs1,* and *vnfA*) were rhizosphere-active, with *nifH* exhibiting 6 to 75 folds higher activity in the rice rhizosphere of acidic soil than those of neutral and alkaline soils. Similarly, genes of GS-GOGAT pathways were highly upregulated in the rhizosphere of acidic soil with 5 to 41% higher transcriptional activity. Urease enzyme was mainly produced by *Actinomadura madurae, Alicycliphilus denitrificans, Burkholderia vietnamiensis, Variovorax sp., Sorangium cellulosum,* and *Vitreoscilla filiformis.*

4.8. ENVIRONMENT SCIENCE

4.8.1. Climate change impacts, adaptation gains, GHG emissions, global warming potential and GHG mitigation in rice-wheat cropping system in the Indo-Gangetic Plains

4.8.1.1 Creation of CMIP6 climate change scenarios over India for agricultural seasons

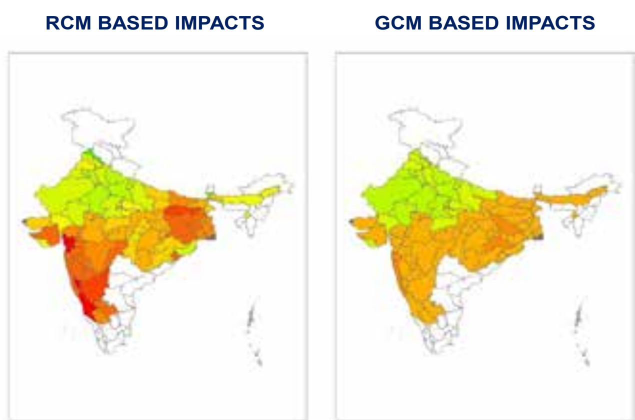
The surface (2 m) daily data on temperature (min, max), precipitation, solar radiation, windspeed, etc. were downloaded from the Earth System Grid Federation (ESGF) source for the CMIP6 23 Global Climate Models (GCMs). The data has a spatial resolution ranging from 1°x1° to 5°x5°. All these data are being processed to re-gird the data to IMD observed data spatial scale for further identification of bias and correction to develop the Ensemble data. This will be used for impact and adaptation assessments.

4.8.1.2 Identification of vulnerable districts/ ACZs for adaptation prioritization-wheat 2030-RCP 4.5

The impact of climate change on wheat productivity in RCP 4.5 was analysed agro-climatic zone-wise. The crop models (InfoCrop, DSSAT and APSIM) based analysis indicated that in RCP 4.5 2030 scenario (2010-2039), impacts are projected to be more in Regional Climate Model Scenarios as compared to Global Climate Model Scenarios. The agro-climatic zones in the eastern, north eastern, central and south central are more vulnerable to climate change as far as wheat productivity with current management is concerned.

The analysis indicated that number of districts in Punjab projected to be vulnerable with current managements are three under RCM climate scenarios of RCP 4.5 in 2020s and 2030s as compared to one district under GCM similar climate scenarios. Similarly, in Haryana, the number of vulnerable districts is 6 and 3 under RCM and GCM RCP 4.5 climate scenarios in 2020s and 2030s.

Similar analysis indicated 35 and 32 districts of Madhya Pradesh vulnerable under RCM and GCM RCP 4.5 climate scenarios in 2020s and 2030s. In Uttar Pradesh, such number of districts are 33 and 28, respectively. The number of vulnerable districts with current management are projected to significantly increase in RCP 4.5 climate scenarios of 2050 and 2080.



Impact of climate change on wheat productivity in different agro-climatic zones

4.8.1.3 Simulation of methane emission from direct-seeded rice fields

A simulation analysis using the calibrated and validated InfoCrop rice model (v2.1) was done for the methane emission from direct-seeded rice (DSR) fields under different management and agro-climatic conditions in India. The simulation was performed for 30-year period in 146 locations in India. The results indicated that methane emission from DSR fields ranged from 1.5 to 4.7 kg/ha.

4.8.2 Emission factor of nitrous oxide in sugarcane, blackgram and potato cultivation

The emission of nitrous oxide (duration of 337 days) ranged from 0.61 kg N_2O-N/ha with control to 2.17 kg N_2O-N/ha under 200 kg NCU-N/ha treatment. The applied N lost as N_2O ranged from 0.75 to 0.78% under the different NCU treatments which was lower than the IPCC default emission factor (EF) of 1%. The blackgram cultivar TAU1 was grown with the application of 25 kg N/ha. The emission of nitrous oxide during the crop growth period was observed to be 598 ± 21 g N_2O/ha resulting in an EF of 0.49% of N_2O-N. Potato variety Kufri Bahar 3797 was grown with the application of 150 kg N/ha through neem coated urea (NCU) and sulphur coated urea (SCU). The nitrous oxide EF ranged from 0.412 to 0.448% N_2O-N under the different fertilized treatments. The application of PG did not have any effect on N_2O emission, however, the potato yield increased by 4.8%.

4.8.3 GHGs mitigation in rice wheat system using slow-release fertilizer

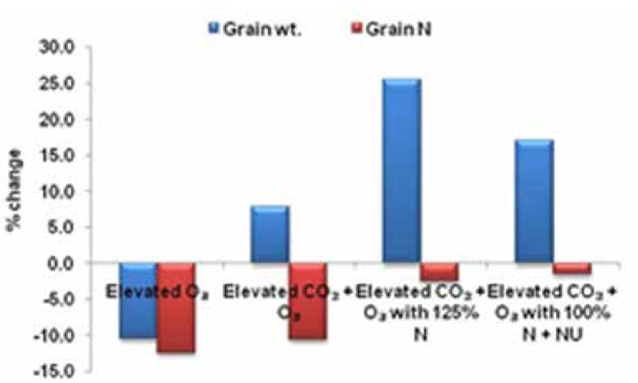
Field experiments with rice (var PB 1509) and wheat (var HD 2967) under N fertilizer treatments were conducted to study their impact on greenhouse mitigation and crop production. The treatments included Control (no N), neem coated urea (NCU) and resin coated urea (RCU) as slow release fertilizer. Rice grain yield varied from 2.8 to 4.95 t/ha and wheat grain yield varied from 2.83 to 4.89 t/ha among the different N treatments. The grain yield in NCU and RCU treatments were at par in both rice and wheat crops. The use of resin coated urea could reduce the methane emission by 8.4% compared with NCU in rice. The emission of N_2O was reduced by 11.3% in rice and 10.6% in wheat.

4.8.4 Emission of air pollutants and GHGs from rice residue burning in North-west India

Emissions of GHGs and air pollutants due to burning of rice residues in districts of Punjab were quantified based on real time monitoring of area under residue burning. In 2022, ~70 % of rice stubble was burnt in the districts of Punjab compared to 54.4% in 2021. Of the total biomass generated, ~63% was burnt on farm and ranged from 27% in SAS Nagar to 92% in Barnala. Rice stubble burning in districts of Punjab resulted in emission of 24.19 m tonnes of GHGs (CO_2 eq), 1.74 m tonnes of air pollutants (CO, NMVOC, SO_x & NO_x) and 0.28 m tonnes of PM ($PM_{2.5\ \&10}$) during the year 2022.

4.8.5 Interactive effect of elevated ozone (O_3) and carbon dioxide (CO_2) on wheat

An experiment was conducted in Ozone-FACE facility at IARI to study the interactive effect of elevated O_3 and CO_2 on wheat crop. Grain yield of wheat significantly reduced in elevated O_3 treatment while in elevated O_3 and CO_2 interaction treatment, the yield loss was compensated. The quality of wheat grain in terms of grain N concentration was reduced by 10.6% than ambient CO_2 treatment. Application of additional nano urea spray improved grain N concentration but it was still lower (1.5%) than ambient.



Response of wheat to elevated O_3 and CO_2 interaction

4.8.6 Impact of elevated ozone, carbon dioxide (CO_2) and their interaction on pollination ecosystem services in Indian mustard

The study was aimed at quantifying the impacts of elevated O_3 (65±10 ppb) and CO_2 (550±10ppm) with interaction (O_3*CO_2) on pollination ecosystem services of Indian mustard under free air ozone enrichment (FAOE) and free air CO_2 enrichment (FACE). The pistil metabolomics revealed that sucrose, sulfur metabolism and amino acids declined in elevated O_3 and CO_2 resulting in reduced pollinators' attraction towards mustard flowers. The colour intensity of flowers also declined in eO_3 which affected the foraging rate of pollinators in elevated O_3, CO_2 and interaction. The stigma was receptive for a maximum of 4 days in eO_3, 5 days in eO_3*CO_2, 6 days in eCO_2 and 7 days in ambient. Under eO_3, pollen was viable till 3 days with fewer numbers and in eCO_2 and eO_3*eCO_2 viable pollens thrived till 4 days. The total antioxidant capacity of pollen and pistil was high in eO_3>eO_3*eCO_2>eCO_2.

4.8.7 Establishing village resource centers for building climate resilience of farming communities

Pusa Kisan Vikas Samiti was formed with 35 farmers to manage the interventions in the adopted village Dohari in Gaya (Bihar). Similarly, a village resource centre committee is formed at Hadai village of Chandouli district, UP. Village resource centres-managed custom hire system was also established. The farmers can have access to farm machineries like laser leveller, rotavator, seed drills, sprayers, sprinklers, raingun, threshers, etc in these two villages. Farmers Recource Centre under Scheduled Caste Sub Plan (SCSP) of NICRA project in Bairgarh village Hadai of Block Naugarh Block in Chandauli District will also provide farm implements such as rotavator, seed cum fertilizer drill, chaffcutter, raingun, mini sprinkler, zero till seed cum fertilizer applicator, cultivator and Pusa-STFR to the farmers.

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 chemical molecules were identified to form a part of integrated management. Identification of resistant sources will certainly help breeders develop insect pest and disease-resistant varieties.

5.1 PLANT PATHOLOGY

5.1.1 Disease diagnosis and pathogen characterization

Maintenance of fungal cultures and disease specimens: Fungal cultures (4160) were maintained at the Indian Type Culture Collection in the Division. About 50,600 disease specimens were preserved. A total of 325 authentic fungal and bacterial cultures were supplied on request to various scientific and industrial institutions. Fungal cultures (184 nos.) were identified and 10 cultures were given accession numbers.

Virus indexing services: Virus indexing and certification have been carried out for banana, potato, gerbera, and sugarcane samples.

Characterization of SIX genes in *F. oxysporum* f. sp. *pisi*: Four secreted in xylem (SIX) effectors, SIX11, SIX13, SIX6, and SIX2 were identified in Indian races. The conserved nature of the SIX genes within *forma specialis* showed similarity with *F. oxysporum* f. sp. *pisi.*

Characterization of mycelial compatibility groups (MCGs) in fifty *Sclerotium rolfsii*: Fifty *Sclerotium rolfsii* isolates were categorized into 10 MCGs.

Diversity and cross infectivity of *Bipolaris sorokiniana* inciting spot blotch of barley: Forty-five *Bipolaris sorokiniana* isolates collected from different hot spot locations of Uttar Pradesh and Bihar were characterized (NCBI *GenBank* accessions OR262899-OR262943). The *B. sorokiniana* isolate of barley was less virulent in wheat and B. sorokiniana isolate of wheat was highly virulent in barley.

Isolation and characterization of aflatoxigenic *Aspergillus* spp. from maize: Forty *Aspergillus* isolates collected from 12 states of India revealed that AF-11, AF-14 and AF- 20 produced higher levels of aflatoxin.

Characterization of fungi associated with post flowering stalk rot (PFSR) in maize: Of the 55 maize stalk samples exhibiting symptoms of PFSR, 18 were identified as *Macrophomina phaseolina*, 30 as *Fusarium* spp. and four as *Lasiodiplodia* spp.

Characterization of bakanae pathogen *Fusarium fujikuroi* pathotypes: A total of 15 pathotype groups were identified among 97 isolates of *Fusarium fujikuroi*.

Development of LAMP-based detection method for *Magnaporthe* spp. and *S. sclerotiorum*: A Loop-mediated isothermal amplification (LAMP) was developed for detecting *Magnaporthe*. The detection limit of this assay was 0.4 fg μl^{-1} of genomic DNA per reaction.

Identification of citrus tristeza virus (CTV) mild strain for cross-protection of decline strain in Khasi mandarin of NE India: Codon usage bias (CUB) analysis indicated that citrus tristeza virus (CTV) isolates (50) collected from Assam might be mild strains.

Appearance of cotton leaf curl disease (CLCuD) begomovirus variants cause higher disease incidence in cotton growing areas of NW India: A survey in North-western India revealed that the disease incidence due to variants of cotton leaf curl Multan virus (CLCuMuV) was 67.3%.

An isothermal RT-RPA assay for detecting citrus yellow vein clearing virus (CYVCV): An RT-RPA assay was developed to detect CYVCV from both RNA extract and crude saps. This assay has higher sensitivity than the conventional RT-PCR. Further duplex RT-PCR was also developed for the detection of CYVCV and CiYMV.

First report on fenugreek phyllody: The prevalence of fenugreek phyllody was reported among 146 germplasm accessions of fenugreek at NBPGR research farm, Jodhpur. The phytoplasma belonged to 16Sr group I ('*Ca. P. asteris*') and subgroup B. This is the first report of fenugreek phyllody caused by the 16SrI-B subgroup worldwide.

First report of pea witches' broom in India: Survey of pea fields at National Seed Corporation Farm, Hisar, Haryana showed the prevalence of witches' broom disease of pea: This is the first report of phytoplasma 16Sr I-B group associated with this disease in India and worldwide.

On-site detection of the chili leaf curl virus: A CRISPR-Cas12a-based lateral-flow-based dip-stick assay was standardized, and a kit was developed for on-site detection of the chili leaf curl virus using crude leaf extract.

5.1.2 Host-pathogen interaction

Genome-wide identification and characterization of Cytokinin-O-Glucosyltransferase (CGT) genes of rice specific to potential pathogens: In a genomic identification of rice CGTs, 41 genes with the plant secondary product glycosyltransferases (PSPG) motif of 44-amino-acid consensus sequence characteristic of plant uridine diphosphate (UDP)-glycosyltransferases (UGTs) were identified. 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*, *Xanthomonas oryzae* pv. *oryzae* and *Magnaporthe oryzae*.

Elucidation of the role of miRNA in *Magnaporthe* rice pathosystem: During the *Magnaporthe* invasion, 70 unique miRNAs were identified in the resistant, and 106 were identified in the susceptible rice variety. A miRNAChr10_39610, which modulates the mRNA surveillance pathway, was also identified.

Development of CRISPR-Cas based management strategy against papaya ring spot virus: The efficacy of seven Cas13a constructs targeting HC-Pro, CP, VpG, and NIa regions in PRSV genome was evaluated through agroinfiltration and subsequent challenge of PRSV in squash, an alternative host of PRSV. The qRT-PCR assay indicated reduced accumulation of viral RNA after seven days. A booster dose of crRNA-Cas13a provided more protection than a single module.

On-site diagnostic kit for chilli leaf curl virus

Relative expression of PR genes in wheat challenged with *Puccinia triticina*: Relative expression of some pathogenesis-related (PR) genes revealed increased PR gene activities at one-day post-inoculation (dpi) in Resistant (C 306 + Lr28) as compared to susceptible (C 306 - *Lr*28) genotype.

5.1.3 Genomics and transcriptomics

Improved genome sequencing of *Tilletia indica* (Karnal bunt of wheat): The HiC sequencing of *Tilletia indica* generated 22.27 gb data with 659x coverage. The genome assembly size was 33.87 Mb with 469 scaffolds.

Genome sequencing of *Bipolaris maydis*: Whole genome sequence analysis of *Bipolaris maydis* was done, and the genomic data was submitted *via*. GenBank vide SRA: SRR19262264, SRR19262263.

Whole genome sequence of *Alternaria brassicae:* Whole genome sequence of two isolates of *A. brassicae* causing disease in *Brassica juncea* was done, and genome data was submitted to the NCBI-SRA database (PRJNA880459 and PRJNA880453).

Whole genome sequencing of *Penicillium oxalicum:* Whole genome sequencing of *Penicillium oxalicum* isolate UV4 was performed and submitted to the NCBI-SRA database (PRJNA70227).

Genome-wide mining and characterization of *NBS-LRR* candidate genes in finger millet (*Eleusine coracana* L.) for foliar blast resistance: The genome-wide scanning of the finger millet genome resulted in 116 nucleotide binding site leucine-rich-repeat (*NBSLRR)* genes. The expression analysis revealed the role of target *EcNBLRRs* in Finger millet-*Magnaporthe grisea* interactions at early and late infection stages.

Association of a begomovirus and beta-satellite with leaf curl disease of bell pepper: Full-length genome sequences of two isolates of begomovirus (OQ442224 and OQ442225) and the beta-satellite associated with leaf curl disease of bell pepper identified as tomato leaf curl Bangladesh beta-satellite (ToLCBDB).

Virome profile of Indian grapevine rootstocks: High-throughput sequencing (HTS)-based virome analysis of Indian grapevine rootstocks revealed the infection of three viruses: grapevine rupestris stem pitting associated virus: GRSPaV, rupestris stem pitting associated virus: RSPaV, and grapevine virus B: GVB) and five viroids.

Pear virome analysis revealed the expanded host range of rubod and ilar virus: Virome analysis of pear samples of Himachal Pradesh reports for the first time, the infection of a rubodo (ARWV-1) and an ilarvirus (ApNMV) from pear trees.

Virome analysis of citrus (Kinnow mandarin): CiYMV in Kinnow mandarin is being reported for the first time in India.

Virome analysis of Plum: Virome analysis of plum samples collected from Jammu and Kashmir and Himachal Pradesh identified the infection of prunus necrotic ring spot virus (PNRSV), American plum line pattern virus (APLPV) and apple chlorotic leaf spot virus (ACLSV), little cherry virus 1(LChV-1), plum bark necrosis stem pitting-associated virus (PBNSPaV) and hop stunt viroid (HSVd).

5.1.4 Disease epidemiology

Climate change impact on false smut in rice: Thermal index f (T) as an indicator of *U. virens* growth rate has been developed. Climate change impact due to temperature rise indicates a likely increase in false smut incidence in the *kharif* season.

Early detection of leaf curl virus infection in chilli- through RGB/Thermal infrared sensors: Early detection of leaf curl infection eight days after inoculation with 80.0 and 86.5% accuracy levels based on k-Nearest Neighbors and Naïve Bayes classifiers was optimized through Thermography.

5.1.5 Host plant resistance

Wheat: Race-specific adult plant resistance in AVT wheat materials (77) revealed that some of the genotypes, *viz*., HD 3349, PBW 826, PBW 876, DBW 313, PBW 826, WH 1283, HD 3354, HI 1654, HD 3368, HD 3368, HD 3368, HD 3360, HI 1653, HD 3360, HD

3368, HD 3368, PBW 848, HD 3369, K 1317, UP 3062 possess high degree of resistance to both virulent stripe rust (46S119, 110S119) and leaf rust (77-5) pathotypes. The IARI-CVT entries *viz*. IARI 20-66, IARI 20-67, IARI 20-78, IARI 20-79, IARI 20-91, IARI 20-119, IARI 20-129, IARI 20-132, IARI 20-133, IARI 20-148, IARI 20-151, IARI 20-153, IARI 20-158, IARI 20-164 and IARI 20-165 were found resistant to all the rusts at seedling stage across the test locations.

Evaluation of a set of AVT lines (137 lines) and MDSN lines (38 lines) received from IIWBR, Karnal revealed that eight genotypes *viz*., IC 535470, IC 73595, IC 082302, IC 573145, IC 356111, IC 279825, IC 138554, IC 273946 were identified as slow blighting. Evaluation of 238 wheat germplasm against Karnal bunt (KB) of wheat under artificial inoculation conditions showed that 53 genotypes were resistant.

One hundred ninety accessions of barley were screened against spot blotch of barley; three accessions (EC0328964, IC0393134, IC0446132) were resistant and five accessions were moderately resistant (EC0492255, EC0492140, EC0578947, IC0372268 and IC0247772), 14 moderately susceptible, 128 were susceptible and 40 were highly susceptible.

Advanced breeding lines of wheat (497) were evaluated against Karnal bunt disease. One hundred fifty-two genotypes were resistant, 96 genotypes were moderately susceptible, 89 were susceptible, and 29 were highly susceptible.

A total of 100 exotic wheat germplasm (PG-Parent genetic pool, GS-Genomic selection genotype of CIMMYT-BISA, CIMCOG-CIMMYT Mexico core germplasm panel) were studied for rust resistance at seedling and adult plant stage. Five important stripe rust resistance genes, viz. YrA, Yr2, Yr9, Yr18 & Yr27, and eight leaf rust resistance genes, *viz*., *Lr1*, *Lr3*, *Lr10*, *Lr13*, *Lr19*, *Lr23*, *Lr26*, *Lr34* were characterized singly or in combination with other *Yr* and *Lr* gene(s).

Rice: Out of 500 landraces evaluated against bakane and sheath blight disease of rice, 11 accessions *viz*. IC558270, IC466755, IC99435, IC466765, IC458791, IC206805, IC207194, IC388575, IC455352, IC126326, and IC464473 were identified resistant against bakanae and 15 (IC462765, IC247997, IC449740X, IC466765, IC121912, IC583113, IC134817, IC206456, IC460514X, IC124088, IC123259, IC463956, IC311855, IC379077, IC460553X) were identified as moderately resistant against sheath blight disease.

Lentil: The accessions IC20156 (*Lens culinaris* subsp. *culinaris*), EC714243 (*L. culinaris* sub sp. *odemensis*) and EC718238 (*L. nigricans*) were highly resistant to races of Fol. Accessions belonging to *L. culinaris* subsp. *culinaris* (IC201693 and IC241532) were found susceptible to all the races of Fol.

Identification of citrus tristeza virus (CTV) free Khasi mandarin mother stock for scion bank for production of disease-free planting material for NE India: Analysis of Khasi mandarin (KM) mother identified six samples as CTV-free. These CTV-free mother stocks can be used as scion banks to produce planting materials for the farmers of NE India.

5.1.6 Disease Management

Post-harvest disease management: A potent antagonistic yeast strain, *Hansenia sporauvarum* LE-1, was effective against Alternaria alternata, *Colletotrichum musae*, and *Penicillium italicum*. A volatile compound, Trans-2-decenal, was identified as an effective antifungal compound.

Metabolite/chemical profiling of rice phyllosphere-associated microbiomes: The metabolome of EMPIRE™ consisted of a mixture of Cyclo (4-hydroxyprolinyl)-leucine, Dimethoxy-phenol, Viscosinamide, Cyclo (L-pro-L-tyr), 2,4 Diacetyl phloroglucinol, Pyoluteorin, Dapdiamide A, Dapdiamide D, Dapdiamide B, Pantocin A, Δ-2,11-Methyl dodecanoic acid and Agglomerin A which showed activities such as antimicrobial antibiosis, plant growth promotion, quorum sensing and plant defense induction.

Mycobiome of maize for management of banded leaf and sheath blight caused by *Rhizoctonia solani* f. sp. *sasakii* under a conservative agriculture system: Based on an experiment conducted on disease management in maize, 84 fungal isolates have been isolated as pure cultures. The field-level assessment of selected fungal isolates such as *Aspergillus niger*, *Penicillium oxalicum*, and *Aspergillus* spp. showed the ability to delay disease (BLSB) progress on plant tissues from 10 to 25 days after treatment of their spore solutions.

Biocontrol of sheath blight of rice (*Oryza sativa* L.) through alteration in expression dynamics of candidate effector genes of *Rhizoctonia solani* AG1-IA during pathogenesis: Hypothetical pathogenicity genes (52 nos.) were identified through *in silico* analysis, and the candidate genes were highly expressed in the aggressive strain (RIRS-K) in comparison to the less aggressive one (RIRS-17). Further analysis revealed pre-colonisation by a potent biocontrol consortium comprising Bacillus subtilis (S17TH), *Pseudomonas putida* (TEPF-Sungal-1), and *Trichoderma harzianum* (S17TH).

Management of bakanae disease of rice: Minimum disease incidence was observed in the treatment consisting of *Fusarium fujikuroi* + seed treatment (*Pseudomonas fluorescence*) + seedling treatment (Jeevamrit) + Foliar spray (Tebuconazole 50% + Trifloxystrobin 25% w/w WG (75 WG).

Evaluating biocontrol agents against spot blotch of barley: *Trichoderma asperellum* 8686 and *Trichoderma asperellum* 8687 showed the highest percent inhibition of 71.73 and 71.37%, respectively, under *in vitro* conditions.

Evaluation of *Beauveria bassiana* against chickpea pathogens: *In vitro* confrontation assay of four *B. bassiana* isolates (*BbR1, BbR2, BbR3* and *BbR4*) against chickpea pathogens showed a strong antagonistic effect against *Sclerotinia sclerotiorum*.

Microbial elicitors for crop health management: This study investigated the effects of volatile organic compounds (VOCs) emitted by *Pseudomonas putida* BP25 and its synthetic VOC, 2, 5-dimethylpyrazine, on anthracnose in mango cv. Chausa. The bacterial-volatile blend and 2, 5-dimethyl pyrazine can potentially prevent and treat anthracnose in mango.

Evaluation of *Purpureocillium lilacinum* and species of *Paecilomyces* against *Meloidogyne incognita:* Bioassays showed that *P. lilacinum* 6887 and *P. lilacinum* 6553 were highly effective in inhibiting egg hatching of *M. incognita*. The isolate Pl 6887 reduced the number of galls and egg masses/cm root length up to 71.2 and 79.4%, respectively, compared to the control.

Evaluation of bioagents, organic materials, and fungicides for management of charcoal rot of maize: Application of Azoxystrobin 18.2% w/w + Difenoconazole 11.4% @ 0.1% and Hexaconazole 5% EC @ 0.1% at 30 days after sowing (DAS) resulted in significant reduction of charcoal rot incidence (32.2 & 35.1% respectively) along with significant increase in yield (44.0 and 35.7%, respectively).

5.1.7 Evaluation of durum wheat germplasm at the seedling stage

Out of 200 durum germplasm, 103 germplasm were found to carry seedling resistance against stem rust pathotypes, 109 germplasms were resistant to leaf rust pathotypes, 67 genotypes were found to be resistant to both stem and leaf rust pathotypes.

5.1.8 Screening of All India Coordinated Wheat and Barley pathological nurseries for rust resistance

Of the 1747 entries, 854 resisted stem and leaf rust at Indore. While 53.6% of PPSN entries showed resistance to both the rusts and 45.9% of IPPSN entries were resistant. Around 20.9% of AVT entries (153) were resistant to both stem pathotypes. The Indore entries *viz.*, HI 1650, HI 1655, HI 1665, HI 1666, HI 8826, HI 8830, HI 8840, HI 8846, and HI 8847 possess high resistance to both stem rust pathotypes.

5.1.9 Chemical evaluation for leaf rust control

Foliar application of Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.06% along with Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1% and Azoxystrobin 11% + Tebuconazole 18.3% w/w SC @ 0.1% were found to be effective in controlling the leaf rust infection. The highest yield was recorded in the plot sprayed with Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.06% when applied at disease initiation, followed by two sprays at 14-day intervals on wheat foliage.

5.1.10 Chemical evaluation for stem rust control

Application of Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.06% showed the lowest ACI score (13.21). All the fungicide treatments showed a significant gain in percent yield in comparison to the unsprayed control.

5.1.11 Screening of IARI advanced generation lines for stem and leaf rust resistance

Out of 458 genotypes in the preliminary disease screening nursery (PDSN) evaluated, 278 entries showed resistance to stem and leaf rust at Indore. Indore entries, HAS nos. 17, 25, 29, 33, 47, and 48 genotypes were resistant to all three rusts in multi-locations. Of the 167 Common Varietal Trials (CVT) entries evaluated for seedling response to leaf rust pathotype 77-5 and stem rust pathotype 40A, 13 entries were segregated, and out of the remaining 154 entries, 68 entries were resistant to both pathotypes. Out of 553 advanced generation lines (345 bread wheat and 208 durum), 491 were resistant to stem and leaf rust diseases.

5.1.12 Association of cucurbit aphid-borne yellows virus (CABYV) with Indian round gourd (*Praecitrullus fistulosus*)

The association of Cucurbit aphid-borne yellows virus CABYV has been reported for the first time from the country in diseased samples of Indian round gourd or tinda (*Praecitrullus fistulosus*), a popular cucurbit.

Indian round gourd (*Praecitrullus fistulosus*) **showing Cucurbit aphid-borne yellows virus (CABYV) infection**

5.1.13 Musk mallow (*Abelmoschus moschatus*): a new host of Cucurbit aphid-borne yellows virus

Cucurbit aphid-borne yellows virus (CABYV) was detected in all diseased samples of Musk mallow (*Abelmoschus moschatus*), a common weed of the Deccan region of India. Molecular analysis using two-step RT-PCR confirmed the infection, making it the first report of CABYV infecting *Abelmoschus moschatus* worldwide.

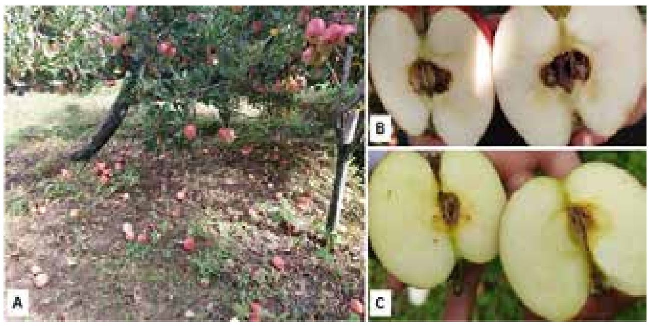
Musk mallow plant infected with cucurbit aphid-borne yellows virus (CABYV)

5.1.14 Selection of tomato germplasm for vector/ virus resistance

Seln-29, a selection of tomato germplasm line EC-538421 (semi-indeterminate type), showed high tolerance to leaf curl virus disease with good horticultural characteristics.

5.1.15 Post-infection alteration in the nutritional attributes of apple fruit due to core rot disease

Core rot is becoming an important post-harvest disease in parts of the North-western Himalayan Region due to changing climate. The causal organism of core rot was identified as *Fusarium fujikuroi*. This is the first report of the core rot of apple caused *by Fusarium fujikuroi* in India.



Survey of apple orchards for collection of core rot-infected fruits. A: Apple tree of Royal Delicious variety showing heavy fruit drop, B-C: vertically cut apple fruits showing symptoms of core rot

5.1.16 Wheat powdery mildew

The viability and infection potential of wheat powdery mildew pathogen were ascertained: Asexual conidia retrieved from low and subfreezing temperatures have practical utility in terms of augmentation and recurrent inoculations during off-season and screening wheat genetic stocks.

Race analysis/Pathotyping of wheat stem rust: Evaluation of 25 stem rust samples by inoculating on Indian standard differential sets at IARI, RS, Wellington revealed that the pathotype 40-A with seven isolates was virulent on *Sr13*.

5.1.17 Host resistance

AICW&BIP trials at IARI, Regional Station, Wellington: Stem rust scoring was done for two thousand seven hundred two (2452) wheat breeding lines received under different disease screening nursery trials *viz*., IPPSN, EPPSN, PDSN, MDSN, PPSN, and CVT of the AICWIP program during *rabi* 2022-23.

5.1.18 Management

Biocontrol efficacy of *Trichoderma* sp. against wheat pathogens: Two native isolates of *Trichoderma* sp. were tested against stem rust, leaf rust, and head scab (*Fusarium graminearum*) pathogens of wheat.

Evaluation of fungicides against stem rust of wheat under field condition: Field evaluation of eight fungicides showed that Tebuconazole 50% + Trifloxystrobin 25% WG and Tebuconazole (0.1%) were more effective against stem rust.

5.2 ENTOMOLOGY

5.2.1 Insect Physiology

Whole genome transcriptomics of hibernation and non-hibernation *Chilo partellus*: The whole genome transcriptome sequencing of hibernation and non-hibernation *C. partellus* revealed variation in both strains, with 544 genes being down regulated and 660 up-regulated.

Biochemical regulation in different body tissues of hibernation and nondiapause *Chilo partellus*: Significant variations were noticed for total sugar, glycogen, sorbitol, trehalose and glucitol contents in different body parts, life stages of hibernation and non-hibernation *C. partellus.* Total sugar content started declining, while sorbitol, trehalose, and glucitol increased in all the body parts as the *C. partellus* larvae progressed from pre-hibernation to hibernation. In hibernation larvae, sorbitol and trehalose in cuticular tissues and glucitol in haemolymph were greater than in other body parts. The glutathione S-transferase activity was greater in the non-hibernation larvae and pupae than in the hibernation larvae and post-hibernation pupae of *C. partellus*.

Biological and behavioral studies on fall armyworm and spotted stem borer in maize: Significant differences in phenological traits and damage by fall armyworm and spotted stem borer were observed among the maize genotypes. The maize genotypes PML 25, PML 55, PML 102, RR/G 357, RNG 364, 22048, 25541, and 25951, having moderate glossiness, anthocyanin pigmentation, and seedling vigor, recorded significantly lower borer damage.

Transgenerational effect of heat stress on progenies of *Spodoptera frugiperda*: The persistent trend of thermal stress on biological and reproductive traits was studied for the invasive fall armyworm, *Spodoptera frugiperda (J. E. Smith)*. The survival of larvae was minimal at 45°C, single (88%), and multiple thermal stress (92.5%). The carry-over effect of thermal stress was evident up to F_2 generation. Reproductive parameters reduced drastically due to thermal stress in F_0 generation, and the effect persisted up to F_2 generation on fecundity and gonadosomatic index.

Gut bacterial diversity in insects: Gut microbial diversity was estimated in white grub species *Anomola dimidiata, Maladera insanabilis* and functional characterization identified cellulolytic lipolytic gut bacteria from *A. dimidiata*. The study showed that the anaerobic gut bacteria isolated from whitegrub, *A. dimidiata,* exhibited higher nitrate reductase activity. Metagenomic analysis of honey bee species, *Apis mellifera, A. cerana indica, and A. cerana,* revealed the presence of novel beneficial gut bacteria that could be utilized to prepare probiotic consortia for *A. mellifera*.

Molecular characterization of phosphine resistance in insect pests: Functional mutants associated with phosphine resistance have been identified in the redox sites of the gene Dihydro lipoamide dehydrogenase (DLD) in the stored product insect pests *Tribolium castaneum* and *Rhizopertha dominica*. The biochemical basis of phosphine resistance has been elucidated by estimating moon-lighting activities of the key metabolic enzyme, DLD, in *R. dominica.*

Evaluation of dsRNA constructs against whitefly *Bemisia tabaci*: Six potent dsRNA constructs of ECR, GST Chitin synthase and VATPase, JHMAT, and JHEH showed >70-80% mortality as per *in vitro* assays. The most promising dsRNA constructs, *ECR and chitin synthase,* have been used to develop spray formulations.

Identification of novel attractants/repellents against whitefly *B. tabaci*: Two promising volatile organic compounds showing repellence/oviposition deterrence have been identified for developing novel lures for managing whitefly *B. tabaci*.

Field evaluation of a novel attractant lure at Delhi, Haryana, Rajasthan revealed 66-200% increased attraction to whiteflies.

Field evaluation of Attractant Lure for management of whitefly *Bemisia tabaci*

Endophytic establishment of native *Bt* strain in maize plants and its efficacy against *Spodoptera frugiperda*: A native *B. thuringiensis* (BtVKK5) isolate showed insecticidal activity against *S. frugiperda* and bio-efficacy studies demonstrated that seed treatment followed by soil drenching and foliar application of this isolate resulted in 50% mortality of *S. frugiperda* larvae

Double-stranded RNA mediated knockdown of sucrase (*AgSuc1*) and trehalose transport (*Agtret1*) genes of *Aphis gossypii*: Silencing of genes involved in osmoregulatory (*AgSuc1)* and sugar transportation (*AgTret1)* functions through oral feeding of dsRNA constructs which recorded 56 and 66%, respectively, mortality in cotton aphid, *Aphis gossypii*.

5.2.2 Biological Control

Evaluation of laboratory-prepared water-dispersible granules of *Metarhizium rileyi*: The water-dispersible granules of *M. rileyi* were found to be effective against several pests like cotton bollworms, hairy caterpillars, fruit flies, etc.

5.2.3 Insect Toxicology

Contact toxicity of insecticides against rice weevil, *Sitophilus oryzae*: The contact insecticides, spinetoram and lambda-cyhalothrin, were found to be the most promising alternatives in comparison to conventional insecticides (malathion, deltamethrin) on rice weevil, *Sirophilus*, *oryzae*, on test surfaces like jute bags, floor tiles, and glass.

Insecticide resistance studies in brown plant hopper, *Nilaparvata lugens*: Sublethal and lethal effects of triflumezopyrim on biological parameters were studied in brown plant hopper (BPH). In comparison to the control, there was a significant difference in fecundity (146.09±2.73), female longevity (12.34±3.121), and honeydew excretion (172 mm^2).

5.2.4 Integrated Pest Management

5.2.4.1 Cereals

Host plant resistance studies in rice against brown plant hopper (BPH), *Nilaparvata lugens*: Among the tested varieties, RP 2068-18-3-5 and Salkathi showed the least damage, at par with the resistant check PTB 33, indicating high resistance to BPH.

Effect of planting method on pest population in rice: The incidence of pests and natural enemies in direct seeded and transplanted rice was studied. A significantly higher incidence of BPH and WBPH was observed in transplanted rice (TPR) (4.81±0.66; 0.24±0.04, respectively). The overall percent of leaf folder damage was also significantly higher in TPR (1.01±0.12). The percentage of white ears was high in DSR (2.83%) compared to TPR (1.87%). Similarly, no significant difference was observed in natural enemy populations, *viz*., spiders and rove beetles.

5.2.4.2 Oilseeds

Mustard-aphid biochemical interactions in wild *Brassicas*: A total of 29 accessions from 18 different wild *Brassica* species, along with three *B. juncea* genotypes, were evaluated for mustard aphid, *L. erysimi* resistance. The studies revealed that the antioxidants, phenol, FRAP, tannins, and carotenoids increased in response to aphid damage in both buds and silique of the test wild species.

Assessment of avoidable yield loss due to *Lipaphis erysimi* damage in recently released Indian mustard varieties: The yield loss assessment due to *L. erysimi* was carried out on three recently released Indian mustard varieties *viz*., Radhika, Brijraj, and PM 30. The seed yield under protected conditions was 2537.0, 2201.8, and 1819.2 kg/ha, while under unprotected conditions, 2296.9, 1761.8, and 1600.6 kg/ha in Radhika, Brijraj, and PM 30, respectively.

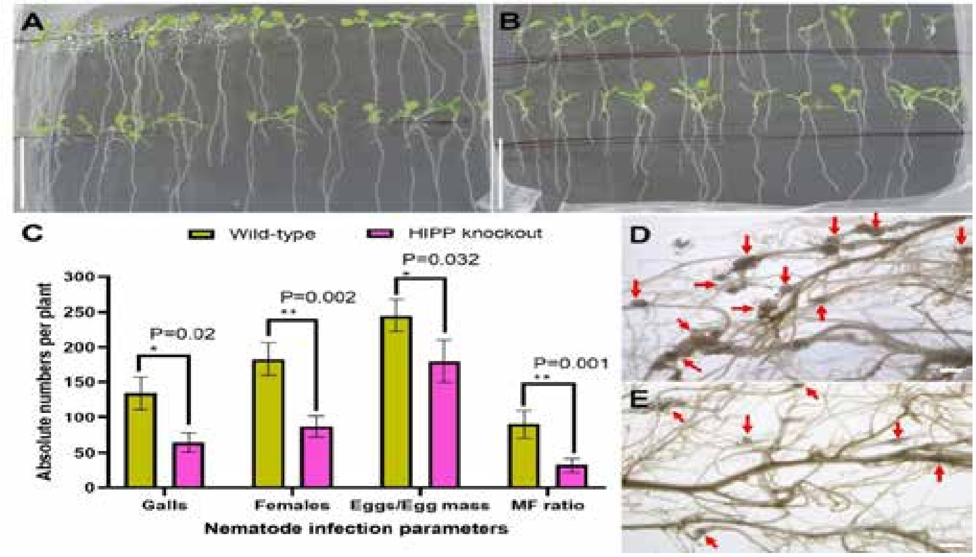
Evaluation of pigeonpea genotypes against pulse beetle, *Callosobruchus chinensis:* Evaluation of pigeon pea genotypes (50) against pulse beetle, *C. chinensis* revealed that IPAB 18-21 and Pusa Arhar-16 were resistant to *C. chinensis* with low adult emergence (57 and 52.35%, respectively), longer developmental period (21.67 and 21.96 days, respectively) and low growth index (GI) (0.412 and 0.398, respectively). Genotype IPAB 18-21, having more seed hardness (507.67 N) and seed coat hardness (63.6 g), was least preferred by *C. chinensis* for oviposition. Variety Pusa Arhar-16 had more anti-nutritional factors like phenols (35.18 mg/g), tannins (367.76 mg/g), α-amylase inhibitor (3.06 %) and trypsin inhibitor (39.22%).

5.3 NEMATOLOGY

5.3.1 Molecular Nematology

RNA-Sequencing of various stages (Egg, Pre-parasitic J2s, Post-parasitic J2s and J3-J4 stages) of rice root-knot nematode *Meloidogyne graminicola* showed upregulation of 599, 1138, 1070 and 332 genes, and down-regulation of 1069, 1595, 1600 and 84 genes, respectively.

Mi-vit 2, a vitellogenin gene of *Meloidogyne incognita* was identified as the target gene for host delivered RNAi. Transgenic *Arabidopsis* plants expressing dsRNA targeting *Mi-vit-2* showed reduction in root galls (59.17 %), adult nematode females (41.75 %), egg masses (49%), and eggs per egg mass (32.84 %) compared to wild types. In addition, *Arabidopsis* plants with gRNA for KRP-6 gene have been developed. KRP6 protein belongs to the KRP family of cyclin-dependent kinase



Loss-of-function of HIPP27 increased *A. thaliana* resistance to *M. incognita*.

(CDK) inhibitors and plays a key role in regulating the cell cycle by inhibiting the activity of CDKs.

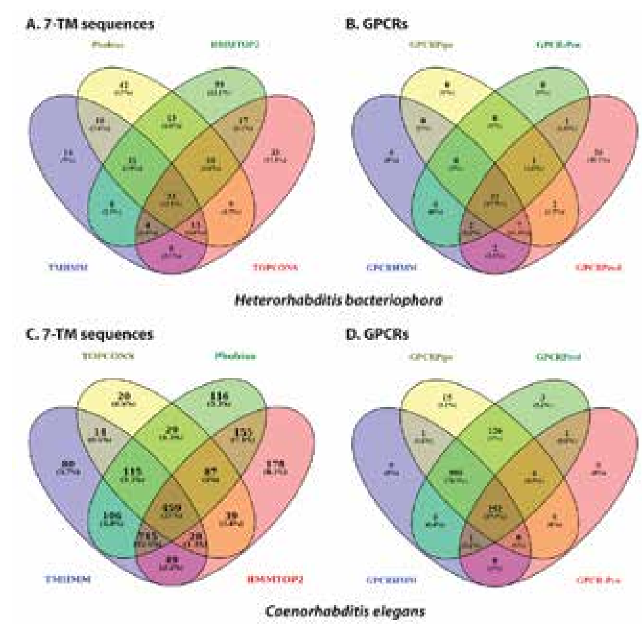
Using overexpression study, a putative susceptibility (*S*) gene heavy metal-associated isoprenylated plant protein (*HIPP27*) was characterized from the model plant *Arabidopsis thaliana* that proliferated *Meloidogyne incognita* infection. Two guide RNAs (corresponding to *HIPP27* gene) were artificially synthesized and sequentially cloned into a Cas9 editor plasmid, mobilized into *Agrobacterium tumefaciens* strain GV3101 and transformed into *Arabidopsis* plants using flower bud soaking method. Apart from 1-3 bp deletion and 1 bp insertion adjacent to PAM site, a long deletion of approximately 161 bp was documented in T_0 generation.

Homozygous mutant plants were carried forward and a number of 'transgene-free' plants were obtained in T_2 generation. Phenotypic analysis of T_2 plants revealed reduced nematode infection in mutants compared to wild-type plants. Additionally, no growth penalty was incurred in mutant plants.

5.3.2 Entomopathogenic nematodes

Application of entomopathogenic nematode *Heterorhabditis indica*-phagostimulant-based beads against neonates of FAW increased the plant's fresh weight by 36.7% within 10 days of application as compared to untreated plants.

An improved protocol for RNAi in the entomopathogenic nematode *Heterorhabditis*



The prediction of transmembrane sequences and GPCR proteins by various tools. Venn diagram representing numbers of sequences in *Heterorhabditis bacteriophora* genome- A) 7-TM sequences predicted by 4 different tools (TMHMM2, Phobius, HMMTOP2 and TOPCONS); B) GPCRs predicted by 4 different platforms (GPCRHMM, GPCRPipe, GPCRPred and GPCRPenD), and in *Caenorhabditis elegans* genome- C) 7-TM sequences, and D). GPCR sequences identified using the same tools

bacteriophora was developed. In addition, a stringent bioinformatic pipeline was developed and 21 GPCRs were identified in entomopathogenic *Heterorhabditis bacteriophora*.

To identify the potential receptors of *Photorhabdus* toxins in *G. mellonella*, a number of receptor candidates were *de novo* characterized from *G. mellonella* using Bt toxin as the ligand for *in vivo* toxicity assays. The full-length sequences of nine putative *Cry* receptor genes (CAD, ABCC, ALP, APN, prohibitin, GLTP, α-amylase, ADAM, and UDP-GT) were cloned from *G. mellonella*. The receptor genes were significantly overexpressed in the midgut tissues of fourth-instar larvae upon early exposure to a sub-lethal dose of Cry1AcF toxin. Oral and independent delivery of bacterially-expressed dsRNAs (corresponding to CAD, ABCC, ALP and APN) in *G. mellonella* suppressed the transcription of target receptors, significantly reducing the larval sensitivity to Cry1AcF toxin. However, targeted knockdown of prohibitin, GLTP, α-amylase, ADAM, and UDP-GT led to variable effects on insect susceptibility to Cry1AcF toxin. This indicated the redundant role of many receptors in *Cry* intoxication process.

5.3.3 Nematode management

Several nematode-antagonistic bacteria were isolated and identified. The isolates *viz*., SRB7, SRB9, SRB13 and SRBS9 were identified as *Bacillus subtilis* (OL716087), *Bacillus cereus* (OL716088), *Bacillus megatherium* (OM816754) and nonpathogenic *Pseudomonas stutzeri* (OL716089), respectively. Bioefficacy evaluation of pure compound (Piperitenone oxide) from *M. longifolia* essential oil against *M. incognita* showed 100% mortality and egg hatching inhibition at 500-1000 ppm after 72 hrs of exposure period.

Among the four nematicidal bacteria isolated. *B. subtilis* was selected for bioefficacy comparison with *Trichoderma asperellum* MT702882. Though Velum Prime resulted in the highest reduction in juvenile density in soil and a decrease in root galling and reproduction factor of the nematode among the bio-agents, the dual application of *T. asperellum* was most effective, followed by *B. subtilis*. Soil solarization resulted in 65.8% reduction in galling as compared to 79.0% by *T. asperellum* and an average of 57.3% reduction in eggmass production, as compared to 75.2% by *T. asperellum*.

5.3.4 First report of *Meloidogyne hapla* infestation on *Parthenium hysterophorus* from India

A survey targeting the "Susceptibility of weed species to Root-knot nematodes (RKN), *Meloidogyne* spp. revealed the presence of RKN-induced galls in the roots of *Parthenium hysterophorus*, an invasive weed in India. This is the first report of *Meloidogyne hapla* infesting, establishing, and reproducing on *Parthenium hysterophorus*.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Development of active molecules for crop protection

5.4.1.1 Synthesis and evaluation of indazolylchromone derivatives against plant pathogenic fungi

A series of twenty 2-indazol-1-yl-chromen-4-one derivatives were synthesized (yield: 76.35 - 93.86%) and characterized using spectroscopic techniques (IR, ^{1}H NMR, and ^{13}C NMR), out of which nineteen compounds are novel and not reported earlier. Indazolylchromones showed good antifungal activity against *Sclerotium rolfsii* and *Fusarium oxysporum*. Among the tested compounds, compound 6f displayed good activity against *F. oxysporum* with an ED_{50} value of 27.82 ppm. *In vivo* (pot culture) studies suggested that compounds 6 t and 6f (1000 ppm) effectively controlled the disease with PDI values of 26.66 and 30%, respectively, and were at par to the commercial fungicide, hexaconazole 5% SC, (PDI=25%). However, compound 6f was found less active against *F. oxysporum* (PDI of 35%) than commercial carbendazim 50% WP, (PDI - 24%).

5.4.1.2 Synthesis and antifungal activity of prenylated chalcones

Two series of prenylated chalcones were synthesized by conventional and microwave methods.

The synthesized compounds showed significant *in vitro* antifungal activities against *S. rolfsii* and *F. oxysporum.* 2′-Hydroxy-4-bromo-4′-*O*-prenylchalcone (5E) (Series 1) with ED_{50}= 23.27 mg L⁻1, exhibited the highest level of anti-fungal activity against *S. rolfsii* and compound 2′-Hydroxy-2,6-dichloro-4′-*O*-prenylchalcone (5B) with ED_{50}= 25.46 mg L^{-1}, was found most effective against *F. oxysporum*. 2′-Hydroxy-4-benzyloxy-5′-*O*-prenylchalcone (6P), a compound (Series 2) was found most potent against both fungi with ED_{50} values of 25.02 and 31.87 mg L^{-1} against *S. rolfsii* and *F. oxysporum*, respectively.

5.4.1.3 Evaluation of the antifungal and nematicidal activity of imidazolyl chalcones and pyrazole derivatives

In-vitro fungicidal bioassay studies of imidazolyl chalcones (IC) and pyrazoles (P) identified IC-8, IC-10, P-2, P-11, and P-25 as the best compounds. Results revealed that plants drenched with P-11 showed the lowest disease incidence (PDI) of 0 and 8.26% at 7 and 15 DAI, respectively, against *Rhizoctonia solani*. Nematicidal assay against *Meloidogyne incognita* showed that soil drenching with P-5 was most effective with the lowest number of galls formation, 8.33 and 1.33 at 30 DAI and 60 DAI, respectively. Plants drenched with P-20 showed the highest shoot (14.07 cm) and root length (11.17 cm) at 60 DAI. Both fungicidal and nematicidal activity were higher in soil drenching than in the root dipping method.

5.4.1.4 Pest control activity of the extracts/oils/pure compounds

The aphicidal activity of oil, methanolic extract, and piperine from *Piper longum* fruits was carried out against *Lipaphis erysimi* (mustard aphid). Pot experiment showed at 2000 ppm significant reduction of *L. erysimi* population from 162 to 10.6 aphids/plant (oil), 178 to 24.8 aphids/plant (methanolic extract), and 164 to 3.4 aphids/plant (hexane extracts) in mustard crop up to 7 days compared to untreated control (180 to 207 aphids/plant) and positive control dimethoate (175 to 0.6 aphids/plant). The essential oils from citronella and geranium and *Annona squamosa* seed extract (500 and 1000 ppm) showed a reduction of galls/plant of J2s of *M. incognita* in the roots of brinjal.

5.4.1.5 Bioactive phytochemicals from *Litsea glutinosa* for the management of storage pathogens

Monoterpene dl-limonene (58.40%) rich *L. cubeba* exhibited the highest efficacy against pathogenic fungi, *Aspergillus parasiticus* 6365 (EC_{50} 253.3 μg/mL). Untargeted phytochemical analysis using UPLC-QTOF-ESI-MS/MS revealed the identification of 41 putative compounds like boldine (329.1618), litseaglutine A (312.1229), lauroscholtzine (342.1695), obtusilactone B (333.2435), akolactone A (293.2489), litseakolide A (309.2062), obtusilactone A (309.2438), litsealactone B (279.1964) as major compounds.

5.4.2 Formulations for delivery of crop protection inputs

5.4.2.1 Extraction, formulation and bio-efficacy evaluation of *Rhynchosia minima* essential oil (RMEO)

RMEO was extracted from the aerial parts of *R. minima* and characterized by GC-MS analysis. RMEO primarily consisted of sesquiterpenes, mainly caryophyllene (57.89%) and α-humulene (10.34%). Bioefficacy against whitefly under laboratory conditions showed LD_{50} of 2882 ppm (24 h) and 1305 ppm (48 h). A docking study of constituents of RMEO against three target enzymes, *i.e., Ryanodine receptor protein, NADH dehydrogenase, and cytochrome c,* was done. Maximum alkyl and π alkyl interactions were observed, and γ-murrolene was found to be the most effective based on docking studies.

5.4.3 Analytical methods or extraction protocols

5.4.3.1 Development of an analytical protocol for sulfamethoxazole (SMXZ) in water/wastewater

The analytical method was developed for quantitatively estimating sulfamethoxazole using LC-MS/MS. The calibration curve for sulfamethoxazole in the concentration range of 0.001 to 1 μg mL^{-1} was linear

(R^2 - 0.9989). The instrumental LOD was 0.001 ug/mL, and LOQ was 0.005 ug/mL. Solid phase extraction technique using hydrophilic-lipophilic balance cartridges gave extraction efficiency of SMXZ 82.18, 80.45, and 90.66% at spiking levels of 0.001, 0.005, and 0.01 μg/mL, respectively. The developed method was found to be sensitive and precise for the extraction of sulfamethoxazole.

5.4.3.2 Extraction/purification of anthocyanin

Cost-effective anthocyanin purification technology involving ion exchange resin was evaluated. Chemo-profiling of the extracts through UPLC-HRMS revealed the molecular identities of the anthocyanins. Among adsorbent resins, XAD-16 and DIAION HP 20 and ion exchange resins, OPTIPORE L 493 were the best-performing resin in adsorbing acylated and non-acylated anthocyanins. Pseudo 2nd order kinetic model explained better sorption kinetics of both types of anthocyanin. Freundlich model mediated competitive adsorption (R^2 > 0.901, least χ^2 and AIC_c values with maximum R^2_{adj}) was predominant for adsorptions of both acylated and non-acylated anthocyanin, phenolics except sugars.

5.4.3.3 Development and validation of a method for the determination of 103 pesticides in mango fruit drink using LC-MS/MS

A robust method for identifying and quantifying 103 pesticides in a mango fruit drink was developed using LC-ESI-MS/MS-based. Results showed that 5 mL dilution and citrate buffered QuEChERS extraction with anhydrous $MgSO_4$ clean-up to have acceptable recovery for 100 pesticides @ 1 μgmL^{-1} fortification. The method was validated as per SANTE guidelines 11813/2021. Satisfactory recovery of 95, 91, and 77 pesticides was obtained at 0.1, 0.05, and 0.01 μgmL^{-1} fortification with HorRat values ranging from 0.2–0.8 for most pesticides. The method showed matrix enhancement for 77 pesticides with a global uncertainty of 4.72–23.89%. The method's reliability was confirmed by real sample analysis of different brands of mango drinks available in the market. The greenness assessment by GAPI (Green Analytical Procedure Index) indicated the method was much greener than other contemporary methods.

5.4.3.4 Assessment of the effect of storage on the physicochemical parameters of honey quality

The effect of storage on quality parameters of honey (specific gravity, electrical conductivity (EC), moisture content, free acidity, acidity as formic acid) of 8 honey samples was determined for 12 months. During storage, EC and moisture content decreased while acidity increased in all the samples and the change was insignificant.

5.4.3.5 Determination of quality parameters in Jamun honey

Jamun honey samples collected from the market, *krishi mela*, and online platforms were evaluated for quality parameters. The electrical conductivity of all the samples was found within range. Moisture content was at the borderline for two samples, while for two samples, it was higher than the recommended range (FSSAI Max. limit = 20% by mass). The free acidity of the two samples was out of range. The sucrose content and fructose/ glucose ratio were found within FSSAI's recommended limits.

5.4.4 Management and assessment of contaminants in agricultural commodities and environment

5.4.4.1 Adsorptive removal of sulfamethoxazole (SMXZ) from water using mesoporous silica-graphene oxide composite

Among the various groups of antibiotics, the sulphonamide antibiotics stand out as frequently detected environmental contaminants. A total of 11 different adsorbents were synthesized using surfactant-templated methods and the adsorbents were characterized by spectroscopic techniques. Among the adsorbents, the composite MPS-GO showed the highest SMXZ adsorption efficiency of about 87.77% at pH 7 and 0.1 μg mL^{-1}. The adsorption kinetics data was best explained by pseudo 2nd order model. The sorption data were found to be well-fitted into the Freundlich isotherm model (R^2=0.954-0.999), indicating the presence of a heterogeneous layer of adsorbent with multilayer adsorption. Adsorption decreased with an increase in temperature. The current research demonstrated its applicability as a sustainable adsorbent for removing antibiotics from wastewater.

5.4.4.2 Persistence of triclosan (TCS) in agricultural soils

Persistence of TCS in inceptisol (pH 7.67, OC 0.67%)) and entisol (pH 4.97, OC 1.98%) at 5 μg g^{-1} fortification level was studied. Samples were processed using the QuEChERS method and the residues were quantified using LCMS/MS. TCS residues persisted in all treatments beyond 120 days, with 80.53–99.01% and 70.92–92.48% dissipation observed on the 120th day in inceptisol and entisol soil, respectively. The persistence of TCS was highest ($T_{1/2}$ 68.3-73.3 days) in sterile soils and lowest under UV-light exposure ($T_{1/2}$ 36.2-40.1 days).

5.4.4.3 Effect of organic amendments on the mobility of triclosan (TCS) in soils

The leaching potential of TCS was investigated in inceptisol and entisol amended with vermicompost (VC), farm yard manure (FYM), rice straw ash (RSA), and sugarcane trash ash (STA) under continuous and discontinuous flow conditions, simulating the average annual monsoon precipitation in India. Under both conditions, leaching of TCS was greater in inceptisol than entisol. The incorporation of organic amendments further reduced the leaching potential of TCS. Among different amendments, recovery (%) of TCS was higher in soils amended with RSA and STA.

5.4.4.4 Effect of fipronil and imidacloprid co-existence on their fate in soils

Imidacloprid and fipronil premix formulations have been registered for grub management in sugarcane. Therefore, the degradation and leaching behavior of fipronil and imidacloprid, alone and in combination, was studied in three sugarcane-growing soils. Leaching studies suggested imidacloprid was relatively more mobile in soils than fipronil. There was no significant difference in the leaching profile of both pesticides, alone or combination, in all three soil types, although leaching behavior varied with soil types. No effect of pesticide co-presence was evident on the degradation behaviour of imidacloprid and fipronil in laboratory-incubated soils, although fipronil was more persistent than imidacloprid

5.5 WEED MANAGEMENT

5.5.1 Weed dynamics, productivity, and resource use efficiency of pigeon pea–wheat cropping system as influenced by weed management

Broadbed and furrow land configuration exhibited the highest weed control efficiency and decreased weed dry weight in pigeonpea and wheat, resulting in a system productivity increase of 8.3% to 2920 kg/ha. This configuration also increased N, P, and K uptake, moisture use efficiency and net returns (₹ 106,790/ha). Among weed management practices, two hand weedings achieved the highest control efficiency (83.7%), followed by metribuzin 0.25 kg/ha (Pre-em.) combined with hand weeding at 30 DAS (81.45%). Two hand weedings maximized water use efficiency (2.92 kg/ha-mm) and nitrogen use efficiency (21.53 kg yield/kg N applied). The most profitable approach was metribuzin 0.25 kg/ha (pre-em.), followed by imazethapyr+imazamox 75 g/ha (POE) in pigeonpea and metribuzin 0.25 kg/ha (pre-em.) followed by sulfosulfuron 20 g + metsulfuron 3 g/ha at 30 DAS in wheat, yielding the highest net returns (₹ 119,460/ha) and B: C ratio (1.34).

6. BASIC AND STRATEGIC RESEARCH

The work under the basic and strategic research at ICAR-IARI was mainly focused on identification and characterization of novel/putative genes/ QTLs/ proteins/ metabolites linked with stress tolerance and crop yield, crop phenomics and High-Throughput Plant Phenotyping (HTPP) to accelerate future breeding, genome editing to develop climate-smart rice, seed nutrient density analysis of rice, wheat, soybean, lentil, pearl millet, climate change mitigation approaches, application of remote sensing and GIS techniques in natural resource management and sensors based estimation of soil fertility. This section briefly presents the significant achievements under above-mentioned areas.

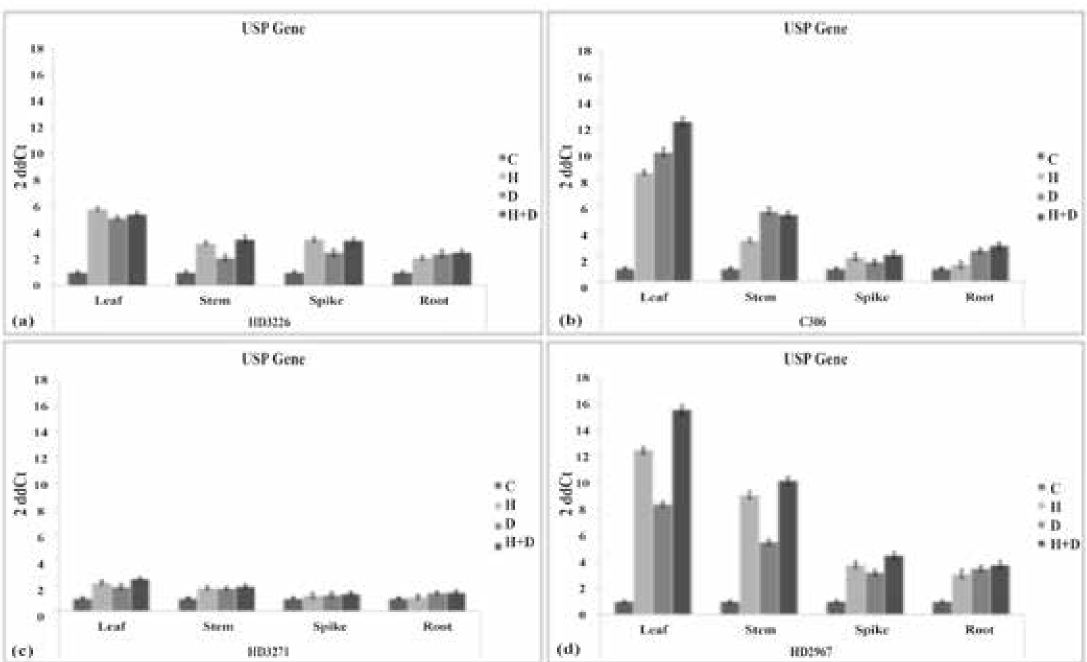
6.1 PLANT MOLECULAR BIOLOGY

6.1.1 Tissue-specific expression analysis of putative universal stress protein (USP) gene

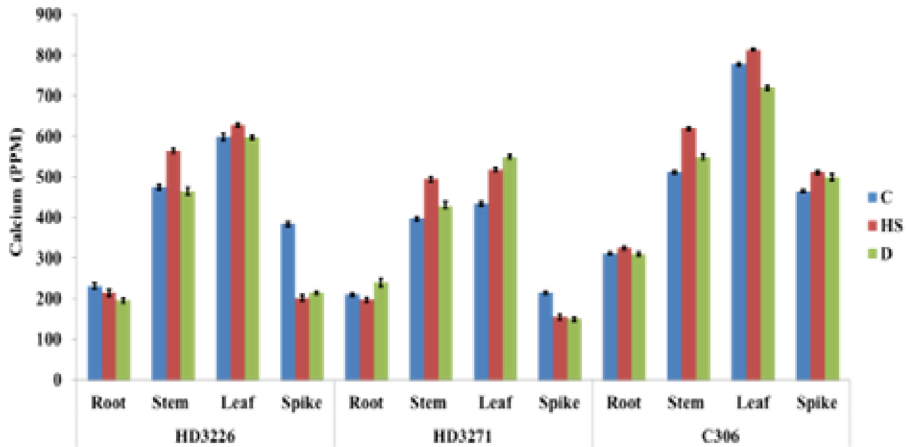
The putative Universal Stress Protein (USP) gene (acc. no. OP376748) cloned from wheat *cv.* HD 2967 showed maximum expression in the leaves of *cv.* C306 (13.1-fold) under heat stress (HS) + drought (D), as compared to control. A gradual decrease in the USP transcripts was observed in stem, spike and root under D and HS.

6.1.2 Ca-profiling of recurrent parent/ donor of wheat *cvs.* grown under drought and heat stress

Ca-profiling using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) showed maximum Ca in leaves of *cv.* HD 3226, followed by stem, spike and root in response to drought and heat stress. The maximum Ca concentration was observed in the leaves of wheat *cv.* C 306 under HS. Overall, HS was observed to trigger the accumulation of Ca in the



Expression analysis of *USP* gene in recurrent parent/ donor of wheat grown under regulated conditions



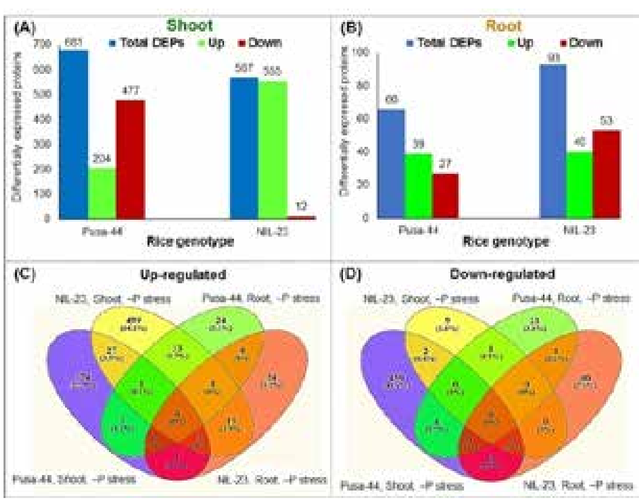
Calcium profile in different tissues of wheat *cvs.* exposed to heat and drought stress; C - 22±3°C, HS-treated - 38±2°C, D- withhold irrigation for 7 days

tissue followed by D; thermo-tolerant *cultivar* showed better Ca accumulation than other genotypes.

6.2 BIOCHEMISTRY

6.2.1 Comparative proteome analysis for phosphorous starvation tolerance in rice

Proteome analysis of a high-yielding rice cultivar Pusa 44 and its near-isogenic line (NIL)-23 harbouring a major phosphorous uptake (*Pup1*) QTL grown hydroponically under control (16 ppm P) and P-starvation (0 ppm P) stress identified 93 and 567 differentially expressed proteins (DEPs) in root



Comparative proteome analysis of differentially expressed proteins (DEPs) under P-starvation stress in rice, (A) shoot, and (B) root of contrasting rice (Pusa-44 and NIL-23) genotypes

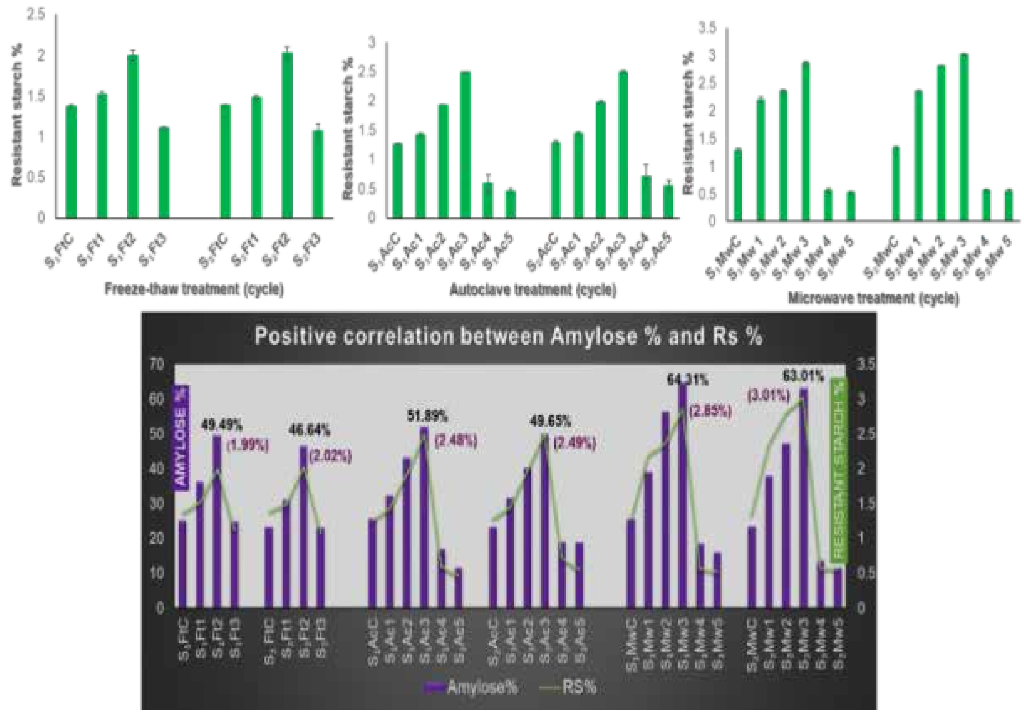
and shoot of NIL-23, respectively. The P-starvation responsive DEPs are transcription factors (mainly ARF, ZFP, HD-ZIP, MYB) and those involved in photosynthesis, starch-/sucrose-/energy-metabolism, phytohormone signalling.

6.2.2 Qualitative phosphoproteomic analysis of wheat under elevated carbon dioxide (eCO_2), heat stress (HS) and differential nitrogen

Unique phosphopeptides (967) corresponding to 1100 proteins and containing 1500 non-redundant phosphorylation sites were identified. Under eCO_2, 29 unique phosphopeptides including 15 unique enzymes were identified of which four were kinases and five were phosphatases. The presence of two phosphopeptide motifs in nitrate reductase enzyme showing significant level of changes in the phosphorylation efficiency under eCO_2 and HS were observed.

6.2.3 Optimization of physical treatments to enhance Type III resistant starch (RS)

White rice varieties contain low RS ranging between 0.33 to 2.7%, hence interventions are required to improve RS III. Here, three different retrogradation strategies (i) Freeze-thaw (Ft) (freezing at -20 ℃, 24 h followed by thawing at 50 ˚C for 90 min), (ii) Autoclave (Ac); 120 ˚C, 1 hr at an interval of 2 h, and (iii) Microwave (Mw); 900 watts, 1 min exposure, interval of 15 min, were subjected to three (Ft) and five (Ac and Mw) cycles in rice varieties Swarna (RS 1.2%)



Physical treatments to retrograde resistant starch type III (RSIII). S1= Swarna, S2=BPT 5204, Ft= Freeze-thaw treatment, [freezing at -20^0 C, 24 h followed by thawing at 50^0 C for 90 min], Ac= Autoclave treatment, [120^0 C, 1 h at an interval of 2 h], Mw=Microwave

and BPT 5204 (RS 1.26%) for enhancing RS III. The highest increase in RS III content (~2.5 fold) was observed in the 3rd cycle of Mw treatment.

6.2.4 Preparation of steam-infused protein blends

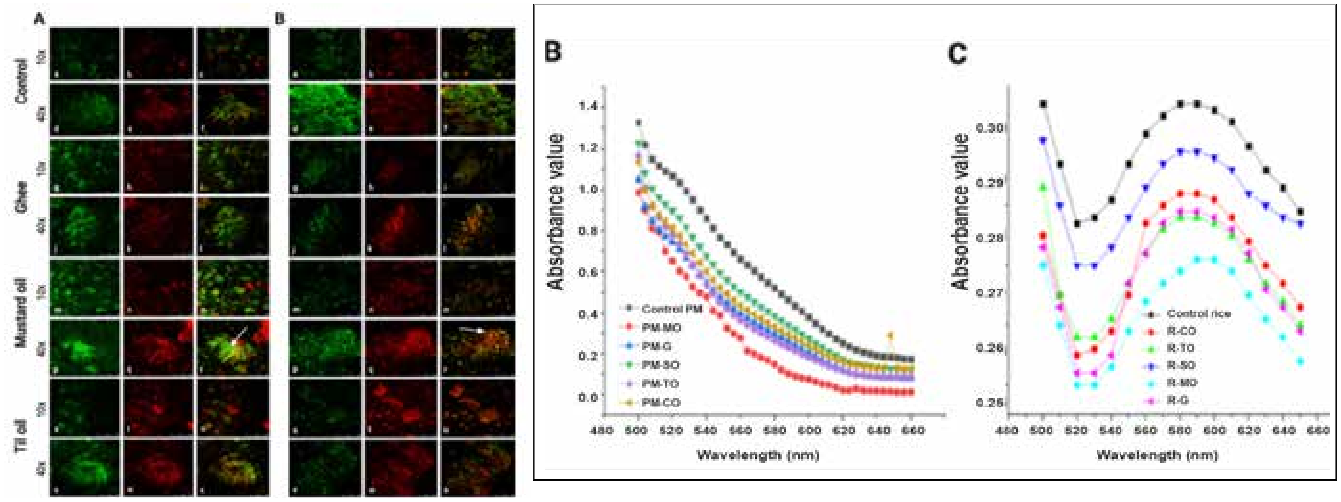
Plant protein blends were developed from steam-infused peanut and chickpea protein isolates and non-steam-infused brown rice protein isolates in the ratio of 30: 30: 40, respectively. Steam-infused protein blends (SIPB) were found to have well-balanced amino acid scores of >100 for all the essential amino acids, the highest protein content (84.44%) and protein digestibility (89.61%) with better physico-chemical properties, and less free sulfhydryl content (6.04 µmol/g). Hence, the developed protein blends can serve as an excellent protein source in daily diet.

6.2.5 Identification of nutrient-dense hulless barley genotypes for food

Fifty-two hulless barley genotypes were evaluated for different nutritionally relevant traits. Around 2-fold variation were observed in the content of most of the traits except protein content. The genotypes were scored, and the genotypes with the best combination of all the nutritional traits were identified and recommended for food purposes. The donors for each trait were identified which can be utilized in hulless barley improvement programmes.

6.2.6 Lipid-induced digestive resistance of starch limiting glucose bioavailability

Five cooking fats (ghee [GH], coconut oil [CO], sunflower oil [SO], mustard oil [MO], til oil [TO] having varied fatty acyl chain length and degree of saturation were used to understand their effect on altering the inherent glycemic potential (IGP) of rice and pearl millet. The addition of MO in both starches enhanced the network of long and short-range starch molecular assemblies (degree of crystallinity, CD%, and R1047/1022), which ultimately limited the accessibility of digestive enzymes. *In-vitro* glucose diffusion assay (GDRI) showed less glucose release of MO-induced complexes (PM-MO and R-MO) into the system.



Left: Starch-lipid interaction through confocal microscopy Right: Complexing index of starch and lipids

6.2.7 Phenolic profiling of differently pre-treated processed orange carrots

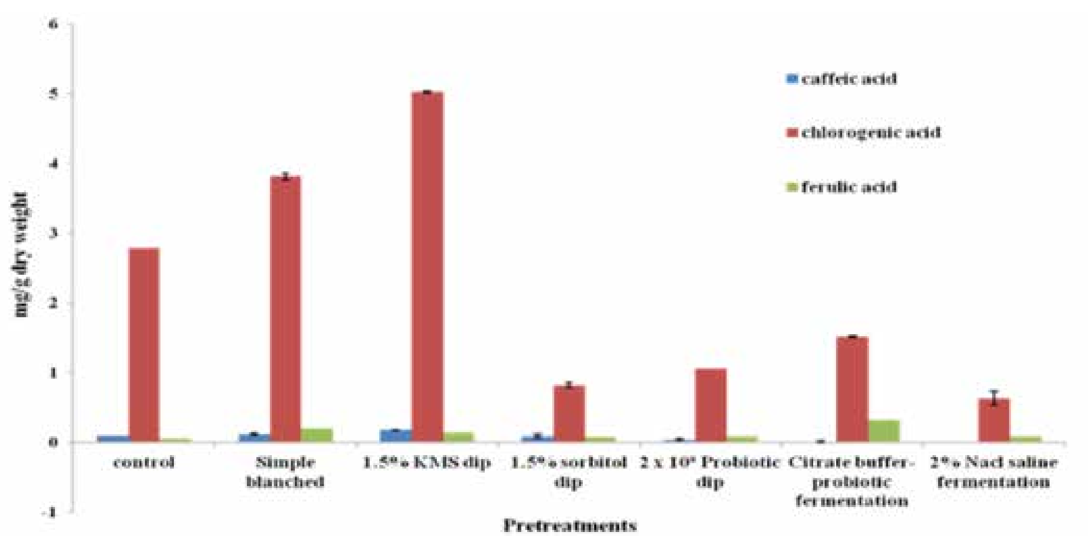
Maximum caffeic acid was observed in 1.5% potassium meta bi-sulphate (KMS) dipped slices (0.18 mg/g DW) followed by simple blanched slices (0.12 mg/g DW). Similarly, high chlorogenic acid was observed in 1.5% KMS dipped slices (5 mg/g DW). The ferulic acid content was higher in citrate buffer-probiotic fermented slices (0.31 mg/g DW).

6.3 PLANT PHYSIOLOGY

6.3.1 Abiotic stress tolerance

6.3.1.1 Effect of waxiness in imparting heat stress tolerance in wheat mutants

Twelve mutant lines (gamma irradiated seeds, M_5 generation) of wheat *cv*. HD 3086 namely, 51-03, 60-08, 70-02, 70-03, 70-04, 85-09, 139-02, 144-03, 179-06, 202-04, 211-01, 215-02 (with variability in waxiness) were



UPLC profiling of phenolic compounds observed in pretreated dehydrated orange carrot products

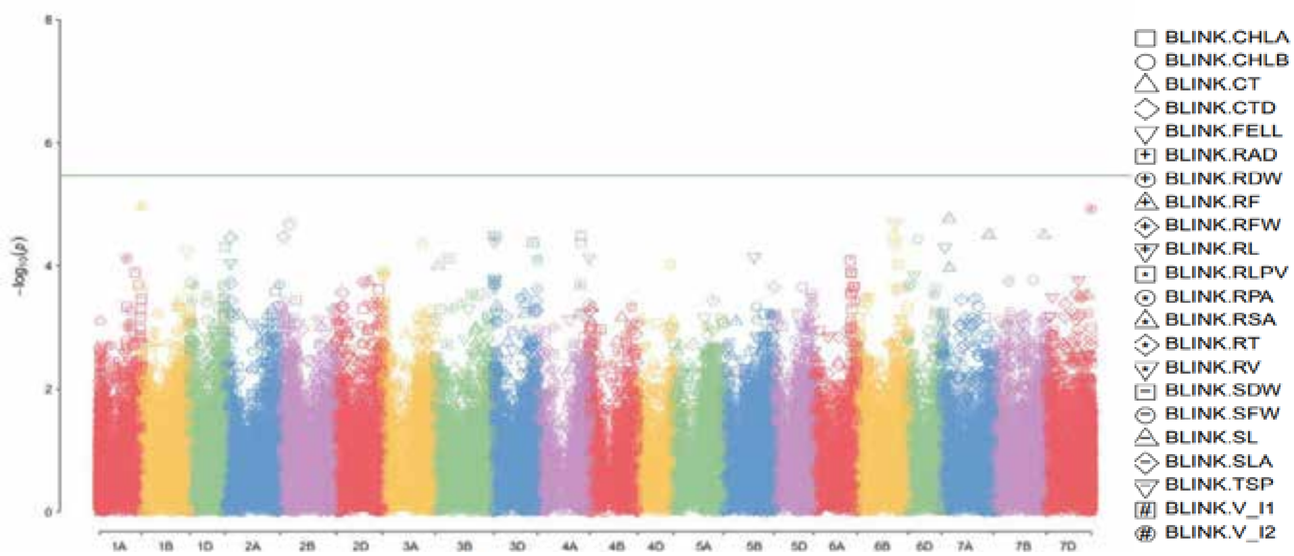
used along with control (wild-type) for analyzing the impact of waxiness in thermotolerance. We observed a positive correlation between lower temperature in flag leaf, peduncle, spikelets and awns during the anthesis and post-anthesis period and grain yield. Based on the content of ECW, mutant lines 139-02 (most-waxy type) and 70-03 (most non-waxy type) emerged as highly contrasting types.

6.3.1.2 Evaluation of wheat germplasm for stay-green traits under multiple stresses

Wheat germplasm (298) was screened for stay-green traits in flag leaves at anthesis and post-anthesis stages under drought, heat, and combined stress conditions. Principal Component analysis (PCA) revealed that the variables explained 76.6% of the total variance in PC 1 and 2 under all four conditions. The correlation and heat map analyses revealed that genotypes HD 3086 and DBW 187 performed well under control and water-limited conditions, with significant positive correlations with the stay-green traits and total grain weight, respectively. Under combined stress conditions, HD 2967 and VL 829 showed a significant positive correlation with stay-green traits.

6.3.1.3 Identification of donors and MTAs associated with seedling stage high night temperature tolerance in wheat

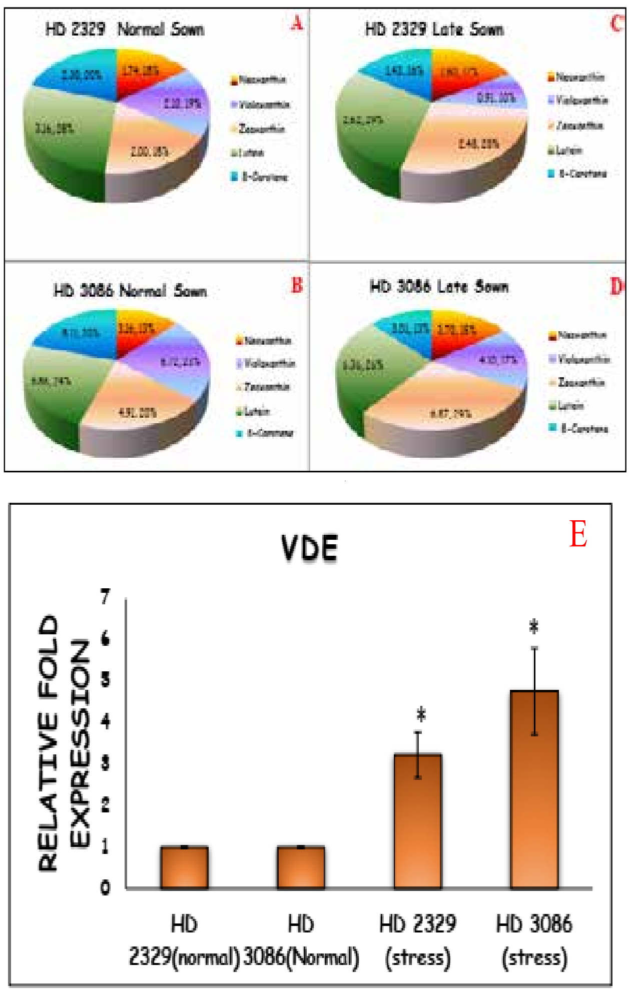
Wheat is sensitive to high night temperature, which causes the establishment of a poor crop stand as it prevails during seedling emergence. A study was conducted to phenotype 290 diverse wheat germplasm to select donors to tolerate high night temperature (HNT) of ~4.9º C over ambient and identify associated SNPs/genes. Phenotypic variability was observed for vigor indices (VI), root and shoot dry weight (RDW and SDW), root architecture, length of first emergent leaf, specific leaf area, chl a/b and total soluble protein. The correlation matrix of 41 selected tolerant genotypes (<10% reduction in SDW) showed that early vigor (VI-II) was positively (r= 0.431***) correlated with HNT tolerance at the seedling stage. Trait association mapping of 290 genotypes, genotyped using the Axiom Breeders 35k SNP array, revealed the presence of 22 SNPs associated with HNT tolerance, with 3 highly significant SNPs located on chromosomes 1A,1B and 7D, being related to early vigor. *In silico* analysis led to the prediction of the Phosphatidyl glycerophosphate phosphatase (PTPMT2-like) gene as an effector for VI-II under HNT.



Manhattan plot representing significant MTAs identified from the traits under HNT

6.3.1.4 Phenotyping of wheat genotypes for photosynthetic pigments in developing green grain to dissect the photoprotective mechanism for heat tolerance

Wheat genotypes (32) were screened based on photosynthetic pigment content, and five genotypes (PET 1239, PBW 555, Raj 3765, HD 3086 and HD 2851) were identified as heat tolerant. Thermotolerant genotypes maintained higher levels of photosynthetic pigments, zeaxanthin, Fv/Fm, Y(II), and NPQ, activities of antioxidant enzymes, expression of VDE, PEPC, and Rubisco genes, yield and its components as compared to sensitive ones. Zeaxanthin cycle pigment was observed to be involved in photo-protection.



Carotenoids Composition (μg g⁻¹ FW) (A-D) and VDE gene expression (E) in developing green grain of wheat varieties HD 2329 and HD 3086 under normal and late sown heat stress condition

6.3.1.5 Precise phenotyping of wheat genotypes for heat stress (HS) tolerance

Diverse wheat genotypes (300), including four checks (HD 3271, HD 3086, HD 3237, HD 2967), were phenotyped for HS-tolerance at the Nanaji Deshmukh Plant Phenomics Centre, ICAR - IARI, New Delhi. Biomass, HI and many other traits were found to be effective for selecting heat-tolerant genotypes. Multi-trait genotype-ideotype distance index (MGIDI) analysis identified superior heat-tolerant donor genotypes.

6.3.1.6 Role of root traits in drought tolerance during different stages of lentil

A set of 119 lentil (*Lens culinaris* Medik.) genotypes was screened in controlled conditions to assess the variability in root traits to drought tolerance at seedling and reproductive stages to select three drought tolerant genotypes (IC560051, IC560032, IC560246), which can be utilized as donors in lentil breeding.

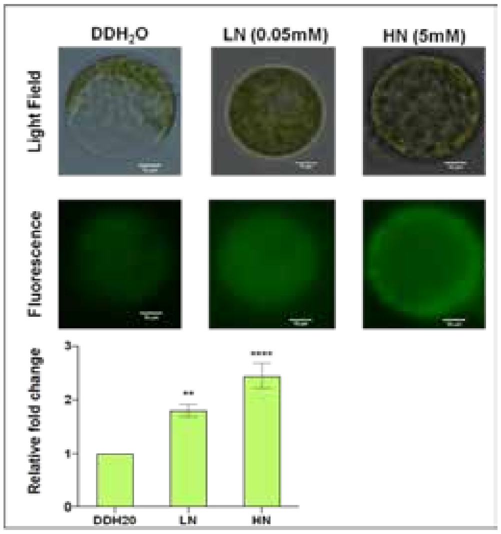
6.3.1.7 Photosynthesis in different ear parts of wheat

Measurement of ear photosynthesis in the whole ear and ear components (*i.e.*, awns, spikelets, grains, and rachis) indicated that the glumes contributed most to the spikelet photosynthesis (72.3%), followed by grains (15.1%), awns (11.1%) and rachis (1.4%).

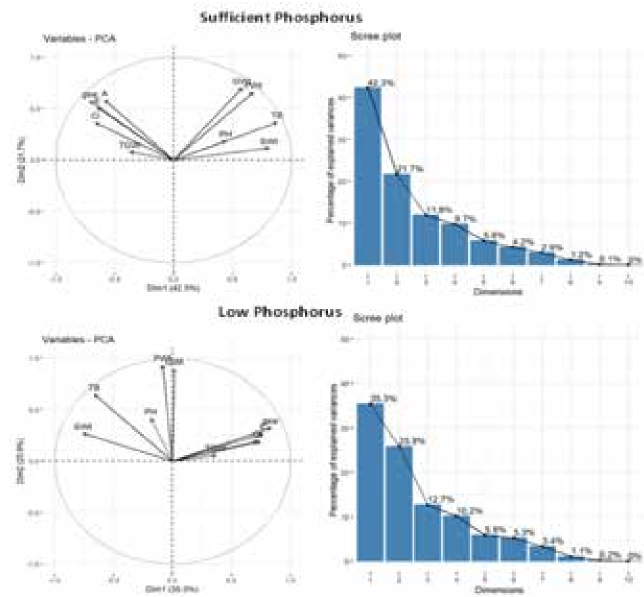
6.3.2 Nutrient use efficiency

6.3.2.1 Calcium dependent regulation of primary nitrate response (PNR) in wheat

Time course changes in expression of PNR sentinel genes; NPF6.1, NPF6.2, NRT2.1, NRT2.3, NR, and NIR in wheat manifested the highest expression level at 30 min after NO_3^- exposure. The use of Ca^{2+} chelator EGTA confirmed the involvement of Ca^{2+} in the regulation of transcription of NPFs and NRTs as well the NO_3^- uptake.



The intensity of calcium fluorescence was observed in leaf protoplasts isolated from 10-day-old N starved seedlings. Protoplasts were pretreated with calcium indicator Fluo-3AM and exposed to low nitrate (LN; 0.05 mM NO_3^-) and high nitrate (HN; 5 mM NO_3^-) were observed under fluorescence microscope



Principal component analysis using 10 traits in 272 diverse rice genotypes grown under sufficient and low P conditions in soils

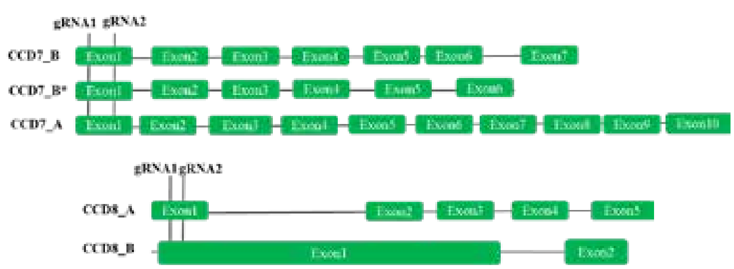
6.3.2.2 Phenotyping of rice genotypes for low phosphorus stress tolerance

Rice accessions (272) were selected from 3KRG panel (IRRI) belonging to ssp. *indica* and the seedlings were transplanted to pots filled with soil having sufficient P (60 kg/ha) and low P (0 kg/ha) levels. Photosynthesis-related traits, plant height (PH, cm), panicle weight (PWt, g), grain weight (GWt, g), 1000-grain weight (TGW, g), straw biomass (SWt, g), total biomass (TB, g) were measured. Data analysis showed that the P × genotype interaction for all traits, except TGW, were significant. Mean values for traits like PH, PWt, SWt, TB, GWt and P_N in low P soil showed a more than 10% reduction compared to sufficient P. The common traits between sufficient P and low P governing genotypic variability were total biomass, shoot biomass, panicle grain weight, stomatal conductance, and internal CO_2 concentration that can be targeted for further studies.

6.3.3 Genome editing in rice and Brassica

6.3.3.1 Development of CCD7/CCD8 genome-edited lines in *B. juncea*

In *Brassica juncea*, CCD7 and CCD8 genes were amplified from PM30. The sequence was BLAST searched with Varuna genome to find out the hits. The first exons of the CCD7 and CCD8 genes were

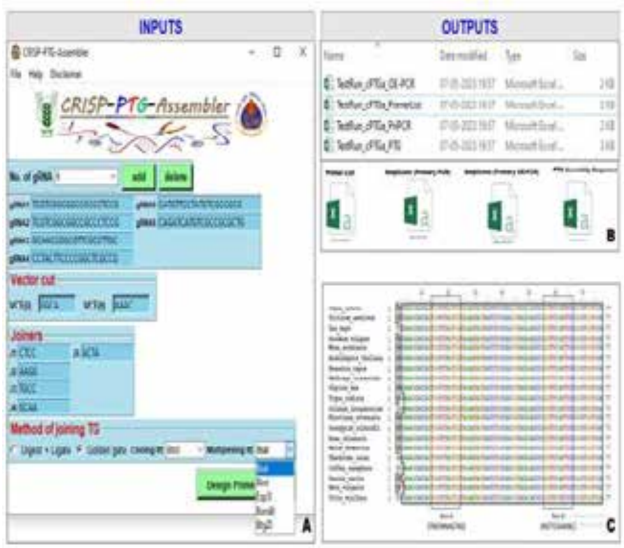


Pre-culturing of explants (hypocotyls) on pre-culture media (MS Basal + 3% sucrose + BAP (2mg/L) + NAA (0.2mg/L) (b) Initiation of callus induction (c) Shoot induction through callus after 15-20 days

used to design SgRNA which were later cloned and transformed in *Brassica* variety PM 30 and Pusa Bold.

6.3.3.2 CRISP-PTG-Assembler: A software for primer designing and assembly of polycistronic tRNA-gRNA (PTG) construct

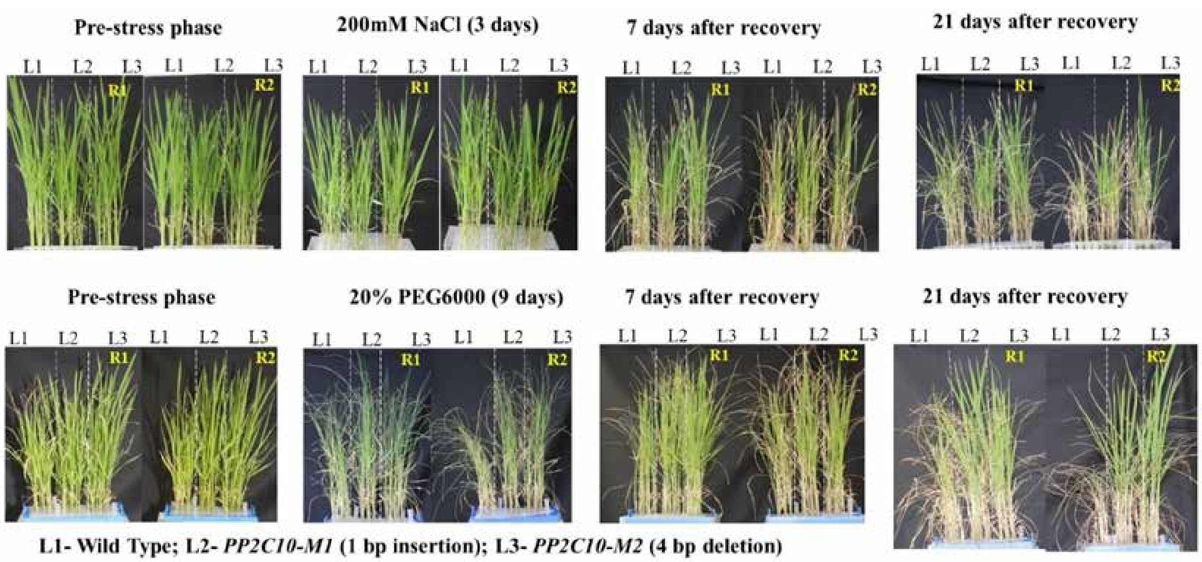
Several strategies exist to perform multiplex genome editing. Generation of multiple Cas9-loadable sgRNA units from a polycistronic tRNA-gRNA assembly (PTG) by exploiting natural tRNA processing system of the cell is one of the most ingenious methods. Designing a PTG *in vitro* requires overlap extension PCR (OE-PCR) followed by Golden Gate assembly (GG)/ Restriction Ligation assembly (RL). With this background, a "CRISP-PTG-Assembler", a Windows-based desktop application (Category: Bioinformatics Software) was developed to hasten the process of primer designing accuracy. The software has wider application for PGT construct designing all plant species.



CRISP-PTG-Assembler Software

6.3.3.3 Enhancing drought & salt stress tolerance in rice through CRISPR-*Cas9* editing of DST gene

Transgenic plants expressing the sgRNA and Cas9 expression cassette (POsU3::-sgRNA1-PUQ::SpCas9n-POsU3::sgRNA2) were successfully developed. The homozygous mutant lines were generated for OsPP2C10 (3 new alleles), OsPP2C12 (2 new alleles), and OsPP2C48 (4 new alleles), along with heterozygous mutants for OsPP2C81, OsPP2C79, and OsPP2C108 (1 new allele). Utilizing the mutants of PP2C10 and PP2C48, double mutants of PP2Cs were created to enhance abiotic stress tolerance in rice cultivar MTU 1010. OsPP2C10 mutants showed improved stress tolerance at the seedling stage.



Drought and salt tolerance of wild type and PP2C10 mutant. Fourteen days old seedlings were treated with 20% PEG6000 (9 days) and 200 mM NaCl (3 days), followed by a recovery period in hydroponic nutrient solution

6.4 GENETICS

6.4.1 Wheat

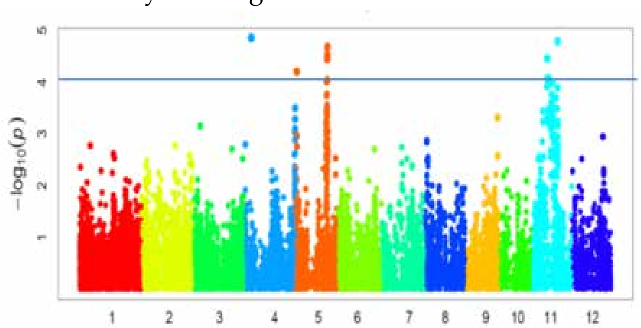
6.4.1.1 GWAS to identify loci and candidate genes for grain micronutrients and quality traits in Indian dwarf wheat *T. sphaerococcum*

The genomic regions associated with six important grain quality parameters (grain hardness index, gluten index, wet gluten, dry gluten, GPro, GFe and GZn) were identified through association mapping of a panel comprising 116 Indian dwarf wheat accessions using 35k genotypic data information. Out of the 322 QTNs, 74 identified in at least two models were reliable. Gene annotation for the highly reliable QTNs identified putative candidate genes like Flavanone 3-dioxygenase 3 and Superoxide dismutase for GZn, Peroxidase 52, U-box domain-containing protein 73, and Probable LL-diaminopimelate aminotransferase for GFe which can be applied to marker-assisted bread wheat breeding program.

6.4.2 Rice

6.4.2.1 GWAS for assessing the variations in Resistant Starch (RS) content in rice germplasm

A GWAS panel consisting of 192 rice germplasm accessions was analyzed for RS content, ranging from 0.15 (CR-2461) to 5.38 (HUR 105). GWAS led to the identification of significant MTAs in chromosomes 4, 5, and 11, of which the MTA in chromosome 5 lies in the Rice starch regulator 1 gene, which codes for a transcription factor regulating the expression of Group 1 starch biosynthesis genes.



Manhattan plot showing the significant MTAs for RS content

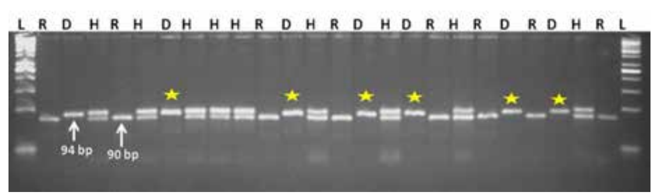
6.4.3 Maize

6.4.3.1 Identification of novel SNP in domain membrane protein (DMP) gene influencing *in vivo* haploid induction in maize

A novel SNP (G to A: SNP2), along with earlier reported SNP1 (T to C) that distinguished wild-type and mutant- alleles of DMP, converted alanine to threonine and methionine to threonine at positions 87 and 44, respectively. Two breeder-friendly PCR-based markers specific to SNP1 and SNP2 were developed. These markers identified four haplotypes, *viz*., Hap-DMP-TG, Hap-DMP-CG, Hap-DMP-TA, and Hap-DMP-CA, among 48 diverse maize inbreds. Both SNP1 and SNP2 were present in DUF769_motif1 and DUF769_motif3, respectively.

6.4.3.2 Development of breeder-friendly marker for *waxy1* (*wx1*) gene

Three polymorphisms *viz*., 4 bp InDel (at position 2406 bp) in intron-7, and two SNPs (C to A at position 3325 bp in exon-10 and G to T at position 4310 bp in exon-13) differentiated the dominant (*Wx1*) and recessive (*wx1*) allele. Three breeder-friendly PCR markers (WxDel4, SNP3325_CT1 and SNP4310_GT2) specific to InDel and SNPs were developed. WxDel4 amplified 94 bp among mutant-type, while 90 bp was amplified among wild-type inbreds. SNP3325_CT1 and SNP4310_GT2 revealed presence-absence of polymorphisms with amplification of 185 bp and 189 bp of amplicon, respectively.



Segregation of WxDel4 marker in BC2F2 population

6.4.3.3 Regeneration protocol from matured embryo

The seeds were allowed that to germinate in a media containing 5 mg/l 2, 4-D caused the hypocotyl region to enlarge which was later split longitudinally and again allowed to regenerate. Multiple shoots (2-5) were obtained in six of 10 genotypes. IARI-derived inbred, PMI-PV5 was identified as the best responsive genotype among the six genotypes studied.

Emergence of shoots from matured embryo

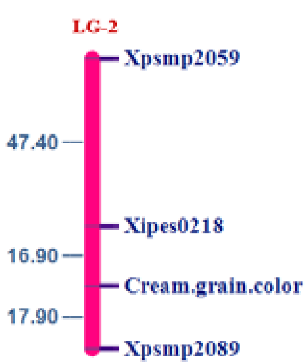
6.4.3.4 CRISPR/Cas9 construct for haploid induction

A CRISPR/Cas9 construct was developed with three guide RNAs designed from the functional domain of the protein encoding *MTL* and *DMP* genes governing haploid induction in maize. The hygromycin resistance gene was utilized as a selectable marker to identify plants successfully transformed with the CRISPR/Cas9 construct targeting the *MTL* and *DMP* genes in maize.

6.4.4 Pearl millet

6.4.4.1 Molecular mapping of gene controlling cream grain colour in pearl millet

Molecular mapping and validation of gene controlling cream grain colour in pearl millet revealed it to be present on linkage group 2 and flanked by markers *Xpsmp 2089* and *Xipes 0218* at a distance of approximately 16.9 cM and 17.9 cM, respectively.



6.4.5 Chickpea

6.4.5.1 GWAS for root and nodulation traits

An association panel consisting of 327 genotypes was evaluated at IARI, New Delhi; SHUATS, Allahabad, UP; GBPUAT Pantnagar, Uttarakhand, with four checks, namely BG 372, BG 3022, BGM 547, and BG 1105. Five SNPs for the number of nodules (NON) were found to be on LG1. Further, one SNP was present on LG3 for root length.

6.4.5.2 Identification of heat stress (HS) transcription factors at the pod development stage

A genome-wide analysis of *Hsfs* gene family resulted in the identification of 22 *Hsf* genes in chickpea in both desi and kabuli genome. qRT-PCR expression analysis of *Hsfs* under HS during pod development and in 15 days old seedling stage showed significant upregulation of *CarHsfA2*, *A6*, and *B2* in both the stages, whereas *Hsfs* (*CarHsfA2*, *A6a*, *A6c*, *B2a*) were upregulated only at seedling stage.

6.4.6 Lentil and Mungbean

6.4.6.1 QTL-Seq for multi-flowering (MF) in lentil

Phenotyping of lentil genotypes revealed that MFX was an MF-type genotype that produced 5-FPP, while ILL7663 was a normal flowering (NF) type that produced 2-FPP. F_2 from ILL7663 × MFX generated displayed 13:3 segregation for MF:NF. A high throughput QTL-seq strategy employed in $F_{3:4}$ lines identified two QTLs on chromosome 3 having five flowering pathway-related candidate genes.

6.4.6.2 GWAS analysis for grain micronutrients and anti-nutritional traits in mungbean

The association mapping panel of 145 diverse mungbean for grain micronutrients (iron and zinc) and anti-nutritional factors (phytic acid and tannin) was evaluated. Based on all four parameters, genotypes Pusa

1333 and IPM 02-19 were observed as desired genotypes with high Fe, Zn but low phytic acid and tannin content. This study identified 185 putative candidate genes linked with grain Fe (Vradi07g30190, Vradi01g09630, and Vradi09g05450), Zn (Vradi10g04830), phytic acid (Vradi08g09870 and Vradi01g11110) and tannin content (Vradi04g11580 and Vradi06g15090).

6.4.6.3 Morpho-biochemical characterization of a RIL population for seed parameters and identification of candidate genes regulating seed size trait in lentil

Linkage analysis was done for seed size in a RIL ($F_{5:6}$) population derived by crossing L830 (20.9 g/1000 seeds) with L 4602 (42.13 g/1000 seeds) which consisted of 188 lines (15.0 to 40.5 g/1000 seeds). Marker PBALC449 differentiated the parents and small seed size bulk without large seeded bulk or the individual plants. The PBLAC449 marker was localized on chromosome 3 having candidate genes like ubiquitin carboxyl-terminal hydrolase, E3 ubiquitin ligase, TIFY-like protein, and hexosyltransferase having role in seed size determination.

6.4.7 Mustard

6.4.7.1 Development of molecular markers for seed coat colour

Two contrasting parents [DRMRIJ-31 (brown) and RLC-3 (yellow)] for seed coat colour were used to study the inheritance of seed coat colour. The trait was identified to be under maternal effect and controlled by digenic-duplicate gene action. Further, Bju.TT8 homologs of both the parents were cloned and sequenced, and functional markers were developed for both the Bju.TT8 homologs. These were also validated in F_2 population.

6.4.8 Soybean

6.4.8.1 *In vitro* androgenesis

Under aseptic conditions, anthers were dissected from buds ranging from 2.9 to 3.1 mm, pre-treated under 4° C for 24 hours and cultured in BNN medium supplemented with 10 mg/L 2,4-D and 1 mg/L BAP initially incubated at 7 °C under dark for one week followed by 16/8 light cycle at 26±2 °C continuously. After four weeks, the calli were transferred into MS media supplemented with 1.5 mg/L BAP & 0.5% activated charcoal and proliferated under 16/8 photoperiod at 26±2 °C for two weeks. The protocol developed was found to be simple, rapid and beneficial for mass multiplication.

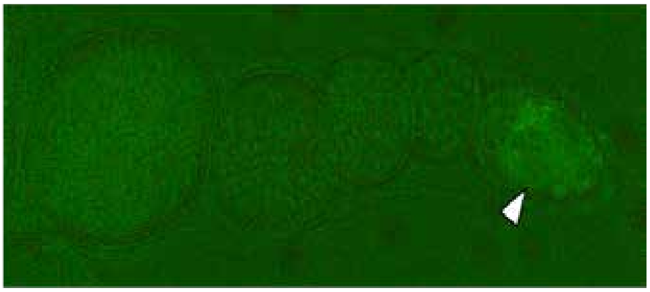
6.4.9 Drosophila

6.4.9.1 Transcript localization of *DWnt4* by RNA *in situ* hybridization in novel *DWnt4* mutant allele and other segment polarity genes

A clone containing *DWnt4* CDS in the TOPO TA pcrII vector was developed. The clone that could generate an antisense RNA probe was chosen to synthesize the *DWnt4* RNA probe using T7 reverse transcriptase and quantified using dot blot hybridization assay. The expression of *DWnt4* was similar to the gene *wingless* but it started after stage 8 and continued until stage 14-15 of embryo development. The segment polarity-like pattern was visible in embryos at stage 10, which was marked by an extended germ band.

6.4.9.2 MARCM clones in the germline ovaries of *DWnt4*^{AL7}

The germline clones of *DWnt4*^{AL7} are arrested in stage 6 of oogenesis. With the technique of MARCM (Mosaic Analysis with Repressible Cell Marker) clones of cells positively marked with GFP in the ovarian niche can be generated. The MARCM clones of *DWnt4*^{AL7} were generated in the terminal filaments



Single germarium showing MARCM clones induced in terminal filaments

of the developing ovaries to be used in studying the expression of 1B1 and other stem cell-specific markers.

6.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS AND AGRICULTURAL METEOROLOGY

6.5.1 Soil Physics

6.5.1.1 Development of tillage and residue mulching module in InfoCrop V2.1 model

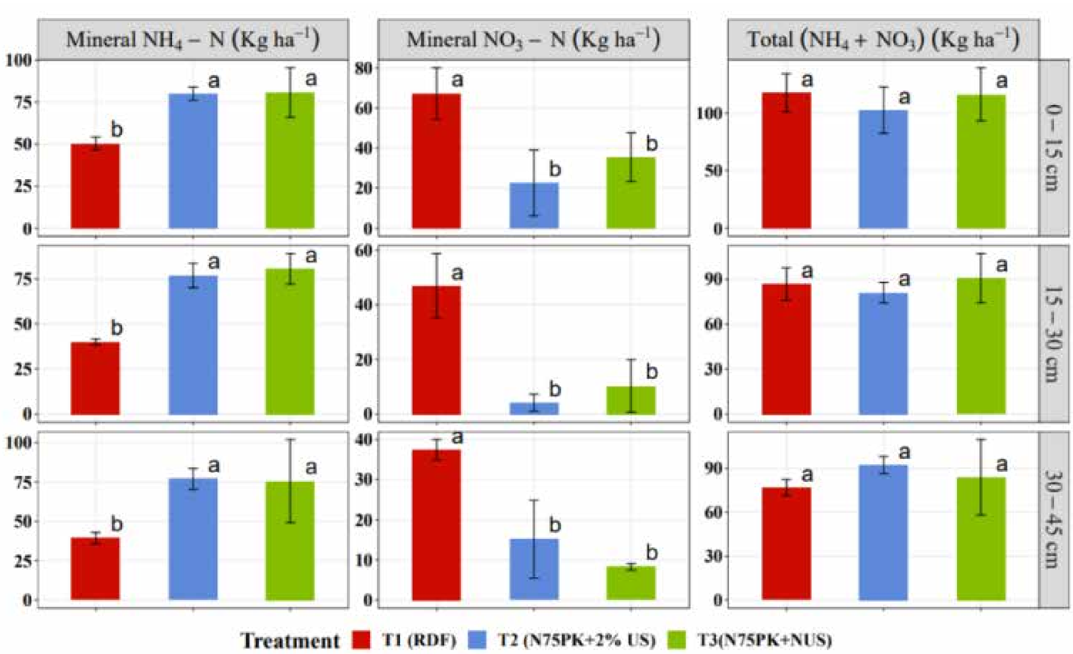
The evaluation of the modified InfoCrop-Tillage and Residue Mulching module showed that the model could account for 84% variation in the observed grain yield with an RMSE of 384 kg/ha and nRMSE of 8.6%. It also showed satisfactory result for validation of WP and NP with R^2 0.82 and 0.97, RMSE of 0.11 and 4.67, and nRMSE of 7.5 and 10.7%, respectively.

6.5.1.2 Use of fractal dimension in four machine learning algorithms improves the prediction accuracy of mean weight diameter of soil

A total of 121 soil samples from 0-15 and 15-30 cm soil depths were collected from 17 villages of Nilokheri, Nissing, and Assandh blocks of Karnal district. In the training dataset, RMSE (mm) for the SVM model was 8.33% lower with fractal dimension than with texture as the input, whereas, in the testing dataset, it was 16.67% lower.

6.5.1.3 Farm irrigation scheduling using open-source multi-sensor satellite data

To monitor ET estimation in real-time, Surface Energy Balance (SEB) models based on optical-thermal bands (Landsat 8/9) and Optical Trapezoidal Model-based Evapotranspiration (OPTRAM-ET) model based on optical bands (Sentinel 2) and six SEB models using remote sensing observations were evaluated, and SEBAL had the highest correlation coefficient (r) of 0.93 and a root mean square error (RMSE) of 0.58 mm d^{-1}, while OPTRAM-ET also provided reliable ET estimation with r = 0.89 and RMSE = 0.9 mm d^{-1}. GBM and RF ML algorithms with selected covariates using Boruta performed the best (r ~0.83 and RMSE ~2.9%) in capturing the profile soil moisture. Landsat remote sensing was more accurate in estimating soil moisture profiles than Sentinel-2.



Mineral nitrogen (NH_4 + NO_3) contents in soil after the harvest of rice crop

6.5.2 Biophysics

6.5.2.1 Efficacy of nano- versus prilled urea on plant biophysical attributes and nitrogen uptake in rice

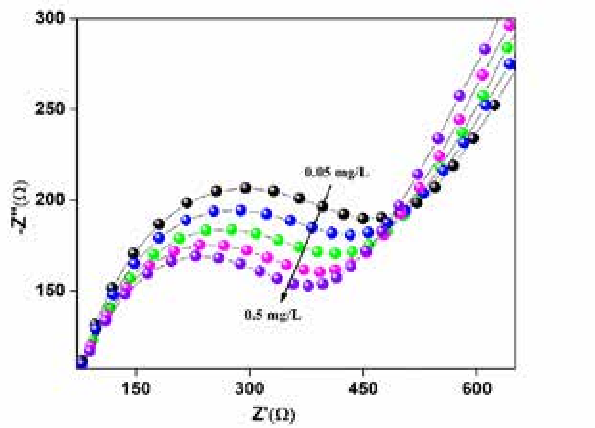
Pusa Basmati-1692 was treated with - T_1 [recommended dose of N, P, and K-soil application], T_2 [75% of N-soil application + foliar sprays of 2% prilled urea solution at active tillering and flowering stage], and T_3 [75% of N + foliar spray of nano-formulation @ 4 mL L^{-1} at active tillering and flowering stage]. The study found that 25% savings of N can be achieved through nano urea foliar spray without any reduction in yields, but with lower total N uptake.

6.5.2.2 Estimation of yellow rust severity in wheat and chickpea wilt severity using visible and thermal imaging coupled with machine learning (ML) algorithms

Field experiment was conducted to obtain visible and thermal images of 24 wheat cultivars with different disease resistance levels to yellow rust at critical growth stages. Machine learning (ML) models achieved an R^2 and d-index above 0.95 during calibration and up to 0.67 and 0.87, respectively, during validation. The cubist model with the indices was the best model to predict WYR severity. Similarly, Cubist was the best ML algorithm, while the KNN model was the poorest predictor of chickpea wilt severity under field conditions.

6.5.2.3 Development of electrochemical impedance biosensor using organic nanotubes deposited on screen printed electrodes

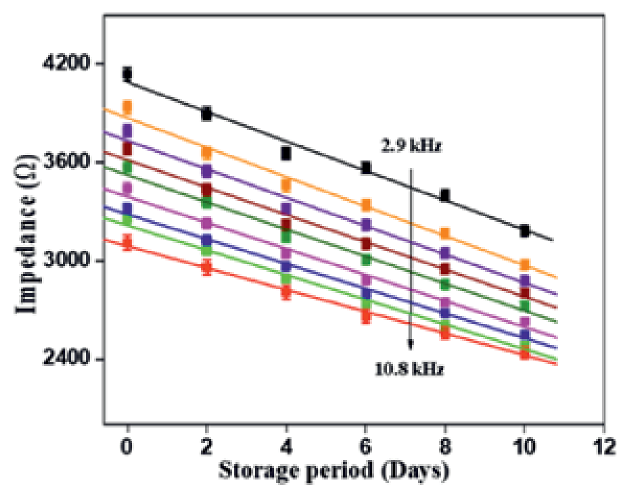
The electrochemical impedance spectroscopy (EIS) technique was used to fabricate and develop the biosensor. Heterogeneous electron transfer rate constant for SPE, MWCNT/SPE and NiR/MWCNT/SPE electrodes were found to be 1.03×10-6 cm/s, 2.21×10-6 cm/s and 2.44×10-6 cm/s, respectively. Using the developed biosensor, a sensitivity of $9.01 \times 10^{-4}\ \Omega^{-1}$ $(mg/L)^{-1}$ is obtained for nitrate detection in soils.



Nyquist plot for the biosensor with varying analyte concentration

6.5.2.4 Non-destructive technology for quality evaluation of agricultural produce

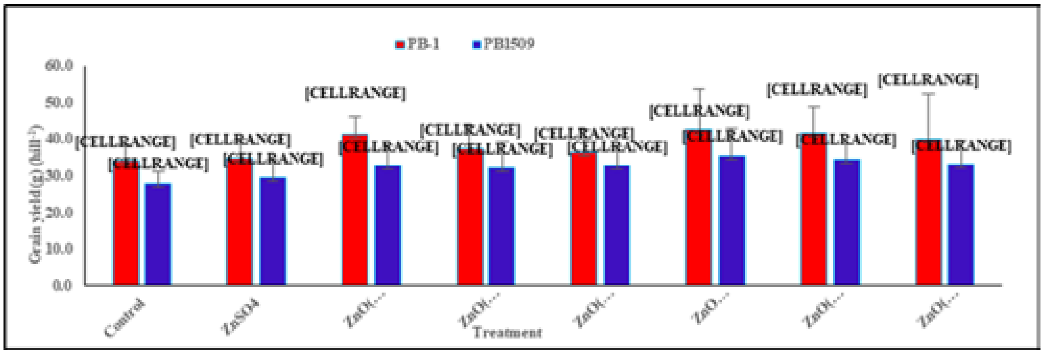
Studies were conducted to develop a technology for quality evaluation of guava fruit (*Psidium guajava*) by impedance spectroscopy. The impedance of the guava fruit decreased with the storage period. The peak value of impedance was the highest for the lower threshold frequency (2.9 kHz) and at higher frequencies (>50 kHz) the impedance values did not show significant change with the storage period.



Measured peak impedance vs. storage period at different threshold frequencies

6.5.2.5 Effect of Zinc Oxide Nanoparticels (ZnO-NPs) on growth and yield of rice

Zinc oxide nanoparticles of varying size (38, 45 and 95 nanometers) as well as $ZnSO_4$ through the soil (20



Effect of ZnO-NPs (soil+ Foliar) treatments on grain yield of rice

mg/kg) and foliar (40 ppm ZnO-NPs for each size) were applied on two rice genotypes (PB-1 and Basmati 1509). The physiological parameters such as photosynthetic rate and chlorophyll content and biochemical parameters (catalase, superoxide dismutase and proline content) of rice crops notably increased ($p<0.05$) under ZnO-NP soil + foliar applications. The yield attributes such as grains ($spike^{-1}$), grain yield ($hill^{-1}$) were the highest under the smallest size ZnO-NPs soil + foliar treatment compared to other treatments.

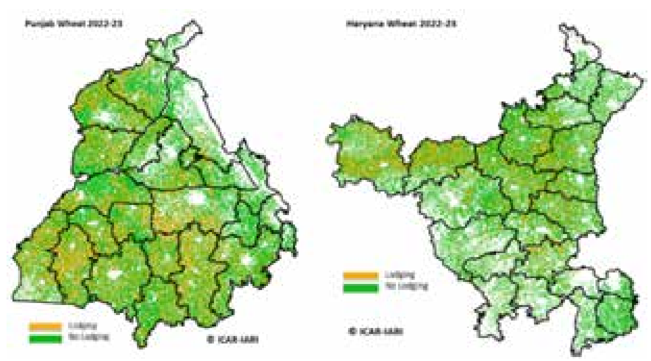
6.5.3 Remote Sensing and GIS

6.5.3.1 High-resolution *kharif* season composite agricultural drought index (ADI) for India

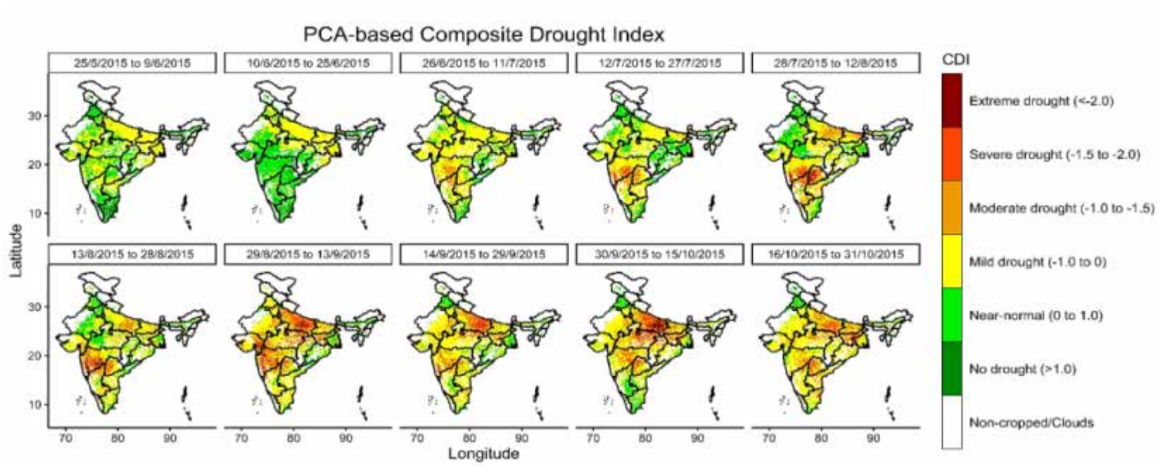
Research work was undertaken for developing a composite ADI for India at a grid size of one km using meteorological and remote sensing indices at 16-day intervals from 2001-2021. Fortnightly CADI maps for *kharif* season of 2015 capturing drought intensity across India.

6.5.3.2 Mapping extent of wheat lodging due to extreme rainfall in North-west India

Three major extreme rainfall events were observed in North-west India between March 26 and April 01, 2023, coinciding with the grain-filling and ripening stages of wheat crop. About 34.6% of wheat area in Punjab and 29.5% of wheat area in Haryana was estimated to be affected by lodging.

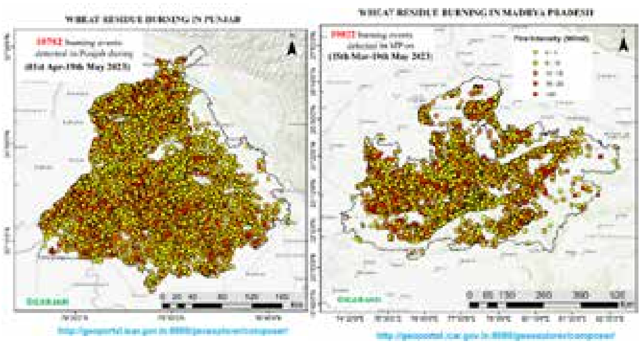


Maps showing wheat lodging estimated in Punjab and Haryana states during rabi 2022-23



6.5.3.3 Monitoring crop residue burning using satellite remote sensing during 2022-23

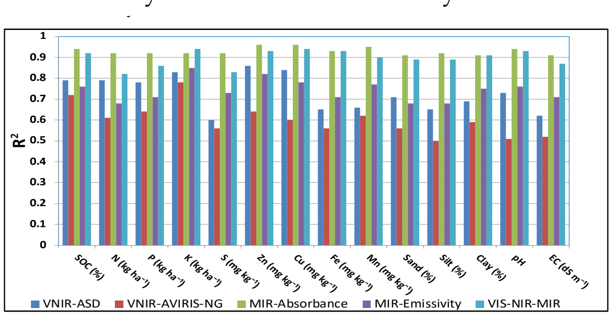
Total 38520 wheat burning events were detected in the five states between April 01, 2023 and May 31, 2023, which were distributed as 11355, 1900, 6427, 05, and 18833 in Punjab, Haryana, UP, Delhi, and MP, respectively. A total of 57209 rice-burning events were detected in the six states between September 15, 2022, and November 30, 2022, which were distributed as 36650, 2296, 3985, 05, 1773, and 12500 in Punjab, Haryana, UP, Delhi, Rajasthan, and MP, respectively.



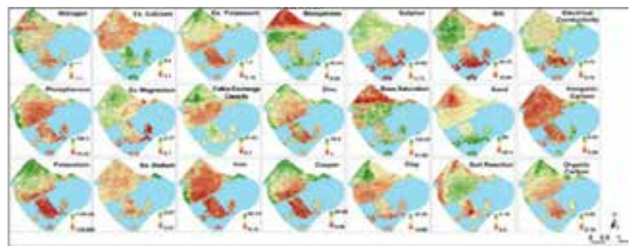
Maps showing active wheat residue burning events detected by satellites in Punjab and Madhya Pradesh during April 01 to May 19, 2023

6.5.3.4 Sensor-based rapid assessment of soil fertility and digital soil mapping

Predictive models were developed for 14 soil fertility parameters using different machine learning algorithms, and results obtained from wet chemistry were evaluated. The result revealed that MIR-absorbance spectroscopy-based technology was the best in estimating soil fertility (with R^2 mostly above 0.85) followed by the reflectance-based spectroscopy for soil fertility assessment in laboratory conditions.



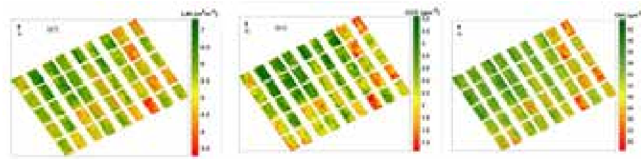
Prediction of soil fertility using different hyperspectral sensors



Digital Soil map of IARI for 21 soil fertility attributes

6.5.3.5 Drone based near real monitoring of crop condition for precision farming

Drone Remote Sensing technology was developed to monitor near real-time crop conditions through quantitative assessment of plant biophysical parameters such as leaf area index (LAI), canopy chlorophyll (CCC), and nitrogen content (CNC) of wheat crop for site-specific nitrogen application using variable rate technology. This is quite a cost-effective and environment-friendly technology that can be immediately used by the farmers.



Biophysical parameters of wheat field derived from Drone imaging

6.5.4 Agricultural Meteorology

6.5.4.1 Estimation of actual evapotranspiration using operational simplified surface energy balance (SSEBop) model

Performance of SSEBop model was evaluated using available cloud-free Landsat-8 data for *kharif* and *rabi* crops-grown during 2022–2023. Comparison and validation of SSEBop-based results with the field-based BREB approach showed a good agreement between them with $R^2 = 0.74$, higher d-index (0.75) and root mean-square (0.52 mm day^{-1}).

6.5.4.2 Yield optimization of Indian mustard by adjusting sowing dates through crop modelling

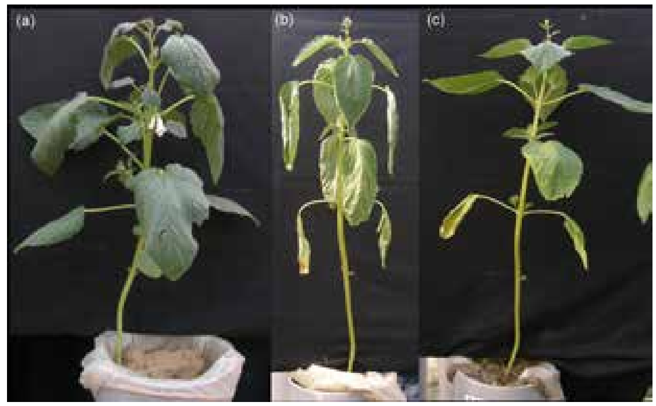
Two crop growth models, AquaCrop and InfoCrop were calibrated using the experimental data generated through field experiments on Indian mustard cultivars, *viz*, Pusa Vijay, Pusa Mustard 21 and Pusa Bold at ICAR-IARI, New Delhi over the period (2014-2022). The simulation through AquaCrop model indicated that the yield to be the maximum in *cvs.* Pusa Vijay (2.401 t/ha) and Pusa Mustard 21 (2.387 t/ha) and through InfoCrop model 2.497 t/ha for Pusa Vijay and 2.402 t/ha for Pusa Mustard 21, respectively, when sowing is done on October 15. However, *cv.* Pusa Bold can be sown on October 20 for the highest seed yield (2.231 t/ha) according to AquaCrop and around October 10 by InfoCrop to get the highest yield.

6.5.4.3 Weather based Agromet Advisory

Weather-based bilingual advisory bulletins based on past, real-time and forecast weather data were prepared on two days (Tuesday and Friday) a week and disseminated through print and electronic media to different stakeholders of the NCR region. Based on rainfall forecast during *Rabi* 2022-23, farmers saved three irrigation and three sprays (₹ 9,600/acre for each crop, ₹ 3200/acre for each spray).

6.6 NATIONAL PHYTOTRON FACILITY (NPF)

The controlled environmental facilities of the NPF was used by scientists and students from IARI and other ICAR institutes including NIPB, NBPGR, University of Delhi, etc. Experiments related to climate change, transgenic crops, gene expression and regulation, physiology of nutrient use efficiency, plant-pathogen interaction, biochemical and genetic interventions for crop improvement, etc. carried out at NPF. During this year, 123 new experiments were accommodated along with a few on-going experiments. Bulk of these experiments were from the In-house projects of the IARI post-graduate researches (78 Nos. constituting 63.41%); Institute's in-house projects (40 Nos. constituting 32.52%); and the paid experiments from out-funded projects and non-ICAR-institutes (3 Nos. constituting 2.44%) along with special herbicide-tolerant transgenic development programme from Ministry of Agril. (GOI) (2 Nos. constituting 1.62%). The NPF was visited by several students, trainees and Govt. officials for gaining practical experience of working in the Phytotron. Further, the Peer Review Team NAAC and a delegation from Guiana visited the Phytotron. The XV Genetics Congress Trust, New Delhi also arranged six visits for higher secondary biology students from various schools located in Delhi NCR.



Effect of drought on sesame plants: (a) control, (b) wilted plant after imposed drought at flowering and (c) Recovery of the drought-imposed plants after irrigation

6.7 VEGETABLE SCIENCE

6.7.1 Chilli

6.7.1.1 Doubled haploid production in capsicum (*Capsicum annuum* L.) hybrids

Ideal parameters for getting uninucleate or early binucleate pollens in the hybrids (Indra and Lakshmi) were standardized. Buds were pretreated at 4°C for 24 hours followed by pretreatment of anthers with 0.3 M mannitol solution and culturing on MS medium supplemented with 3% sucrose, 2.5 gm/l activated charcoal, 4 mg/l NAA, 1 mg/l BAP, silver nitrate 15 mg/l and 2.6 gm/l gelrite (pH 5.8). The anthers were kept in dark incubation for 3 to 4 weeks and subsequently transferred to 25°C with 16/8 h photoperiod. Embryo induction was observed in anther derived microspores after 8-9 weeks of culture.

6.7.1.2 Mapping of QTLs/ genes for heat tolerance in hot pepper

We identified 21 major QTLs, controlling nine morphological, three physiological and two biochemical traits controlling heat tolerance through comprehensive phenotyping and double digest restriction-site associated DNA (ddRAD-seq) sequencing of F2 population (developed through the crossing of heat tolerant DLS-161-1 and heat susceptible DChBL-240 along with the parental lines).

6.7.2 Cauliflower

6.7.2.1 Expression analysis of genes linked with developmental transitions in orange and white curd

Expression of ten genes *viz*. BoFLC2, Bo FH, BO VrN2, Bo VRN2, BO Rem, BO FT, Bo LFY, Bo Cal, Bo AP2 Bo CCE and Bo Ful D involved in developmental transitions in Brassica showed higher expression of Bo CCE and Bo Lfy in Heterozygous (*Or/or*) mutants having yellow and good curd.

6.7.2.2 Identification of QTLs for dietary minerals content in cauliflower

Genotyping by sequencing (GBS) of 141 cauliflower genotypes revealed 35006 SNPs. Association analysis with eight dietary nutrients in leaf and curd portions (analysed for 3 years) resulted in a total of 148 significant SNPs for dietary mineral contents in curd and leaf portions including Cu (16, 16), Fe (9, 9), Zn (11, 11), K (32, 30), Mn (20, 21), Na (20, 20) and Ca (16, 16).

6.7.3 Cucumber and muskmelon

6.7.3.1 Optimizing a hydroponics-based protocol for drought stress response in cucumber

Eight tolerant genotypes were identified with high seedling survivability percentage, minimum reduction in root–shoot dry weight, fresh weight and water content percentage, highest DTMS and minimum yield reduction under field stress conditions compared with seven identified sensitive genotypes.

6.7.3.2 Molecular mapping of downy mildew and ToLCNDV resistance in cucumber and muskmelon

QTL-seq analysis successfully identified 383 SNPs on chromosome 3 and 180 SNPs on chromosome 6. Nine putative candidates involved in disease resistance were identified on chromosome 3 and three on chromosome 6. Using the QTL-seq approach, a QTL of 0.7 mb governing resistance to ToLCNDV and harboring 24 candidate genes was found on Chromosome-2. Using a similar QTL seq approach, we identified 2,851,624 polymorphic SNPs in muskmelon.

6.7.3.3 Understanding the genetic and molecular basis of extended shelf-life in cucumber

The study revealed that a single recessive gene governs the retention of green color in cucumber (DC-48), while the remaining traits were polygenic. One QTL detected through QTL-seq on chromosome 4 was associated with retention of green color over a region of 5.01 Mb. RNA-seq and RT-PCR analysis at two different developmental stages revealed two genes in the QTL region namely, Csa_4G000860 and Csa_4G016490.

6.7.4 Bitter gourd

6.7.4.1 Molecular mapping and identification of putative candidate genes associated with gynoecious sex expression in bitter gourd

PVGy-201 (Gynoecious), Pusa Do Mausami (Monoecious), and two contrasting bulks were constituted for deep-sequencing. Based on the ΔSNP index, 1.31 Mb regions on the chromosome 1 was identified to be associated with gynoecious sex expression in bitter gourd. In the identified QTL region, 1019 homozygous variants with twelve genes were identified between PVGy1 and PDM genomes and 71 among them were non-synonymous variants (SNPs and INDELs).

6.7.5 Okra

Plant regeneration protocols from embryo and epicotyls explants were standardized in popular okra-cultivated genotypes, *viz.*, Pusa Sawani, DOV-92, Pusa Bhindi 5, Arka Anamika, and Parbhani Kranti.

6.7.6 Onion and garlic

6.7.6.1 Doubled haploid development in Onion

Bhima Safed (9.52%) and Bhima Dark Red (9.14%) recorded the highest gynogenesis efficiency. Cold pretreatment for 2 days in Bhima Dark Red (7.33%) was superior to control (6.67%). For diploidization, treatment of 500 µM colchicine for 4 h was superior with a 75% survival rate.

6.7.6.2 Development of genomic resources in Onion and Garlic

We identified 171 new genomic SSR markers from assembled genome sequence (GCA_905187595.1) and used them for the onion diversity assessment. We amplified 125 SSRs and observed 62 SSRs to be polymorphic. Screening of 22 onion lines using 16 polymorphic SSRs along with *A. fistulosum* as outgroup showed the presence of four clusters - cluster 1 (7 genotypes), Cluster II (14 genotypes), Cluster III and IV (one genotype each).

7. SOCIAL SCIENCE AND TECHNOLOGY TRANSFER

The School of Social Sciences carried out studies on the assessment of e-NAM, impact assessment of IARI varieties, biofertilizer adoption, economic evaluation of seed production model, estimation of nitrogen budget in Indian agriculture, the impact of Human-Wildlife Conflicts (HWC) in agriculture. Also, there were studies on the evaluation of government programs and schemes, technological interventions and capacity building for agripreneurship, and studies on the models to ensure agri-nutritional security. An evaluation of the multi-media-based extension model Pusa Samachar has been conducted. The successful IARI technologies were assessed and outscored with the help of collaboration with ICAR institutes, SAUs and voluntary organizations to enhance farm income. The performance of IARI's improved varieties and technologies through OFTs and FLDs was assessed.

7.1 AGRICULTURAL ECONOMICS

7.1.1 Performance of e-NAM (e-National Agriculture Market)

The main aim of the e-NAM portal is to provide better price discovery by removing information asymmetry between farmers and buyers. As of July 4, 2023, around 55% of the principal markets were linked in e-NAM, with 14% of the total cultivators participating. The trader density was 123/lakh ha gross cropped area, and about 67% received a unified license. The total e-NAM trade value was about 2% of the agriculture gross value added (AgGVA). The largest traded commodity group in 2021-22 was oilseeds, cereals, fruits and vegetables. Rajasthan and Haryana were the two states that recorded the highest trade share in terms of value and volume. The e-NAM has effectively provided higher price realization for farmers with an increase from 23% (cases) in 2019-2021 to 52% (cases) in 2019-2022. Findings from primary surveys in Haryana and Rajasthan revealed that only 23% of farmers were aware of the e-NAM. The cartelization of the traders and delays in the settlement of payments were the major problems perceived by the farmers. Better assaying facilities and quality standards are required to promote inter-market transactions and better price discovery.

7.1.2 Economic impact of IARI varieties

The economic impact of IARI rice and wheat varieties was analyzed using the economic surplus model. The basmati rice variety PB 1509 is preferred by farmers as it gives a higher yield when sown on time and fetches good returns. The variety has led to the generation of consumer and producer surplus for the year 2021-22 to the tune of ₹ 4264.61 crores and ₹ 4467.90 crores, respectively. Thus, the variety has benefitted both the consumers and producers. The wheat variety HD 3086 has led to the generation of consumer and producer surplus for the year 2021-22 to the tune of ₹ 1377.44 crores and ₹ 2156.44 crores, respectively.

7.1.3 Biofertilizer adoption among paddy farmers in Indo-Gangetic Plains

A duration analysis was conducted among the selected paddy farmers in Haryana and Uttar Pradesh regarding adopting biofertilizers. The analysis indicated that the average duration of adoption of biofertilizers is 3.5 years. The duration of adoption can, however, be enhanced through training and other targeted measures. The findings indicate that farmers may increasingly abandon sustainable agricultural technologies over time due to evolving economic conditions.

7.1.4 Economic evaluation of seed production models of field crops in North India

Various benefits and constraints to the farmers associated with different seed production models, *i.e.*, IARI-SPU, FPO-NSC, and Seed Licensed Firm, were studied. Among these, the IARI-SPU model valued higher price realization, recognition, networking, and technical support but faced challenges related to late payments and stringnent/complex conditions. The seed producers linked to the IARI-SPU model exhibited a higher overall technical efficiency (TE) of 79.61% compared to the other seed producers. In terms of marketing efficiency, the IARI-SPU channel was found to be the most efficient. Seed licensing firm participants found assurance in contracts but experienced issues with contract compliance and output rejection. Farmers Producer Organization (FPO) engaged farmers who appreciated payment reliability and market access but encountered challenges related to technical guidance, payment delays, and input costs. National Seed Corporation (NSC) affiliated seed growers benefitted from higher prices and market assurance but faced late payments and transportation cost hurdles.

7.1.5 Estimation of nitrogen budget in Indian agriculture

A nitrogen (N) budget was constructed for Indian agriculture from 1961-2017. Nitrogen input to Indian croplands increased from 4.87 million tons (mt) to 24.08 mt. Among the different components of N use in 2017, the contribution of fertilizer is the highest (70%), followed by biological nitrogen fixation (16%), manure (9%), and atmospheric deposition (4%). The analysis portrayed Indian agriculture's transformation from the N deficit value of -0.61 mt in 1961 to a surplus-value of 1.21 mt as of 2017. The crop N use efficiency during the period decreased from 72% to 55%. The fertilizer application rate (FAR) is the most important among the major crop production factors that drive N fertilizer use. The study proposes that the surplus N fertilizer in Indian agriculture, hastened by higher FAR, may pose serious sustainability issues, if not addressed.

7.1.6 Economic & environmental impact of direct seeded rice (DSR) in Haryana

A study was conducted in the Karnal district of Haryana to compare the economic and environmental benefits of direct-seeded rice (DSR) to puddled transplanted rice (PTR). Factors influencing the adoption of DSR in the study area included membership in cooperatives, training, seed drill availability, and extension agent support. DSR requires less labour, machinery, and specific inputs than PTR. DSR showed a significant reduction in the number of irrigations and irrigation water usage, leading to improved water productivity. Despite higher expenses in certain areas, DSR maintained lower overall costs, making it economically feasible and competitive in gross and farm business incomes. However, concerns about weed infestation were prominent among farmers. While DSR offers environmental and economic advantages, practical and perceptual challenges need to be overcome for wider adoption in Indian rice cultivation.

7.1.7 Impact of human-wildlife conflicts (HWC) in agriculture

A study was conducted to explore the extent of economic losses by wildlife damage based on primary data collected from 426 farmers in the villages located in the Eco-sensitive Zone (ESZ) of Bannerughatta National Park (BNP), Karnataka. The findings of the study showed that elephants and wild boars were major depredators, causing significant crop losses. The amount of crop loss varied from 9.28% in mulberry to 50.13% in the case of paddy. Groundnut, paddy, kodo, little, and foxtail millet are major crops replaced by mulberry cultivation to avoid HWC. The study finds the need for more scientific mechanisms in compensation fixation for each crop, as it takes a minimum of 6 to 18 months to receive the compensation. Farmers showed willingness to pay an additional 1.30% of the premium towards PMFBY, if HWC-based crop loss is covered under the scheme.

7.1.8 Analysis of the prevalence of child and adult malnutrition

An analysis of National Family Health Survey data in India between 2015-16 and 2019-21 revealed a modest decline in child stunting, with urban areas having 30% prevalence and rural areas at 37%. Child stunting is more prevalent in rural regions. While most states showed declining trends, some, like Meghalaya, Maharashtra, and West Bengal, recorded higher rates of stunting. Hot spot analysis identified areas of high and low risk, with Eastern, Northern, Western, North-eastern, and Southern states as hot spots. Determinants of child stunting include factors like child age, mother's education, and sanitation facilities. Anemia is a significant concern among women aged between 15-49 in India, with over 50% prevalence. The issue is more pronounced in rural areas. Hot spots are present in Eastern, Northern, North-eastern, and Western states. Determinants of anemia include age, education, occupation, and region. A survey-based women's empowerment index (SWPER) was developed, Using demographic and health surveys. Bivariate analysis indicated that nearly one-third of Indian women were highly empowered. Logistic regression analysis revealed that women's empowerment could significantly reduce the stunting, wasting and underweight of children in India.

7.2 AGRICULTURAL EXTENSION

7.2.1 Evaluation of farmer-centric government schemes and agricultural extension policy advocacy

The socio-economic impact of Pradhan Mantri Krishi Sinchai Yojana (PMKSY) was assessed in Haryana, Rajasthan, and West Bengal. In Haryana, farmers suggested the need for a crop height-adjustable sprinkler irrigation system for improved efficiency. Beneficiary farmers of Rajasthan perceived that PMKSY saved the cost of irrigation by 40% and led to extra crop yield (31%). In West Bengal, there was 3.23 times increase in the availability of irrigated areas; cropping intensity increased from 1.18 to 1.90, agricultural productivity increased by 43% and the income of farmers increased by 48%.

Performance of the National Food Security Mission (NFSM) in Karnataka and Uttar Pradesh showed that the annual income, crop diversification, social participation, and agricultural productivity were comparatively better for Karnataka beneficiary farmers, while material possession was better for beneficiary farmers of Uttar Pradesh. Performance of Rashtriya Krishi Vikas Yojana in Karnataka and Uttar Pradesh showed that socio-economic indicators were significant for beneficiary farmers of both states after the launch of the program, which reiterated the fact that RKVY-RAFTAAR had created an impact on the lives of the beneficiaries. Karnataka beneficiary farmers fared comparatively better than beneficiaries of Uttar Pradesh.

A study of Pradhan Mantri Fasal Bima Yojana (PMFBY) showed that the non-loanee farmers' share had increased from 23.99% to 35.66% and the share of loanee farmers reduced from 76.01% to 64.40% in 2020-21. It was found that there was a higher increase in the registration of marginal and small farmers under the scheme and this led to a reduction of area insured per farmer from 0.98 to 0.72 ha from 2016-17 to 2020-21. The farmer-based claim ratio (Claim received by the farmer/premium paid by the farmer) has increased from 4.15 to 5.84 from 2016-17 to 2019-20.

A study of crop residue management in Punjab, Haryana and Delhi was conducted. The socio-economic factors, namely residue burned because their neighbor burned, continued from generation to generation and reduction in the cost of labor and insect-pest control cost were found to be the major advantages for crop residue burning.

A Multimedia-based Extension Model named Pusa Samachar was developed for dissemination of technology information dissemination and agro-advisory through social media. The first episode of "Pusa Samachar" was uploaded on IARI's official YouTube channel on 22 August 2020, and every Saturday at 7 pm, a new episode is uploaded. Till now, 155 episodes have been broadcasted from the official channel of IARI. About 100 episodes in regional languages (Tamil, Telugu, Kannada, Bangla, and Odiya) have also been uploaded. The subscriber count for the channel is around 38,000. In every episode, time specific crop management practices, successful farmer stories, weather forecast and query redressal through Pusa WhatsApp salaah is being broadcasted. Critical evaluation of Pusa Samachar revealed that 88.67% of farmers regularly watched Pusa Samachar and 81.13% of them shared this content with their colleagues.

7.2.2 Converging agri-preneurship, farmers' innovations and modern technologies

Designed and tested farm entrepreneurship development process models which were certified by ICAR in 2022. Case studies of Farmer Led Innovations (FLIs) were conducted to draw lessons for developing agri-preneurship among other farmers in the region with socio-economic background as part of outscaling FLIs. Based on learnings derived from case studies of innovator farmers, critical advisory support was provided for agri-preneurship process development in project villages. Significant entrepreneurial competencies were identified as opportunity recognition, drive for excellence, quality concern, risk-taking behavior, innovativeness, and business orientation. Among the key factors of entrepreneurial climate were, availability of technical guidance, availability of credit, special government schemes, effective networking, infrastructural ease of transport, and marketing avenues. Attributes of a successful Agri-enterprise were delineated as establishment, survival, growth, diversification, and higher profits. Based on this model, training modules were devised, and training courses were conducted among the project villages for farmers, farm women, and youth. Mentoring and handholding of nascent entrepreneurs in the project villages were also done. Linking the trained farmers and farm women was done with marketing agencies. Two Farmer Producer Companies (FPCs), “Grofree” Producer Company Limited, Tigipur, New Delhi, and Dauji Phool Utpadak Producer Company Limited, Fatehpur Billoch, Faridabad, 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 program was facilitated to continue the program.

7.2.3 Agricultural extension for nutrition and health (AE4NH)- strategies and models

A study conducted among thirty children of rural secondary schools in the Arwal district of Bihar found that mothers' farming responsibilities, limited time for child care, nuclear family structure and limited parental education in balancing their work responsibilities and education levels have implications for child’s well-being, nutrition, and overall development. The study, with a sample of 200 students from various State Agricultural Universities, used the validated Compulsive Eating Scale (CES), developed by Kagan and Squires in 1984, to assess the psychological factors influencing eating habits among the students. It examined 13 psychological and social factors that could influence eating habits, out of which, eight were found to be significantly associated with eating habits. This suggested that certain psychological and social factors have a notable impact on the dietary habits of the students.

The knowledge levels of individuals in Delhi regarding organic foods were also assessed. Based on the score in the knowledge index, the respondents were divided into the following five groups of the level of knowledge, respectively, *i.e*. Very low (<5.045), Low (5.045–10.090), Medium (10.091–15.135), High (15.136–20.18) and Very High (>20.180). This information must be useful in designing educational campaigns or interventions aimed at improving knowledge and awareness about organic food and also identifying the gaps in knowledge that need to be addressed. Dietary diversity was assessed, and the mean score of On-Farm Diversity (OFD) was around 3, indicating that, on average, each household was cultivating three different food crops on their fields, whereas the Food Consumption Score (FCS) was estimated to be 65.01. A significant positive correlation (0.316) between FCS and OFD indicated households with more diverse food sources from their own farms tend to have higher FCS, implying better nutritional security.

The National Family Health Survey (NFHS) study's findings suggest that maternal autonomy, financial control, household characteristics, the importance of programmes like ICDS, and freedom of movement can potentially improve a child's nutrition. Various capacity-building programmes were organized, like an awareness campaign on millets for rural women in village Chidana, Sonipat district, Haryana, with the collaboration of Ayurvet Research Foundation, an NGO based in New Delhi, on the occasion of International Year of Millets, 2023. Rural women from project villages were mobilized to supply nutritious *bajra laddoos* on the occasion of the International Year of Millets celebration at IARI, New Delhi on Jan 01, 2023. In collaboration with KVK Sonipat, a training program on "Bakery products preparation" for rural women at Jagdishpur village of Sonipat district of Haryana was organized.

7.2.4 Evaluation of farmer-centric government schemes and agricultural extension policy advocacy at RS Kalimpong

The major problems in the adoption of micro-irrigation under per drop more crop were partial withdrawal of subsidy under another intervention component (60%), lack of water source (42%), water shortage in the winter season (62%), lack of land record for tea gardeners and forest dwellers (44%).

One mobile expert system on large cardamom using React JS with Firebase as a background database was developed. The app is very small in size, so farmers with cheap mobile phones can also use this app to get agro-advisory services. A total of 649 farmers installed the app, and so far, 1984 agro-advisory services have been provided using the app.

7.2.5 Agricultural extension for nutrition and health (AE4NH)-strategies and models at RS Kalimpong

Nutritious crops and varieties like Red cabbage (Red Jewel), leafy vegetable kale (Pusa kale 64), Lettuce (Great Lakes), Yellow cauliflower, Carrot (Sahiba, Sachi), Cucumber (ADV 268, Nalini-F1), Bitter gourd (Palee F1, Harithwa, NHBI-2009 F1), Spinach (OP), Cowpea (Pusa Sukamal) were promoted in Kalimpong and Jalpaiguri districts of West Bengal. A total of 437 farmers adopted nutri varieties in a 267 acre area.

7.2.6 Evaluation, multiplication and supply of elite healthy clones of citrus in North Bengal: Lab to Land solution at RS Kalimpong

An extensive survey was carried out in various mandarin growing areas of Kalimpong and Darjeeling districts for identification of superior germplasm of Darjeeling mandarin. The findings revealed that the fruits of genotype MSG 5 had the highest weight (156 g) & volume (149 ml) whereas genotype S31 had the lowest fruit weight of 53.1 g and volume of 36.7 ml, respectively. The maximum pulp weight was recorded in the MSG 2 genotype (112.2 g).

7.3 TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Assessment and out-scaling of IARI technologies for enhancing farm income

During *rabi* 2022-23, the project was in operation at four villages, namely Nidana (Rohtak, Haryana), Maholi (Palwal, Haryana), Kanvi (Hapur, U.P) and

Inauguration of a large cardamom mobile app during the Annual Zonal Workshop 2023

Basoli (Baghpat, UP). The location-specific improved varieties of wheat, mustard, chickpea, lentil, carrot, onion and palak were assessed through 302 trials over an area of 112.39 ha. The performance of the IARI varieties were compared with local checks. At Nidana (Rohtak, Haryana), the yield of wheat varieties in timely sown condition, HD 2967 (5.16 t/ha), HD 3086 (5.43 t/ha), HD 3237 (4.97 t/ha) and HD 3226 (5.41 t/ha) were higher than local cultivar WH 711 (4.4 t/ha). However, the average yield in all varieties was less than the potential yield of respective varieties due to heavy rain at the time of harvesting. HD 2967 and HD 3086 exhibited profuse tillering, no lodging and good *chapati-making* quality.

In Maholi, Palwal (Haryana) assessment trials of the technologies were conducted through group-oriented action through members of Farmers Producer Company, Hodal, Palwal. The average yields of late-sown wheat varieties HD 3271 and HD 3059 were 4.65 t/ha and 4.60 t/ha, respectively and approximately 15-16% higher than local check Raj 3765.

At Kanvi (U.P.), among four timely sown wheat varieties, the highest average yield was recorded in HD 3226 (5.77 t/ha), followed by HD 3086 (5.73 t/ha), HD 2967 (5.65 t/ha) and HD 3237 (5.55 t/ha) as compared to local check DBW 303 (5.25 t/ha). In late sown condition, wheat varieties HD 3271 and HD 3059 yielded 5.12 and 5.00 t/ha, respectively. The mustard variety Pusa Vijay yielded (1.94 t/ha) higher than the local cultivar Coral 432 (1.92 t/ha). At Basoli, Baghpat (U.P.), chickpea variety Pusa 3062 yielded 1.82 t/ha, which is 21.66% higher than the local check Desi variety.

During *kharif 2022*, a total of 195 assessment trials were conducted on paddy varieties (PB 1847, PB 1885, PB 1692, PB 1509 and PB 1886) and moong bean (Pusa Vishal, Pusa 1431) covering an area of 57.96 ha in four adopted villages. The highest average yield of PB 1847 (6.25 t/ha), followed by PB 1692 (6.17 t/ha), and PB 1885 (5.22 t/ha) was recorded with an average yield increase of ~19 to 25% and B: C Ratio ~1.55 to 2.05 at Nidana, Rohtak. In Maholi, Moong Pusa 1431 (1.01 t/ha) and Pusa Vishal (1.12 t/ha) yielded ~15.05 to 19.89% higher than local check (SML 668) with an economic gain of 2.46 and 2.82 B: C Ratio, respectively. In Kanvi, Hapur's average yield of paddy PB 1692, PB 1509, PB 1847, and PB 1885 were 5.12, 4.86, 5.43 and 5.28 t/ha, respectively, which was ~14 to 27% higher than local check (4.25 t/ha). In Basoli, Baghpat average yields of PB 1692, PB 1509, PB 1885 and PB 1847 were 4.86, 4.52, 4.55 and 5.18 t/ha, respectively which were ~13.12 to 29.57% higher than local check (4.00 t/ha). Nutri-gardens were promoted in all villages at farmers' fields by providing vegetable kits for promoting crop diversification and enhancing nutritional security.

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/ VOs 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, post-harvest technologies and farm enterprises were discussed based on participatory analysis and joint consultations for the profitable farming system during workshops held at the Institute.

During *rabi* 2022-23 under the NEP collaborative program with ICAR institutes and SAUs, 166 demonstrations involving 26 varieties of 14 crops in nine states were conducted, covering an area of 52.65 ha at 13 locations. A total of 67 wheat demonstrations on IARI varieties HD 2967, HD 3086, HD 3237, HD 3226, HD 3271, HI 1634 and HI 1633 were carried out in an area of 26.80 ha. A total of 37 demonstrations on Mustard varieties Pusa Vijay, PM 28, PM 30 and PM 27 were conducted in 14.80 ha. Altogether, 62 demonstrations of gram (Var. P 547 and P 3062), Onion (Pusa Red and Pusa Madhavi), Spinach (All green and Pusa Bharti), pea (Pusa Pragati), Marigold (Pusa Bahar and Pusa Naragi), carrot (Pusa Rudhira, Pusa Asita and Pusa Vrishti), fenugreek (Pusa Early Bunching), lentil L 4717, cauliflower (Pusa Meghna), marigold (Pusa Narangi), cabbage (Pusa hybrid 1), broccoli

(KTS1), beetroot (Detroit dark red), bathua (Pusa Bathua 1, Pusa green) and veg. mustard (P Saag-1) were demonstrated to the farmers in an 11.05 ha area. In collaboration with voluntary organizations, 229 demonstrations covering 26 varieties of 12 crops in an area of 73 ha were conducted during rabi 2022-23. The wheat varieties *viz*., HD 2967, HD 3086, HD 3237, HD 3226, HD 3271 and HI 1634 were demonstrated in a 38.8 ha area. A total of 44 demonstrations of mustard (var. Pusa Vijay, PM 27, PM 30 and PM 28) were conducted in 19.40 ha. The gram (var. Pusa 30623 and P547), onion (Pusa Red and Pusa Madhavi), palak (var. All green and Pusa Bharti), pea (var. Pusa Pragati), marigold (var. Pusa Bahar and Pusa Narangi), carrot (Pusa Rudhira, Pusa Asita and Pusa Vrishti), fenugreek (Pusa Early Bunching), lentil L 4717, cauliflower (Pusa Meghna), cabbage (Pusa hybrid 1), broccoli (KTS1), beetroot (Detroit darkred), Bathua (Pusa Bathua 1, Pusa green) and veg. mustard (P Saag-1) were also demonstrated in a 14.8 ha area.

During *Kharif* 2022, under NEP, 204 demonstrations on nine crops with 14 varieties covering an area of 28.61 ha were conducted at 13 ICAR Institutes/ SAUs. Under paddy crop, 83 demonstrations were carried out with the paddy varieties viz., Pusa 1692, Pusa 1850, PB 1847 and PB 1509 in an area of 22.20 ha. Also, 121 demonstrations of other crops like moong (Pusa Vishal and Pusa 1431), bottle gourd (Pusa Naveen), sponge gourd (Pusa Sneha), okra (Pusa A-5), cowpea (Pusa Dharni), bittergourd (Pusa hybrid 4) and amaranths (Pusa *Lal Chaulai,* Pusa Kiran*)* were conducted.

In collaboration with voluntary organizations, 436 demonstrations on 9 crops with 16 varieties covering an area of 60.31 ha were conducted at 23 locations of voluntary organizations. 221 demonstrations were carried out for the paddy varieties *viz*., Pusa 1692, Pusa 1850, PB 1509, PB 1847, PB 1885 and PB 1886 in an area of 52.4 ha. Also, 215 demonstrations of other crops like moong (Pusa Vishal and Pusa 1431), bottle gourd (Pusa Naveen), sponge gourd (Pusa Sneha), okra (Pusa A5), arhar (Pusa 991), bitter gourd (Pusa hybrid 4), cowpea (Pusa Dharni), and amaranths (*Pusa Lal Chaulai*, Pusa Kiran) were conducted. To cater to the requirement of the seed for IARI crops and varieties, two seed hubs were established by the Institute which produces seed for farmers, *i.e*., PRDF, Gorakhpur for eastern areas, and YFA, Rakhra for the Northern region.

7.4 AGRICULTURAL TECHNOLOGY INFORMATION CENTRE (ATIC)

ATIC was established in 1999 at ICAR-IARI as a 'Single Window Delivery System' for the institute's products, services and technologies to the farmers/ entrepreneurs, etc. Farm advisory services to 24,650 farmers and other stakeholders were provided at ATIC during the year. Visitors (farmers/ farm women/ entrepreneurs/ officials) visited ATIC to seek advisory services, purchase Pusa seed, farm publications, biofertilizers, and inquiry about the training program. Besides farm advisory services, farmers are given farm advice through the Pusa Helpline (011-25841670, 25846233, 25841039, and 25803600), Pusa Agricom 1800-11- 8989, exhibitions, farm literature, and letters. A IInd level of *Kisan Call Centre* (1800-180-1551) has also been established at ATIC to solve the problems/queries of farmers of Delhi and Rajasthan. A total number of 14,493 farmers' calls from 16 states were received, and queries were answered through Pusa *Agricom* in the year 2022-23. Pusa seeds worth ₹ 15,80,124/- and farm publication of ₹ 6,760/- have been sold to the farmers during the year. In ATIC, the crop *cafeteria* laid out live demonstrations of the recently released varieties of the institute. A herbal block has been developed in the crop *cafeteria* which includes medicinal plants of aloevera, ashwagandha, satavar, coleus, giloe, mushkdana, sadabahar, mint, tulsi (basil), lemon grass, java citronella and turmeric etc. A special issue of hindi farm magazine *Prasar Doot* on millets has been published by the centre during the reporting period. ATIC has also developed functional linkages with agencies like KVKs, State Line departments, SAUs, ICAR Institutes and Farmers Producer Organizations.

Pusa Agri *Krishi Haat*, an innovative model of a direct marketing platform, has been created by IARI for farmers to sell their agri-products directly to consumers. It is an initiative of the Institute to empower and facilitate the agri-preneurs as well as farmers and farm women in marketing their fresh as well as value-added farm products to urban consumers. The *Haat* has been operational since April 2023 for the benefit of the farmers and urban consumers.

Pusa Agri *Krishi Haat*

7.5 KRISHI VIGYAN KENDRA

7.5.1 On-farm Trials (OFT)

KVK has conducted various OFTs on pink bollworm management in cotton weed management and integrated nutrient management in pearl millet and mustard.

7.5.2 Trainings

Capacity building programs on production and processing of millets for export; eradication of anemia in adolescent girls; IPM in pigeon pea, cucurbits, cole crops, and cotton; natural farming; INM in pearl millet; integrated farming system; group dynamics of SHGs and farmers' organizations were organized by KVK.

Training program on natural farming

7.5.3 Agricultural extension activities

The KVK, Gurugram organized field day-cum-farmers trainings on mustard (variety RH 725), chickpea (variety CSJ 515) and pigeon pea (Pusa Arhar). An awareness program on Kisan Samman Nidhi Yojana was organized. Awareness programs on natural farming and Kisan ghoshti on different themes like soil health management, popularization of natural farming, rainwater harvesting, and climate resilient agriculture were organized. A method demonstration on the spray of nano-urea using drones was conducted under Mission LiFE in one hectare area.

Cluster Front line Demonstrations

Crop	Variety	Area (ha)	No.	Remarks
Summer moong	Pusa Moong 14-31	30	62	*zaid* moong with bio-fertilizers as a seed treatment at Gurugram district
Pigeon pea	Pusa Arhar 2018-4	10	19	*Kharif* with bio-fertilizers as seed treatment
Mustard	PM 31, Radhika	75	135	*Rabi* PM-31 under NARI as bio-fortified /double zero mustard
Nutri garden	Summer and winter vegetables	0.3	20	Summer and winter vegetables were cultivated at Tajnagar and Tirpadi village under NARI
Wheat	HD 3298	4.0	10	Under the NARI project a bio-fortified variety
Total		**119.30**	**246**	

Field day-cum-farmer's training on chickpea

Method demonstration-cum-awareness programme on agricultural drone spray

7.5.4 Celebration of important days

Sl. no.	Particulars	Date	No. of partici-pants	Venue
1.	National Girl Child Day	January 24, 2023	20	Uncha Majra, Pataudi
2.	World Environment Day	June 05, 2023	85	KVK, Shikohpur
3.	International Yoga Day	June 21, 2023	28	KVK, Shikohpur
4.	ICAR Foundation and Technology Day	July16, 2023	186	KVK, Shikohpur

Celebration of ICAR Foundation & Technology Day at KVK, Gurugram

8. EMPOWERMENT OF WOMEN IN AGRICULTURE AND MAINSTREAMING OF GENDER ISSUES

While women play a crucial role in advancing agricultural development and securing household livelihood and nutritional security, they remain a vulnerable demographic within the social system, primarily stemming from limited access to resources and opportunities for skill development. Recognizing the imperative of empowering women to foster inclusive development, various efforts have been undertaken to enhance their capabilities in value addition, nutritional security, and group-oriented action.

8.1 Enhancing nutritional security and gender empowerment

To achieve the above mentioned objective, KVK Gurugram organized the following activities in the year 2023, which benefitted 250 village women.

Name of activity	Location	Date	No. of farm women
Training on "Processing and value addition in fruits and vegetables" for practicing farm women	KVK campus	January 9-12, 2023	18
Training on "Nutrients, their role in the human body and their food sources" for practicing farm women	Tirpari village	January 17, 2023	17
Radio talk on "महिलाओं के स्वास्थ्य में मोटे अनाजों का महत्व"	Akashwani, New Delhi	January 18, 2023	-
Training on "Minimization of nutrient loss during cooking/ processing" for practicing farm women	Bhorakalan village	January 23- 27, 2023	19
Training on "Eradication of anemia in adolescent girls" for Anganwadi workers	Anganwadi Center, Manesar	March 02, 2023	17
Training on "Value addition in millets"	KVK, Shikohpur	March 21-24, 2023	14
Training on "Value addition in millets"	KVK, Shikohpur	July 31- August 4, 2023	23
Awareness camp on "Nutrients, their role in human body and food sources"	Sultanpur village	September 15, 2023	41
Awareness camp on "Nutrients, their role in human body and food sources"	Dhani Chittersain village	September 20, 2023	34
Training on "Establishment of nutri-garden to achieve nutrition security at household level"	Dhani Chittersain village	September 25-29, 2023	37
Training on "Preservation of seasonal fruits and vegetables"	Tirpari village	November 9, 2023	12
Training on "Income generation activities for empowerment of rural women"	Kankrola village	November 13- 16, 2023	18

During these programs, the women farmers were made aware about nutrients, and their role in humans. They were motivated to adopt healthy dietary practices and to establish a nutri-garden in their backyard to include more fresh fruits and vegetables in their diet. They were also made aware about the health benefits of nutri-cereals and were motivated to make nutri-cereals like jowar, bajra, ragi etc. a part of their daily diet. A training on "Eradication of anemia in adolescent girls" was organized for Anganwadi workers so that they could make the girls aware of the recommended dietary practices to reduce the cases of anaemia. Two trainings on "Value addition in millets" were organized during March and August 2023, in which women were given hands-on training to prepare millet products (jowar, bajra, ragi and sanwa) and incorporate millets in their routine diet to achieve micronutrient security at household level. During September 25-29, 2023; training on "Establishment of nutri-garden to achieve nutritional security at household level" was organized in Dhani Chittersa village in which 37 women participated and were made aware about various fruit and vegetable crops that can be grown to establish a nutri-garden in their area. A total of 10 Nutri-gardens were established in village Dhani Chittersa under the FLD program, in which they were given fruit plants of mango, guava, lemon, kinnow, amla; curry plant; vegetable seed kit and seedlings of tomato, brinjal, and chili.

8.2 Effectiveness of SHGs for gender empowerment

A total of 12 women SHGs trained under the ARYA project are sustainably running their value-addition enterprises and creating their own identity in the society. Out of these 12 women SHGs, the following SHGs were awarded to recognize their work in their field of activity during the year 2023:

1. Smt. Pooja Sharma, President of Kshitiz SHG (Chandu village), received Nari Stree Shakti Puruskar-2023, from the Hon'ble Chief Minister of Haryana, Sh. Manohar Lal Khattar on March 08, 2023 on International Women's Day with a cash prize of ₹ 21,000/-.

2. SHG "Saheli" (Uncha Mazra village) 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 the SARAS mela in July 2023.

3. SHG "Ekta" (Tajnagar village) was given second prize with a cash prize of ₹ 50,000/- by the Hon'ble Chief Minister of Haryana, Sh. Manohar Lal Khattar during the SARAS *mela* in March 2023.

8.3 Gender mainstreaming

Training programs were conducted in villages Nidana, Rohtak, and, Maholi, Palwal (Haryana) for rural women on nutrition gardens and their importance in combating malnutrition. Vegetable kits were provided for developing kitchen gardens in adopted villages Nidana, Rohtak, Maholi (Palwal), and Kanvi (Hapur) to promote nutritional security, enhance food diversity, and assess their acceptance and marketability. The awareness campaign on International Millets Year was organized on February 03-06, 2023, in villages Nidana (Rohtak) and Maholi (Palwal). Radio Talks were delivered on All India Radio, FM Gold on the topics of 'स्वयं सहायता समुह' for mobilizing women farmers for group-oriented action and on 'ग्रामीण महिलाओं का पोषण' for ensuring health and nutritional security of the rural women.

9. POST GRADUATE EDUCATION AND INFORMATION MANAGEMENT

The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence of more than 117 years in research, teaching, and extension. The Graduate School of IARI continues to provide national and international leadership in Human Resource Development by awarding degrees in 26 disciplines. So far, 4823 M.Sc., 100 M.Tech., and 5360 Ph.D. students have been awarded degrees, which includes 509 international students. The Institute has received accreditation from the National Assessment and Accreditation Council (NAAC) of UGC, valid for a period of five years (2023-2028) with an 'A' Grade, as well as from the National Agricultural Education Accreditation Board (NAEAB) of ICAR for a period of five years *i.e*. (2020-2025) with 'A' grade.

9.1 POST GRADUATE EDUCATION

The Graduate 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. programmes 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 2023-24, admission under the open scheme is given below.

9.1.1 Admission during the Academic Session 2023-24

Total of 35 students were admitted under different schemes; 8 under ICAR in-service (Ph.D.); 10 under faculty up-gradation scheme (Ph.D.), 5 under departmental technical (4 Ph.D. and 1 M.Sc.); 2 under departmental scientific scheme (Ph.D.), 5 under CWSF (2 Ph.D. and 3 M.Sc.); 5 for wards of Kashmiri Migrant and Kashmiri Pandit/Kashmiri Hindu Family (Non-Migrant) living in Kashmir valley (2 Ph.D. and 3 M.Sc.). In addition, 4 international students (2 M.Sc. and 2 Ph.D.) from Nepal and Myanmar were also admitted. Currently, the total number of students on roll is 2805 (747 UG, 575 M.Sc. & M.Tech. and 1483 Ph.D.), including 18 international students (5 M.Sc. & 13 Ph.D.).

9.1.2 Convocation

IARI organized its 61st Convocation in the Bharat Ratna Shri C. Subramanium Auditorium of NASC Complex, New Delhi, on February 24, 2023. Sh. Jagdeep Dhankar, Hon'ble Vice President of India, graced the occasion as the Chief Guest of the function. The program was also attended by Hon'ble Union Minster of Agriculture and Farmers Welfare, Shri Narendra Singh Tomar, Hon'ble Union Minister of State, Ministry of Agriculture and Farmers Welfare, Sh. Kailash Chaudhary, as the Guests of Honour. Dr. Himanshu Pathak, Secretary DARE and Director General, ICAR also graced the occasion.

During the Convocation, the Hon'ble Vice President awarded the IARI merit medals to 6 M.Sc./M.Tech. and 5 Ph.D. students. He also awarded the IARI Best Student Award 2022 to Mr. Rahul Kumar, a doctoral student of the Division of Genetics and NABARD-Professor VL Chopra Gold Medal-2022 to Mr. Tarun Sharma, M.Sc. student of Division of Agronomy. He also presented the Dr. H.K. Jain Memorial Young Scientist award to Dr. Amlendu Ghosh, Senior Scientist, Division of Plant

Pathology, for the year 2021 and to Dr. Aditi Kundu, Senior Scientist, Division of Agricultural Chemicals, IARI, for the year 2022. A total of 403 students (222 M.Sc./M.Tech. and 181 Ph.D.) from India and other countries received their Post Graduate and Doctorate degrees.

On this occasion, the Hon'ble Vice President released different varieties of field and flower crops. In wheat, 10 varieties were released, which included HD 3406, HD 3407, HD 3411, 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); in rice two varieties *viz.* PB 1882 and Pusa Sambha 1853; in maize two varieties, MH 2, MH 3; chickpea, Pusa JG-16; in mustard Pusa Mustard-34. In flowers, two varieties of rose (Pusa Lakshmi and Pusa Bhargava); two marigold (Pusa Parv and Pusa Utsav); and one each of gladiolus (Pusa Rajat), chrysanthemum (Pusa Lohit) and Bougainvillea (Pusa Akansha) were released. Three publications including a textbook on "Basics of Agro-Chemical Formulations: Highlighting the Importance of Expanding the Domain of Agrochemical Research and Development", PG School Annual Report 2021-22, and Agro-Startup Innovation (A compilation by ZTMBPD unit), were also released.

The convocation ended with a formal vote of thanks by Dr. Anupama Singh, Joint Director (Education) and Dean, IARI, New Delhi.

9.1.3 Special Lectures

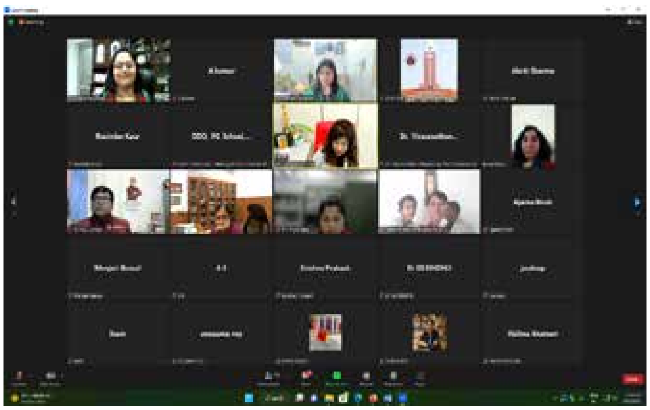
Lal Bahadur Shastri Memorial Lecture: The Indian Agricultural Research Institute initiated a series of annual lectures in 1968 as a mark of respect to the late Shri Lal Bahadur Shastri, the second Prime Minister of Independent India. As a part of the Convocation Week, the 53rd Lal Bahadur Shastri memorial lecture was delivered by Dr. Usha Barwale Zehr, Director and Chief Technology Officer, Mahyco Private Limited, Jalna, Maharashtra and Chairman and Executive Director of Grow Indigo Private Limited (GIPL) on February 23, 2023 in Dr. B.P. Pal Auditorium, IARI, New Delhi. The session was chaired by Dr. Himanshu Pathak, Secretary, DARE & DG, ICAR, New Delhi.

Dr. Usha Barwale Zehr, Director and Chief Technology Officer, Mahyco Private Limited, during Lal Bahadur Shastri lecture

National Youth Day: The National Youth Day is celebrated on January 12 every year to commemorate the birth anniversary of Swami Vivekananda. On this occasion, Dr. Meena Mishra, Director, Brain Behaviour Research Foundation of India, New Delhi, delivered a lecture on "Positive Psychology for Stress Management in Youth" *via.* online mode.

National Girl Child Day Lecture: ICAR-Indian Agricultural Research Institute, New Delhi, celebrated National Girl Child Day 2023 on January 24, 2023, through virtual mode. Prof. Sujata Sharma, Professor, Department of Biophysics, All India Institute of Medical Sciences, New Delhi, delivered the National Girl Child Day lecture on "Happy and Healthy Girl

Child - Symbol of Progressive Family and Country" and a picture presentation was displayed of all the girl children with their parents at IARI. The programme was chaired by Dr. Anupama Singh, Joint Director (Education) & Dean, ICAR-IARI. On this occasion, Dr. Renu Singh, President of PILA, New Delhi, was the Guest of Honour. The program ended with vote of thanks to the Chairman of the function and other participants of the program by Dr. R.R. Burman, Principal Scientist, Division of Agricultural Extension, IARI, New Delhi.



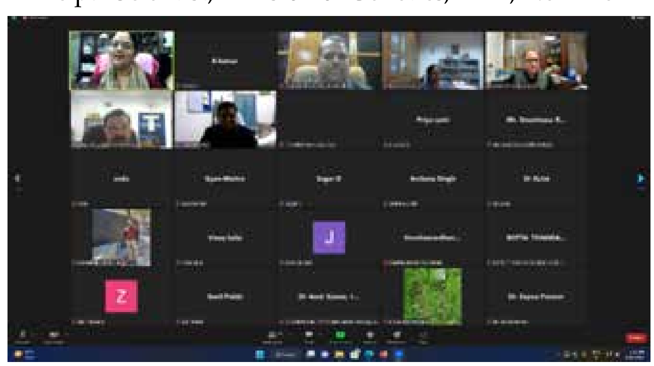
National Girl Child Day lecture by Prof. Sujata Sharma, Professor, Department of Biophysics, All India Institute of Medical Sciences, New Delhi

International Day for Women and Girls in Science: ICAR-Indian Agricultural Research Institute, New Delhi celebrated International Day for Women and Girls in Science on February 11, 2023. On this occasion, Dr. Archana Sharma, Senior Advisor, International Relations, Head, Engagement Office, CMS Experiment, Principal Scientist, CERN Laboratory, Switzerland, delivered a lecture on 'Unlocking Secrets of the Universe and Why Should I Care?' through virtual mode. Dr. Anupama Singh, Joint Director (Education) & Dean, ICAR-IARI, New Delhi, was the program's Chairperson. Dr. Atul Kumar, Associated Dean, The Graduate School, ICAR-IARI, New Delhi, welcomed the speaker. Dr. Sunita Yadav, Scientist, Division of Environmental Sciences, ICAR-IARI, New Delhi, presented the vote of thanks.

Lecture by Dr. Archana Sharma (CERN, Switzerland) on INTERNATIONAL DAY OF WOMEN & GIRLS IN SCIENCE

National Women's Day: National Women's Day was celebrated on February 13, 2023, at the ICAR-Indian Agricultural Research Institute, New Delhi, and all women researchers were felicitated on different platforms of IARI in the form of a curated picture collage. An essay writing competition on the National Women's Day theme was also organized, and winners were felicitated with certificates and prizes.

National Science Day: National Science Day lecture was organized on February 28, 2023, through online mode where Dr. P.S. Brahmanand, Project Director, Water Technology Centre, ICAR-IARI, New Delhi, delivered his talk on 'Science for Society and Human Development', and Dr. Subhash Babu, Senior Scientist, Division of Agronomy, ICAR-IARI discussed 'The Young Minds' perspective on Agriculture, in integration with STEM. Dr. Anupama Singh, Joint Director (Education) & Dean, ICAR-IARI, presided over the function. The program ended with words of thanks by Dr. Gyan Mishra, Principal Scientist, Division of Genetics, IARI, New Delhi.



Lecture by Dr. P.S. Brahmanand, PD, WTC

International Women's Day Lecture: Every year, March 8 is celebrated as International Women's Day. ICAR-Indian Agricultural Research Institute, New Delhi, celebrated International Women's Day on March

8, 2023, in which a poetry writing event was organized under the theme 'Gender Equality for Women.'

Dr. BP Pal Memorial Lecture: The 30th Dr. BP Pal Memorial Lecture, organized by the Graduate School, IARI, New Delhi, and the Genetics Club of IARI, was held on June 19, 2023, at Dr. B.P. Pal Auditorium, ICAR-IARI, New Delhi. Dr. Swapan Kumar Datta, Former Founder Vice-Chancellor of Biswa Bangla Biswabidyalay, Bolpur, Former Vice-Chancellor of Viswa-Bharati University, Santiniketan, West Bengal & Former DDG (Crop Science) at ICAR, New Delhi, delivered the lecture on "Human Face of Agriculture: Genome Changes with Time" and enlightened the audience. Dr. Himanshu Pathak, Secretary, DARE, and Director General, ICAR, presided over the event.

During the Lecture at Dr. B.P. Pal Auditorium, ICAR-IARI

International Yoga Day: The 9th International Yoga Day was celebrated jointly by the ICAR Headquarters and ICAR-IARI, New Delhi, from 7:00 AM onwards on June 21, 2023, at NASC complex with the participation of staff, students, and family members of the staff. During the event, different types of yoga mudras and asanas were practised.

Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR, Dr. A.K. Singh, Director, ICAR-IARI and other staff during Yoga

Teachers' Day Lecture: The Teachers' Day Lecture 2023 was organized jointly by the Graduate School and the Genetics Club, ICAR-IARI, on September 5, 2023, the birthday of former Hon'ble President of India, Dr. S. Radhakrishnan, who was a teacher par excellence. The Teachers' Day Lecture was delivered by Prof. Ashutosh Sharma, President of Indian National Science Academy (INSA), Institute Chair Professor, IIT Kanpur, and former Secretary of DST, Govt. of India. The session was chaired by Prof. Anupam Varma, Former ICAR National Professor and former Dean and Joint Director (Education), ICAR-IARI, New Delhi.

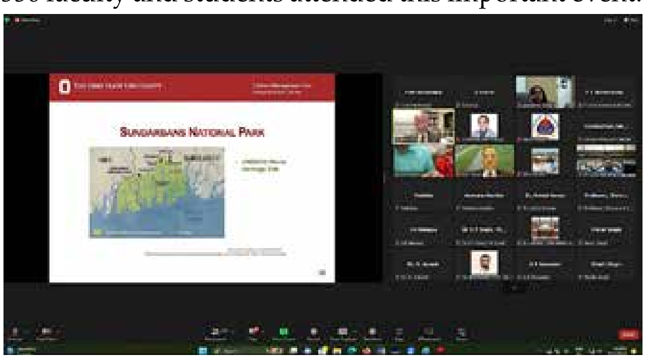
During Teachers' Day Lecture at Dr. B.P. Pal Auditorium, ICAR-IARI

Agricultural Education Day: ICAR-Indian Agricultural Research Institute, New Delhi, celebrated Agricultural Education Day 2023 on December 3, 2023. Dr. R.S. Paroda, Padma Bhushan, former Secretary DARE & DG ICAR, and Chairman TAAS, New Delhi, delivered the AED lecture on "Opportunities in Agriculture". Prof. R.B. Singh (Former President, NAAS & Former Director, ICAR-IARI, New Delhi) presided over the function. More than 500 students and faculty participated in the event in hybrid mode. An inter-school painting competition was also arranged for the celebration, in which 60 students participated. The Chief Guest of the function, Dr. R.S. Paroda, presented awards and certificates to the winners. The students from various

IARI hubs and IARI, New Delhi interacted with Dr. R.S. Paroda and Prof. R.B. Singh and sought their insightful guidance.

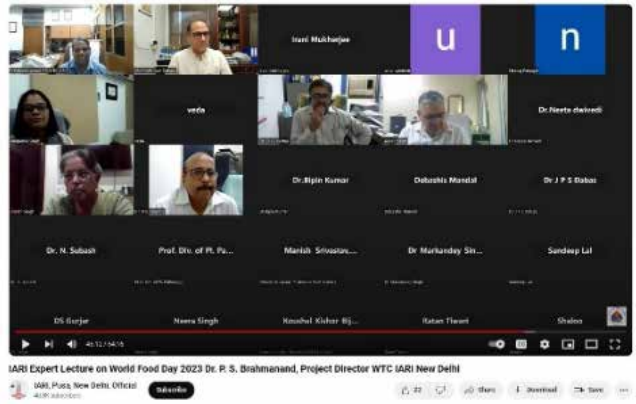
Dr. R.S. Paroda during the lecture at Dr. B.P. Pal Auditorium, ICAR-IARI

World Food Day: ICAR-Indian Agricultural Research Institute, New Delhi celebrated World Food Day 2023 on October 17, 2023. Prof. Rattan Lal, the World Food Prize Laureate and Director, Carbon Management and Sequestration Centre, The Ohio State University, Columbus, USA, IARI alumnus and Adjunct Professor, delivered the lecture through virtual mode. Around 550 faculty and students attended this important event.



Prof. Rattan Lal, the World Food Prize Laureate, during the lecture through virtual mode

On the occasion of World Food Day, a special lecture was also organized by the Internal Quality Assurance Cell (IQAC), The Graduate School, ICAR-IARI, New Delhi, on the topic "Water Management for Sustainable Agriculture, Food Security and World Peace" by Dr. P.S. Brahmanand, Project Director & Professor, Water Technology Centre, ICAR-IARI, New Delhi, on October 16, 2023 through online mode.



IARI Expert Lecture on World Food Day by Dr. PS Brahmanand, PD, WTC

Eminent Expert lecture

- IQAC and Student Service Centre, ICAR-IARI jointly organised an eminent expert lecture on 'Stress and Coping Skills' on October 18, 2023, in Dr. B.P. Pal Auditorium of the Institute. Prof. Derick H. Lindquist, a renowned neuroscientist, University of Yale, USA alumnus and currently Dean, Jindal School of Psychology and Counselling, OP Jindal Global University, Sonipat, delivered the lecture.
- The Division of Plant Pathology and IQAC jointly organized an international expert lecture by Dr. Serge Savary, Honorary Professor of Plant Pathology and renowned Plant Disease Epidemiologist, on the topic "Global Impacts of Potential Plant Disease Epidemics: Rice & Wheat" on October 27, 2023 at the Auditorium of Plant Virology Unit, Division of Plant Pathology, ICAR-IARI.
- The Division of Soil Science and Agricultural Chemistry and IQAC conducted an online lecture by the World Food Prize Laureate Prof. Rattan Lal, Director, Carbon Management and Sequestration Centre, The Ohio State University, Columbus, USA, the IARI alumnus, Adjunct Professor to celebrate the World Soil Day on December 5, 2023
- The Division of Plant Pathology and IQAC jointly organized the IARI Alumni Lecture by Dr. H. Pappu, Professor, and Director, Plant Pathology PG Programme, Washington State

University, on October 6, 2023, at the auditorium of Plant Virology Unit, Division of Plant Pathology, ICAR-IARI. He delivered the lecture on the topic "Application of Multiomics for Host-Virus Interactions and Disease Management."

9.1.4 Organization of the Orientation Week Programme for the newly admitted students for the academic session 2023-24

The Graduate School, ICAR-IARI, organized the Orientation Week Programme from November 28 to December 01, 2023, for the newly admitted students to mark the commencement of academic session 2023-24.

On this occasion, a series of activities were planned, including (i) an address by the Hon'ble Secretary, DARE & DG, ICAR, Dr. Himanshu Pathak, to the students during the inaugural open house orientation session held on November 28, 2023 in Dr. B.P. Pal Auditorium of the Institute in hybrid mode; (ii) Special lecture by Dr. Meena Mishra, Director, Brain Behaviour Research Foundation of India, New Delhi on November 29, 2023 at NRL Auditorium (iii) Special motivational session organized on "Heartfulness enabled leadership mastery program" on November 30, 2023 (iv) Dean's address and interaction session with Padma Shri farmers. A campus tour was also organized for the UG students of the academic session 2023-24.

- **Celebration of Constitution Day:** The PGSSU and IQAC, ICAR-IARI, celebrated Constitution Day on November 26, 2023. On this occasion, a debate competition on the topic "Role of youth as embodied in the constitution of India" and a painting competition on the topic "Constitution of India and SDGs" were organized.

9.1.5 Expansion of IARI Regional Academic Outreach

As per the directive of the Secretary, DARE and DG, ICAR to IARI to expand the scope of academic collaboration across ICAR research institutes with similar research mandates as that of IARI, the Academic Council of IARI approved the collaboration across 16 regional ICAR hub clusters in its 418th meeting. Out of the total seats (1197), a total of 1104 students have been admitted for the academic session 2023-24 in IARI New Delhi and the 16 hubs. The sun-planet-satellite model-based system of academic collaboration has been approved by the Governing Body, ICAR.

Seat Matrix and Admission Status of IARI and its Hub Institutes

S. No.	Name of hub	UG		PG		Ph.D.	
		Admitted	Total no. of seats	Admitted	Total no. of seats	Admitted	Total no. of seats
1.	IARI, New Delhi	65	82	108	110	299	**303**
2.	Hyderabad hub	16	20	18	20	19	**20**
3.	Bengaluru hub	-	-	24	27	33	**34**
4.	Baramati hub	24	25	08	08	02	**02**
5.	Nagpur hub	-	-	05	08	03	**04**
6.	Bhopal hub			20	20	16	**17**
7.	Ranchi hub	19	25	14	19	07	**07**
8.	Cuttack hub	25	30	05	06	04	**05**
9.	Kolkata hub	17	20	06	06	04	**04**
10.	Shillong hub	22	25	-	-	-	**-**
11.	Lucknow hub	20	25	09	09	04	**04**

12.	Jodhpur hub	-	-	04	04	04	**04**
13.	Karnal hub	22	25	15	15	07	**8**
14.	Raipur hub	32	35	08	10	04	**04**
15.	Patna hub	22	25	02	02	02	**02**
16.	Assam hub	55	60	32	32	-	**-**
17.	Jharkhand hub	59	66	20	20	-	**-**
	Total	**398**	**463**	**298**	**316**	**408**	**418**

IARI Mega University: Sun-Planet-Satellite Model

9.1.6 International Exposure

IARI has played a key role in the establishment of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Afghanistan.

ANASTU programme

- IARI developed a detailed plan for the establishment of ANASTU as a leading University for agricultural research at Kandahar in Afghanistan in 2013-14.
- Under the ANASTU program, the first two batches of M.Sc. Agronomy of ANASTU graduated in 2016 and 2018. The students of the 3rd Batch of M.Sc. Agronomy was scheduled to arrive at ICAR-IARI on August 17, 2021, for thesis submission and graduation, but they could not travel due to the cancellation of international flights from Kabul. However, they were given online guidance by the IARI Faculty for the completion of their thesis research and thesis writing. All the students of the 3rd Batch of M.Sc. Agronomy has now completed the requirements of the degree program, and their PDCs and final degree certificates have been issued.
- The teaching and research guidance of the 4th Batch of M.Sc. Agronomy has been completed in online mode. All the academic requirements of the batch are expected to be completed by September 2024.
- In 2019, three new M.Sc. courses in Horticulture, Plant Protection, and Animal Husbandry were introduced. The Horticulture and Plant Protection courses were taught at the ICAR-IARI, New Delhi, and that of MSc Animal Husbandry was taught at ICAR-IVRI, Bareilly. The guidance for the students' thesis research was given online. The M.Sc. Horticulture and Plant Protection students have completed all the academic requirements of the degree program, and their PDCs have been issued. The Animal Husbandry students are expected to complete various academic requirements by March 2024.
- The MEA has approved the continuation of online teaching of fresh batches of the ongoing MSc courses of the following four disciplines: 1. Agronomy 2. Horticulture 3. Plant Protection 4. Animal Science.
- The MEA has also approved the online teaching of fresh M.Sc. courses in the following five disciplines based on the 10-year plan of ANASTU: 1. Soil Science and Water Management, 2. Agriculture Economics 3. Extension Technology 4. Livestock Production Management 5. Plant Breeding.

- The teaching of the new courses will be started after their syllabi are prepared and approved by ANASTU.
- To facilitate online teaching, a tele-education facility has been established at the ICAR-IARI, New Delhi. A similar facility will be developed at ANASTU when normalcy returns.

9.2 LIBRARY AND LEARNING RESOURCES

IARI Library was established in the year 1905 in Pusa Bihar, and since its inception, the library has been catering to the literature requirement of the scientific community. In its early collection, there were only 5000 publications donated by the Secretary, Department of Agriculture, Govt. of India. In the year 1934, due to a devastating earthquake on January 15, 1934, the library along with the institute shifted to the present campus in Delhi on July 29, 1936. As a tribute to Prof M.S. Swaminathan, the eminent scientist and father of Green Revolution of India, the IARI Library was renamed "Prof. M.S. Swaminathan Library" on April 29, 2016. In pursuance of the Library Advisory Committee (LAC) 2019 meeting recommendation, the status of Prof. M.S. Swaminathan Library has been upgraded. Henceforth, the Prof. M.S. Swaminathan Library is designated "Prof. M.S. Swaminathan National Agricultural Science Library" w.e.f. January 17, 2020.

Prof. M.S. Swaminathan National Agricultural Science Library is playing the role of National Repository for Agriculture-related literature in India. It is one of the largest and finest agro-biological libraries in South East 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.

The library provides the services as a lead center to all ICAR sister institutes/SAUs and International Institutes. It has 1509 active registered members, *viz.* scientists, students, and technical/administrative staff. Apart from registered members, the library serves approximately 150 to 200 users per day from IARI and also serves users from different Agricultural universities/ICAR Institutes who consult approximately 50-100 library publications/articles daily online/offline. A total of 366 new users were registered from UG/PG/PhD during the period.

9.2.1 Books/Serials

During the period, the library acquired 376 (Gratish journals/Annual reports/) publications, 14 Hindi books, 13 bulletins, and 70 Newsletters. It received 622 IARI theses and uploaded 45 theses (CD Soft copy) in Krishikosh during the period.

9.2.2 Document processing

A total of 1015 documents were processed, consisting of 364 books, 591 post-graduate/ Ph.D. IARI thesis, 30 Bulletins, and 53 Annual Reports.

9.2.3 Resource Management Section

During the period under report, 268 publications were issued, and 224 publications returned. Under the Inter-Library Loan System 11 documents were issued to various institutions.

9.2.4 Document Delivery Service

The Resource Management section of the library provides document delivery services to various users of the Agriculture field through CeRA. The total number of requests received through CeRA during this period was 125, and the requested articles were uploaded on J-Gate.

9.2.5 J-Gate

The Library also subscribed J- Gate (Complete) Database covering 59124+ journals for 2023-24, amounting to ₹ 2,78,775.00. Total number of hits were 13,344. There were 525 total login sessions, 2634 Searches, and 2344 Full Text and Abstract views.

9.2.6 Krishikosh

Krishikosh provides ready software platform to implement all aspects of the open access policy, similar to 'Cloud Service' for individual institution's self-managed repository with central integration. These two products of E-Granth (i) Krishikosh and (ii) IDEAL are being used by all SAUs/DUs/CUs & ICAR Institutes. 622 thesis (CDs) library received, and up to Dec 2023, the library has uploaded 5935 theses in Krishikosh.

9.2.7 E-Language Lab

With the help of a library strengthening program, a Language lab was established with a seating capacity of about 50 participants to facilitate English language classes for IARI foreign/ Indian students. The facility has modern facilities like 30 computers with internet facility, interactive board, visualizes, interactive panel, head phones etc. The language lab is also used for conducting training, LIS Courses, and Summer and Winter School Courses of different divisions and the Directorate to benefit 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 disciplines. The objective of this course is to train the students to search the literature of their interest through literature search tools.

9.3 AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

1. Objectives of AKMU

For modern farming technology, the major role for decision support systems for farmers is Information and Communication Technologies (ICTs) and digital framework. This will help the farmers to connect with all recent information to enhance their knowledge. The activities of this unit are as follows:

- To develop prediction and classification models using Statistical techniques, Non-linear approaches, Artificial Intelligence techniques, Convolutional Neural Networks, Bioinformatics tools, etc., in agriculture.
- To develop methodology, technology, process, and 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.

2. Executive Summary

Krishikosh-a digital repository for NARES: Krishikosh (https://krishikosh.egranth.ac.in/) is a unique repository of knowledge in agriculture and allied sciences, having a collection of theses, old and valuable books, institutional publications, technical bulletins, project, reports, lectures, preprints, reprints, 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 content for compliance with the open access policy of ICAR. It's a central open-access agricultural information platform benefitting Researchers, Peer groups, Ministries & Policymakers, Farmers, and Businesses, having 50 million pages (thesis, research papers, datasets, and articles produced in English and various Indian languages). 109 contributor institutions with an average of 15k daily views. 23.58 Million users using 2,90,800 (195,000 theses across all NARES Institutions) content for research, farming, and educational purposes on the open-access portal.

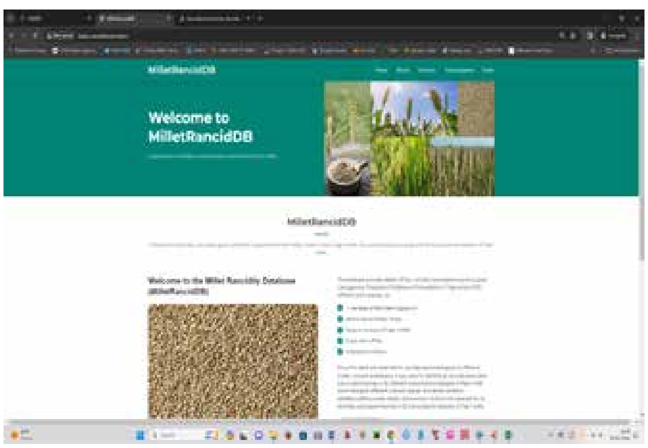
1. **Epidemiology and forecasting of yield, insect-pests, and diseases for value-added agro-advisory:** Developed and validate the forecast models (statistical as well as machine learning approach) for yield & major pests and diseases of Rice, Wheat, Cotton, Mustard, Chickpea, and Pigeonpea at various locations using Agromet and SATMET data on various character *viz.* (i) Crop age at the first appearance of pests, (ii)

Crop age at the maximum population of pests, (iii) Maximum pest population, and (iv) Weekly monitoring of pests. The developed models were converted into web-based systems

2. **AI-based chatbot using natural language processing (NLP):** The AI-based chatbot using natural language processing (NLP) for human-like conversations for FAQ and image analysis based on queries from farmers.

3. **Development of Millet Rancidity Database, MilletRancidDB (http://bajra-rancidity.iari.res.in/index.html):** Millet Rancidity Database, MilletRancidDB (http://bajra-rancidity.iari.res.in/index.html), was developed which is a comprehensive resource dedicated to the exploration of rancidity-associated genes.

4. **Services provided by AKMU:** Web Applications developer, System administrative and Local Area Networks are monitor and maintained by AKMU for main campus of IARI along-with the regional stations.



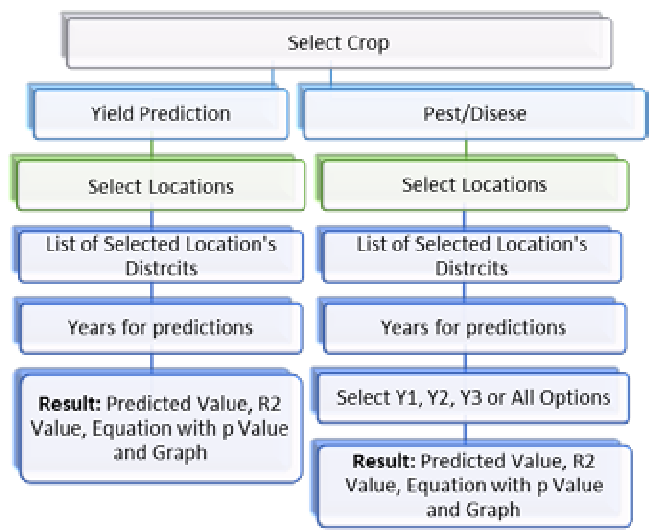
3. Scientific Report:

- **Modified forewarning models for pests (*Helicoverpa armigera* Incidence in Pigeonpea and Chickpea**

Pheromone trap catches: Male moth flight activity was observed throughout the years from 1991-92 to 2011-18 at ICRISAT, Patancheru. Numbers of *H. armigera* catches were recorded at weekly intervals, and expressed as mean number of male moths/trap/week. The roving surveys were conducted to record the *H. armigera* eggs and larvae population in pigeonpea and chickpea from 1998-99 to 2017-18 at ICRISAT, Patancheru. Around 10-15 plants were randomly selected and visual observation of *H. armigera* eggs and larvae populations were recorded. Weekly interval weather data of ICRISAT, Patancheru, from 1991-92 to 2020-21 were downloaded from the ICRISAT website (http://intranet.icrisat.org/). The weather parameters *viz*., rainfall (mm), maximum and minimum temperature (ºC), relative humidity 1 and 2 (%), wind velocity (kmph), solar radiation (mj/m^2) and bright sunshine (hrs) were utilized for the development of weather based model. Data of pheromone trap catches and egg and larval populations were visualized to understand the population dynamics, peak occurrence, and onset of the economic injury levels at critical crop growth stages. The ideal date for pigeon pea planting starts during *kharif* (mid-June *i.e.*, 23 SMW onward) and harvesting season ends around 52 to 04 SMW of next year at ICRISAT, Patancheru. Pigeon pea pod borer moths are to be forecasted first, followed by eggs and larvae for effective management of the population and to maintain the population below an economic threshold level (ETL). Based on the data and crop biology, pigeon pea pod borer moths are predicted at 41-50 SMW, eggs at 41-50 SMW, and larvae at 42-52 SMW, respectively. In case of chickpea, depending on the onset of southwest monsoon chickpea planting starts during *Rabi* (mid-October *i.e.* 40 SMW onward) and harvesting season ends around 9th SWM of next year at ICRISAT, Patancheru. Chickpea pod borer moths are to be forecasted first, followed by egg and larvae for effective management of the population and to maintain the population below ETL level. Based on the data and crop biology, chickpea pod borer moths are predicted at 44-5th SMW of next year, eggs at 45-5th SMW of next year, and larvae at 46-7th SMW of next year, respectively.

Artificial Neural Networks have been developed for crop yield (detrended) of rice, wheat, and sugarcane for six zones of UP. For each variable, weather indices (a technique based on a relatively smaller number of manageable variables and at the same time taking care of the entire weather distribution) were considered as input variables, and detrended yield was as an output variable in model development. The whole data has been divided into two distinct sets, *viz.*, training set and testing set. The MLP architecture using back-propagation learning is one of the most popular neural networks. In this study, the MLP model consists of three layers: an input layer, a hidden layer, and an output layer. Neural network models with different hidden layers (one & two) and different numbers of neurons in a hidden layer with a hyperbolic function as an activation function were explored to select the best architecture, which has the lowest Mean Absolute Percentage Error (MAPE). For ANN models, phyton codes have been developed. For this, input information pertaining to these years was supplied to the trained models as a test data set. MLP-based models neural network models with different hidden layers (1 & 2) and different numbers of neurons (12, 13, and 14) in a hidden layer with hyperbolic function as an activation function were attempted and also obtained MAPE for various models. The trained ANN models have been implemented for the prediction of yields for subsequent cases corresponding to the years not included in the model development.

The web-based prediction system is developed on WordPress CMS, written in PHP, and paired with a MySQL or MariaDB database with supported HTTPS. Features include a plugin architecture and a template system, referred to within WordPress as Themes. The developed system is platform-independent and enriched in various functionalities, which makes the system executable on any operating system. Thus, users does not need do any setup prior to using the system. This web-based Prediction system (http://sbfs.iari.res.in) involves the Prediction of Various Crops Yield like Rice, Wheat, Sugarcane etc., Prediction of Crop age at first Appearance (Y1), Crop age at Peak Population (Y2), and Maximum Population of various pests like Aphids, Jassids, Pink Ballworm in crops like Rice, Cotton, Mustard, and Potato for different locations using satellite-based derived product *i.e.* Satmet data. Postgres database is available for all platforms, *i.e.*, Windows, Linux, Unix, etc.; the major advantage of choosing PostgreSQL in this system is that it is extremely responsive in high-volume environments. GIS plugins can be used to monitor pest infestation at a spatial scale in the future. The forewarning system's user interface is built so that users can easily select pests and locations to know the status of various characters. The platform provides analysis of spatial data by installing postgres. The flow of the prediction model is as follows:



- **Krishikosh** (https://krishikosh.egranth.ac.in/) is a unique repository of knowledge in agriculture and allied sciences, having a collection of theses, old and valuable books, institutional publications, technical bulletins, projects, reports, lectures, preprints, reprints, 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 content for compliance with the open access policy of ICAR. It's a central open-access agricultural information platform benefitting Researchers, Peer groups, Ministries & Policymakers, Farmers, and Businesses, having 50 million pages (thesis, research papers, datasets, and articles produced in English and various Indian languages). 109 contributor institutions with an average of 15k daily views. 23.58 million users are using 2,90,800 (195,000 theses across all NARES Institutions) content for research, farming, and educational purposes on the open-access portal. Setting up a digital repository as a starter and converting legacy data into digital ones, upgraded into a Knowledge Management System through technology and functional enhancements per global standards and stakeholders' needs. Optimized for Google search for enhanced discoverability. AI-based Ontologies and data mining in progress to extract content intelligence, address Semantics, recommender and multi-lingual challenges, real-time data analytics, and geographical spread of users visiting different parts of the repository.

- AI-based chatbot using natural language processing (NLP) also initiated the AI-based chatbot using natural language processing (NLP) for human-like conversations for FAQ and image analysis based on queries from farmers. Chatbots that adopt machine learning approaches use machine learning algorithms to extract information and generate responses and are able to improve through previous conversations. An extensive training set is required for machine-learning-based chatbots. Two types of models are used: retrieval and generative. Retrieval-based models involve choosing the optimal response from a set of responses, and generative models use deep learning techniques to generate the response. The user's input is converted into text, which can be modeled as a stochastic process, and the desired output is the most probable sequence of words *W* that corresponds to the user's input *X*. After the system receives the user's request, it uses the Natural Language Understanding (NLU) component to extract information from the input and produce a representation of its meaning that can be used later on in the process. NLU generally deals with three tasks: dialogue act classification, intent classification, and slot filling. Traditionally, the grammar rules are handcrafted, but over the past decades, more research has focused on assigning the labels automatically. Statistical models, such as the Hidden Markov Model (HMM), are used in labeling problems, the process of assigning a label to each word in a text. The Viterbi algorithm can be used to find the solution, and the forward-backward or Baum-Welch algorithm can be used to train the model.

- **Deep learning-based forewarning models for pest and disease identification**

A model has been developed for predicting tomato leaf disease based on VGG16 architecture. This model is an improvement over Resnet50 and Resnet152. The training dataset comprises 11218 images, while 1245 images are used for testing. The images are 224 by 224 pixels in size and are flattened using the flatten function. Different combinations of activation functions, optimizers, and loss functions were used to achieve the highest accuracy. The employed activation functions include "softmax," "tanh," "real," and "sigmoid," while the optimizers used are SGD, Adam, Adadelta, and RMSProp. The model was trained for 500 epochs with a batch size of 128. After creating the model, it was tested with an image to determine its accuracy. The model provides the probability of a detected disease along with the name of the disease. Additionally, the model's accuracy, loss, and validation accuracy were checked from 0 to 500 epochs to evaluate its performance.

- **Crop yield prediction through the creation of a forecasting model.**

Developed an indices-based forewarning model for crop yield prediction using Long-term memory to analyze data derived from time series (LSTM). Three major crops, wheat, rice, and sugarcane, are not covered by any of the researchers using LSTM. A total of 75 districts of Uttar Pradesh are analyzed in this model development, which is divided into 6 zones. Data from SATMAT obtained from directorate Economics & Statistics, Govt. of India. Two years worth of yields can be predicted with this model. For model development, daily data was converted to weekly data using maximum and minimum temperatures, relative humidity, bright sunshine hours, and relative humidity, Data were considered from $2^{1/2}$ months before harvesting from the 23rd standard metrological week (smw) to 35th smw for rice and wheat data from 40th smw to 52 smw, and sugarcane data from 2nd fortnight of march to 2nd fortnight of September.

- **Machine learning-based approach for the utilization of Google Earth Engine data.**

The forewarning model is influenced by climatic variables such as bright sunshine hours, relative humidity, maximum and minimum temperature, and rainfall. Download the Google Earth Engine data (GEE) and IMD data by applying them to the code. The data obtained from GEE is in Calvin, so convert the bright sunshine hours, relative humidity, maximum and minimum temperature, and rainfall data from Calvin to degree and apply paired T-test on data and obtained t value & p-value and test if the result obtained is significant or not. If the result is highly significant, 0.5 is subtracted from GEE data, and the paired test is applied using code again. The algorithm is applied until GEE data is useful for creating a prediction model.

- **Using CNN approaches, identify biotic stress.**

A detailed analysis was performed for Image Analysis using Inception V3 on plant disease detection. Using the Inception V3 deep learning model, A dataset is trained for plant disease detection in Google Collab, for which took the tomato leaf classification dataset. The dataset has different types of plant disease concerning tomato leaves & download the entire dataset and write a Python code by importing Inception V3 and other important libraries with image size [224,224] using activation 'SoftMax 'with optimizer adam and run it on Google Collab and achieve an accuracy of 0.9018 and valid accuracy of 0.9005. Object detection on images using ML to perform object detection with object segmentation on a custom dataset YOLO V7, which is a multi-purpose tool, is used. This involves creating a virtual environment using Anaconda 3 and applying YOLO V7 to images and videos. It also helps in annotating custom object detection datasets for training and testing. Additionally, it can be used in the field to detect crops and deselect weeds.

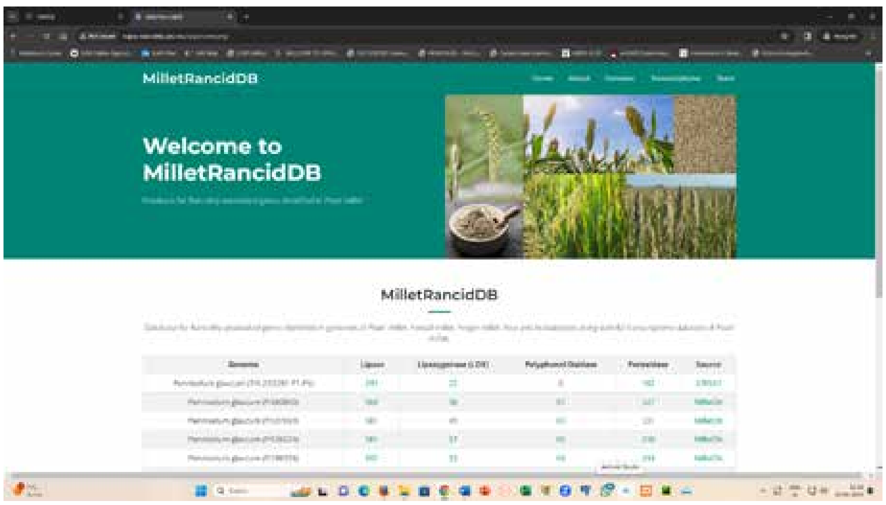
- **Development of Millet Rancidity Database, MilletRancidDB (http://bajra-rancidity.iari.res.in/index.html)**

Millet Rancidity Database, MilletRancidDB (http://bajra-rancidity.iari.res.in/index.html), was developed which is a comprehensive resource dedicated to the exploration of rancidity-associated genes. Genomes of 11 different peal millet varieties (Tift 23D2B1-P1-P5, PI583800, PI537069, PI526529, PI186338, Tifleaf3, PI250656, PI587025, PI521612, PI343841 and PI527388) and one genome each of *Setaria italica* (Yugu1), *Eleusine coracana* (PR202), *Oryza sativa* and Arabidopsis thaliana were taken, resulting in a total of 15 genomes of five diverse plant species. Rancidity-associated genes/enzymes were identified in these genomes, which unveils a wealth of knowledge on 13,263 rancidity-associated genes. Leveraging this rich dataset of rancidity-associated genes, MilletRancidDB has further enabled the identification of rancidity-associated transcripts and enzymes in 82 transcriptome datasets of Pearl millet, representing a variety of cultivars, tissues, and stress conditions, which results in more than 10 lakh hits obtained. The database is online and accessible across the globe.

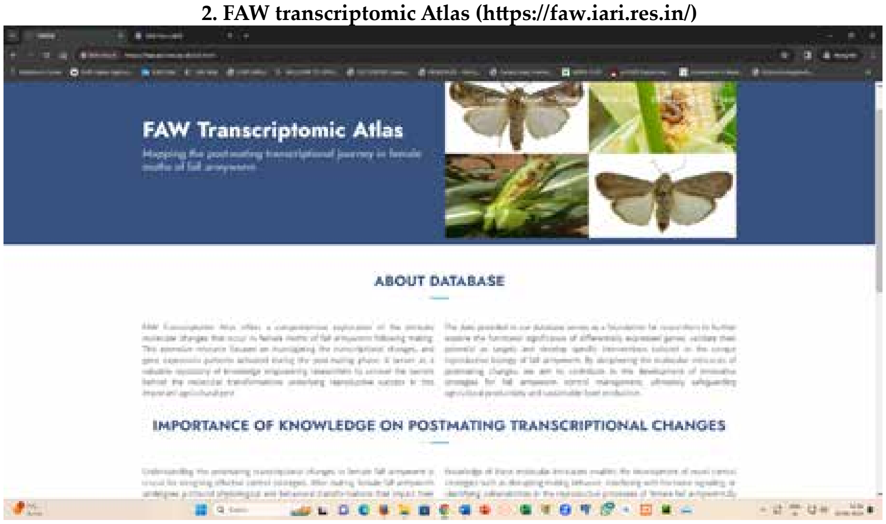
- **Development of FAW transcriptomic Atlas (https://faw.iari.res.in/)**

FAW Transcriptomic Atlas offers a comprehensive exploration of the intricate molecular changes that occur in female moths of fall armyworms following mating. This extensive resource focuses on investigating the transcriptional changes and gene expression patterns activated during the post-mating phase. It serves as a valuable repository of knowledge empowering researchers to unravel the secrets behind the molecular transformations underlying reproductive success in this important agricultural pest. The data provided in our database serves as a foundation for researchers further to explore the functional significance of differentially expressed genes, validate their potential as targets and develop specific interventions tailored to the unique reproductive biology of fall armyworm.

1. Millet Rancidity Database, MilletRancidDB (http://bajra-rancidity.iari.res.in/index.html)



2. FAW transcriptomic Atlas (https://faw.iari.res.in/)



10. PUBLICATIONS

An important mandate of the Institute is to develop an information system, add value to the 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 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 2022 (ISSN: 0972-6136)
- IARI NEWS, April-June, 2023 and July-September, 2023
- IARI Current Events (Monthly) - 12 issues (Available only on IARI website)

10.1.2 Niyamit Prakashan (Hindi)

- पूसा सुरभि (अर्धवार्षिक) (ISSN : 2348–2656)
- वार्षिक रिपोर्ट 2022 (ISSN : 0972–7299)
- पूसा समाचार, अप्रेल – जून, 2023 एवं जुलाई – सितम्बर, 2023
- प्रसार दूत (त्रेमासिक)
- भा.कृ.अ.स. सामयिकी (मासिक) (केवल संस्थान की वैबसाइट पर उपलब्ध)

10.1.3 Technical Publications

S. No.	Title Name of Book	Name of Division/Unit	Date of issue ISBN/ICN No.	ISBN/ICN No.
1.	Agri Startup Innovations	ZTM & BPD Unit	January 30, 2023	978-93-83168-71-2
2.	अध्येता एवं नवोन्मेषी किसान। एक परिचय (Fellow and Innovative Farmer) An Introduction: 2023	CATAT	February 23, 2023	978-93-83168-72-9
3.	Integrated Modelling Assessment on Climate Change Impact, Adaptation and Vulnerability of Indian Agriculture	Environment Science	March 14, 2023	978-93-83168-70-5
4.	Agri-Nutri Information: A Ready Reference	Agricultural Extension	October 12, 2023	978-93-83168-73-6
5.	कृषि पोषण–सारगर्भित संदर्भ	Agricultural Extension	October 12, 2023	978-93-83168-74-3
6.	Indian Agriculture in Climate Change Scenarios: An Assessment on Impacts, Vulnerability and Adaptation	Environment Science	December 28, 2023	978-93-83168-75-0
7.	Advance Techniques in Quality Analysis of Agro-produce	Agricultural Engineering	January 05, 2023	TB-ICN : 288/2023
8.	Bioecology and Physiology of Invasive Fall Armyworm	Entomology	January 05, 2023	TB-ICN : 288/2023

9.	Bioecology and Physiology of Invasive Fall Armyworm	Entomology	January 09, 2023	TB-ICN : 289/2023
10.	Genomics Assisted Insect Pest Management	Entomology	January 30, 2023	TB-ICN : 290/2023
11.	Laboratory Manual on Plant Tissue Culture	Genetics	February 03, 2023	TB-ICN : 291/2023
12.	Airborne Hyperspectral Remote Sensing for Agriculture	Agricultural Physics	February 09, 2023	TB-ICN : 292/2023
13.	Seed Production and Quality Evaluation	Seed Science & Technology	February 20, 2023	TB-ICN : 293/2023
14.	Nutri-Twist: Flavors of Bajra	Biochemistry	February 24, 2023	TB-ICN : 294/2023
15.	Technologies for Shelf Life Enhancement: Popularizing Pearl-Meals for Healthy Life	Biochemistry	February 24, 2023	TB-ICN : 295/2023
16.	Improved Crop Cultivars for Enhanced Productivity Resilience and Nutritional Quality	Genetics	February 24, 2023	TB-ICN : 296/2023
17.	Fungal Genome Sequencing: Basic Biology to Biotechnology	Plant Pathology	March 07, 2023	TB-ICN : 297/2023
18.	Pusa Microbiology Products	Microbiology	March 13, 2023	TB-ICN : 298/2023
19.	Advanced Research Methods and Essential Skills for Social Sciences	Agricultural Economics	March 21, 2023	TB-ICN : 299/2023
20.	Seed Production, Testing and Storage in Field and Vegetable Crops	Seed Science & Technology	March 28, 2023	TB-ICN : 300/2023
21.	Approaches for Doubling Farmer's Income Through Secondary and Smart Agriculture: A Way Forward	CPCT	March 28, 2023	TB-ICN : 301/2023
22.	Tools and Techniques for Analysis of Biomolecules	Biochemistry	April 28, 2023	TB-ICN : 302/2023
23.	Insect Discoveries: ICAR-IARI National Pusa Collection (2017-2022)	Entomology	July 17, 2023	TB-ICN : 303/2023
24.	Seed Production and Certification of Field Crops	Seed Science & Technology	August 03, 2023	TB-ICN : 304/2023
25.	Genomics Approaches for Insect Pest Management	Entomology	August 30, 2023	TB-ICN : 305/2023
26.	Analytical Techniques for Empowering Social Science Research	Economics	September 18, 2023	TB-ICN : 306/2023
27.	Permission for publishing Abstract Book	Biochemistry	October 20, 2023	TB-ICN : 307/2023
28.	Plant Health Management using Genomics Tools	Entomology	November 09, 2023	TB-ICN : 308/2023
29.	Integrated Pest Management	Entomology	November 17, 2023	TB-ICN : 309/2023
30.	Population Diversity, Pathogenomics and Development of Diagnostics Emerging Fungal Plant Pathogens	Plant Pathology	November 17, 2023	TB-ICN : 310/2023
31.	Learning Genomic Tools and Techniques for Improvement of Vegetable Crops	Vegetable Science	November 17, 2023	TB-ICN : 311/2023
32.	Advance Post-Harvest Technologies for Seed Quality Improvement	Seed Science & Technology	November 30, 2023	TB-ICN : 312/2023
33.	Advances in Experimental Design and Genomics for Tailoring Horticultural Crop	Fruits & Horticultural Technology	December 04, 2023	TB-ICN : 313/2023
34.	Agri-Derived Nutrients and Nutraceuticals for innovative Health Foods: Tools and Strategies	Biochemistry	December 11, 2023	TB-ICN : 314/2023
35.	DNA Barcoding of Insects	Entomology	December 19, 2023	TB-ICN : 315/2023

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1.	शेल्फ लाइफ बढ़ाने के लिए तकनीकियां: स्वस्थ जीवन के पर्ल मील्स	Biochemistry	February 24, 2023	ICN: H-205/2023
2.	न्यूट्रिट्विस्ट – जायका बाजरे का	Biochemistry	February 28, 2023	ICN: H-206/2023
3.	उच्च उत्पादकता, लचनशीलता और पोषण गुणवत्ता के लिए फसलों की उन्नत किस्में	Genetics	March 05, 2023	ICN: H-207/2023
4.	पूसा जीवाणु उत्पाद	Microbiology	March 07, 2023	ICN: H-208/2023
5.	जल संचयन	Publication Unit	March 13, 2023	ICN: H-209/2023
6.	मृदा स्वास्थ्य: समस्याएं एवं समाधान	Publication Unit	March 13, 2023	ICN: H-210/2023
7.	प्रशिक्षण पुस्तिका: सीपीडब्ल्यूडी (उद्यान विभाग) के वरिष्ठ मालियों का	Floriculture	July 13, 2023	ICN: H-211/2023
8.	अनार और अमरूद की खेती में सूत्रकृमियों सव समस्या एवं समाधान	Nematology	December 07, 2023	ICN: H-212/2023

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	**799**
	b.	Symposia/conference papers	**438**
2.	**Books/Book Chapters**		
	a.	Books	**61**
	b.	Chapters in books	**284**
3.	**Popular Articles**		**373**

10.3 RESEARCH PUBLICATIONS (NAAS rating >10)

- Adak S, Bandyopadhyay K K, Purakayastha T J, Sen S, Sahoo R N, Shrivastava M and Krishnan P. 2023. Impact of contrasting tillage, residue mulch and nitrogen management on soil quality and system productivity under maize-wheat rotation in the north-western Indo-Gangetic Plains. Front. Sustain. *Food Syst*. 7: 1230207
- Adavi S B, Pratheek H P, Jagadhesan B, Jha S K, Chinnusamy V and Sathee L. 2023. Nitrate supply regulates tissue calcium abundance and transcript level of Calcineurin B-Like (CBL) gene family in wheat. *Plant Physiol. Biochem* 199:107724
- Ambaye T G, Formicola F, Sbaffoni S, Prasad S, Milanese C, Della Cuna, F S R, Franzetti A and Vaccari M. 2023. Treatment of petroleum hydrocarbon contaminated soil by combination of electro-Fenton and biosurfactant assisted bioslurry process. *Chemosphere* 319: 138013
- Arora A, Nandal P and Chaudhary A. 2023. Critical evaluation of novel applications of aquatic weed Azolla as a sustainable feedstock for deriving bioenergy and feed supplement. *Environmental Reviews*
- Aruna T S, Srivastava A, Tomar B S, Behera T K, Krishna H, Jain P K, Pandey R, Singh B, Gupta R and Mangal M. 2023. Genetic analysis of heat tolerance in hot pepper: insights from comprehensive phenotyping and QTL mapping. *Frontiers in plant science 14*
- Aswini K, Suman A, Sharma P, Singh P, Gond S, Pathak D. 2023. Seed endophytic bacterial profiling from wheat varieties of contrasting heat sensitivity. *Frontiers in Plant Science* 14 :1-20
- Avijit G, Biswas D R, Bhattacharyya R, Das S, Das T K, Lal K, Saha S, Alam K, Sarkar A, Biswas S S. 2023. Recycling rice straw enhances the solubilisation and plant acquisition of soil phosphorus by altering rhizosphere environment of wheat. *Soil & Tillage Research* 228: 105647
- Babu S, Singh R, Avasthe R, Kumar S, Rathore S

S, Singh V K, Ansari M A, Valente D, Petrosillo I. 2023. Soil carbon dynamics under organic farming: Impact of tillage and cropping diversity. *Ecological Indicators* 147: 109940

- Babu S, Singh R, Avasthe R, Rathore S S, Kumar S, Das A, Layek J, Sharma V, Wani O A and Singh V K. 2023. Conservation tillage and diversified cropping enhance system productivity and eco-efficiency and reduce greenhouse gas intensity in organic farming. *Frontiers in Sustainable Food Systems* 7: 1114617
- Bana R S, Bamboriya S, Godara S. et al. 2023. Identifying optimum residue levels under long-term conservation agriculture for greater crop and water productivity, sustainability and carbon sequestration of rice-wheat cropping system using APSIM model. *Soil & Tillage Research* https://doi.org/10.1016/j.still.2023. 105745
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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 2023, under the Lab to Land Initiative, fifty-eight (58) innovative technologies of ICAR-IARI were transferred to 189 Industry partners, resulting in revenue generation of ₹ 4,70,43,684. These technologies included the *Bacillus thuringiensis* strains VKK -5, Bitter gourd PDM, Bottle gourd Pusa Samridhi, Bottle gourd c.v. Pusa Santushti, Brinjal Pusa Shyamla, Carrot_ Pusa Asita Pusa Prateek, Chilli c.v. Pusa Jwala, Cow pea c.v. Pusa Komal, Cucumber c.v. Pusa Barkha, Cucumber DPaC 42, Dolichus bean c.v. PEP, HD 3086, HD 3385, HD 3406, HI 1650, HI 1655, HI 8830, HQPM 1, HQPM 1 Improved, HQPM 5 Improved, Methi c.v. PEB, Okra A-4, Onion c.v. Pusa Red, ONION PUSA RED, Onion-Pusa Ridhi, Palak c.v. All Green, PB 1509, PB 1692, PB 1718, PB 1847, PB 1885, PB 1886, PB 1979, PB 1985, PB-1853, Pumpkin Pusa Vikas, Pusa Arunima, Pusa HQPM-1, Pusa Lalima, Pusa Mini Electric Agri Prime Mover with attachments, Pusa Narendra KN1, Pusa Parthenocarpic Cucumber Hybrid-2, Pusa Peetambar, Pusa Pratibha, Pusa Riddhi, Pusa Shrestha, Pusa Super Sweet Corn-1, Pusa Surya, Pusa Vivek QPM 9, Pusa Vivek QPM-9, Renewal of MoA for Mustard variety PM 30, Renewal of MoA for Mustard variety PM 26, Rice Variety Pusa Narendra KN1, Sponge gourd c.v. Pusa Sneha, Sponge gourd Pusa Supriya, VKK -7 for Endophyte technology, Hyrdo Thermal, Manual Multi Crop Planter.

11.2 CORPORATE MEMBER

To create strong and meaningful relationships with the industry and commercial enterprises to disseminate the varieties/ technologies of IARI for the benefit of the society and farmers, ZTM & BPD Unit welcomes partnership through 'Corporate Membership'. Ninety-one new corporate members have been enrolled in 2023, with one hundred eighteen (118) renewals of existing memberships. This created a total number of 209 corporate members and generating a revenue of ₹ 9,39,500 only.

Innovative technologies of ICAR-IARI transferred to Industry partners

11.3 IP MANAGEMENT:

IPRs	Application No./ Registration No./ Grant No.	Name of Innovation/ Technology/ Product/ Variety	Date of Filing/ Registration/ Grant	Application Filed/ Granted/ Registered**
Patents	202311017247	Digital open channel flow measuring device for surface irrigation	March 2023	Filed
	202311030667	Method for extracting graphene from single-use plastic	April 28, 2023	Filed
	202311036906	A walk behind rotary cereal crop harvester and a method thereof	May 29, 2023	Filed
	202311059521	Device and Method for separation of microplastics from soil, sludge and farmyard manure	September 05, 2023	Filed
	201711016288	Method and apparatus for side view imaging for field phenotyping of crop biomass and growth	September 29, 2023	Granted
Trade Marks	4399016	JALOPCHAR	March 31, 2023	Registered
	4430608	SAMARTH	January 17, 2023	Registered
	5481683	AGRI-INDIA HACKTHON	July 10, 2023	Accepted & Advertised
	5481686	SHITIJ	July 10, 2023	Accepted & Advertised
	5481688	SHITIJ	July 10, 2023	Accepted & Advertised
	5481689	BEEJ	July 10, 2023	Accepted & Advertised
	5481690	BEEJ	February 15, 2023	Registered
	5481693	PUSA KRISHI	July 10, 2023	Accepted & Advertised
	5481695	PUSA KRISHI	July 10, 2023	Accepted & Advertised
	5481697	ARISE	July 10, 2023	Accepted & Advertised
	5481699	PUSA KRISHI	July 10, 2023	Accepted & Advertised
	5481700	PUSA KRISHI	February 10, 2023	Registered
	5481701	PUSA KRISHI	February 10, 2023	Registered
	5481702	PUSA KRISHI	July 10, 2023	Accepted & Advertised
	5481703	UPJA	February 15, 2023	Registered
	5481707	AGRIINDIA HACKTHON	July 10, 2023	Accepted & Advertised
	5481709	SHITIJ	February 03, 2023	Registered and Opposed
	5481713	BEEJ	July 10, 2023	Accepted & Advertised

Copyrights	19612/2023-CO/SW	CRISPR PTG Assembler	July 14, 2023	Filed
	21172/2023-CO/SW	SAMARTH	July 31, 2023	Filed
	22663/2023-CO/SW	LnCR-CsExSLDb *cucumis sativus*	July 16, 2023	Filed
	24797/2023-CO/SW	Vignarad Sim v1	March 13, 2023	Filed
	24794/2023-CO/SW	Spinach Simulation model v1	March 13, 2023	Filed
	24796/2023-CO/SW	Cauliflower Simulation model v1	March 13, 2023	Filed
	24650/2023-CO/SW	Printed circuit board (PCB) Design	August 31, 2023	Filed
	24652/2023-CO/SW	AVR C Programme	August 31, 2023	Filed
	20859/2023-CO/SW	LiDAR Based check row planters	July 31, 2023	Filed
	20861/2023-CO/SW	remote control system for smaller tractors	July 31, 2023	Filed

Intellectual property rights from Division of Genetics

IPR	Variety	Details	Date of registration
1.	Pusa Super Sweet Corn 2 (ASKH1)	REG/2021/0201 H	March 27, 2023
2.	PMI-SWT016	REG/2021/0201 P1	March 27, 2023
3.	PMI-SWT017	REG/2021/0201 P2	March 27, 2023
4.	Pusa Super Sweet Corn 1 (ASKH4)	REG/2021/0202 H	March 27, 2023
5.	PMI-SWT019	REG/2021/0202 P1	March 27, 2023
6.	PMI-SWT020	REG/2021/0202 P2	March 27, 2023
7.	Pusa HM4 Improved	REG/2021/0223 H	June 16, 2023
8.	PMI-Q1*	REG/2021/0223 P1	June 16, 2023
9.	PMI-Q2	REG/2021/0223 P2	June 16, 2023
10.	Pusa HM8 Improved	REG/2021/0232 H	July 20, 2023
11	PMI-Q1*	REG/2021/0223 P1	July 20, 2023
12.	HKI161	REG/2021/0232 P2	July 20, 2023
13.	Pusa HM9 Improved	REG/2021/0228 H	July 19, 2023
14.	PMI-Q1*	REG/2021/0223 P1	July 19, 2023
15.	PMI-Q3	REG/2021/0228 P2	July 19, 2023
16.	Pusa Vivek QPM9 Improved	REG/2021/0229 H	July 19, 2023
17.	PMI-PV1	REG/2021/0229 P1	July 19, 2023

18.	PMI-PV2	REG/2021/0229 P2	July 19, 2023
19.	Pusa Vivek Hybrid27 Improved	REG/2021/0230 H	July 19, 2023
20.	PMI-PV3	REG/2021/0230 P1	July 19, 2023
21.	PMI-PV4	REG/2021/0230 P2	July 19, 2023
22.	Pusa HQPM-5 Improved	REG/2021/0222 H	June 16, 2023
23.	PMI-PV6	REG/2021/0222 P1	June 16, 2023
24.	PMI-PV5*	REG/2021/0222 P2	June 16, 2023
25.	Pusa HQPM-7 Improved	REG/2021/0231 H	July 19, 2023
26.	PMI-PV7	REG/2021/0231 P1	July 19, 2023
27.	PMI-PV5*	REG/2021/0222 P2	July 19, 2023

11.4 INCUBATION ACTIVITIES

11.4.1 UPJA (Seed Stage) Incubation Program 2023-24

UPJA 2023, an initiative launched on April 14, 2023, seeks to boost innovation and entrepreneurship in India's agri-startup scene. It's a program supporting agri-startups beyond the prototype stage, having market-ready products. It has a funding provision of up to ₹ 25,00,000 per startup. The application deadline was May 14, 2023. Out of 510 applications, 145 were invited for the Round of Initial Consideration on June 1st, 2nd and 5th, 2023 based on their focus areas. Following thorough assessments by the RIC-1 Selection Committee, 36 startups were selected for a two-month incubation program. The goal is to propel these startups towards sustained growth and success in the dynamic agri-startup landscape.

Launch of UPJA 2023

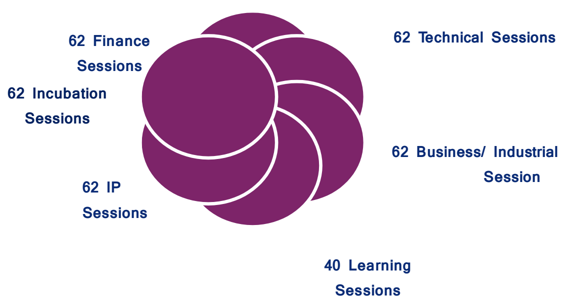
11.4.2 ARISE (Pre-Seed Stage incubation programme) 2023 – 24

ARISE was officially launched on April 14, 2023, marking the transition from idea incubation to concrete business development. The program's goal was to nurture innovation in agriculture and related sectors. In ARISE, there is a provision of funding up to ₹ 5,00,000 per startup, respectively. The submission deadline was May 14, 2023, when aspiring entrepreneurs could present their early-stage ideas. A total of 325 applications were received, each rigorously evaluated by a panel of experts in technology, business, and incubation. Following this evaluation, 44 promising applicants were selected for the ARISE RIC-I phase on June 1, 2 and 5, 2023. These individuals and teams, with diverse focuses in agriculture, underwent technical and business assessments. Ultimately, 26 startups were chosen by the RIC-1 Selection Committee to be a part of a two-month incubation program designed to nurture their concepts and provide essential resources and mentorship.

Launch of ARISE 2023

11.4.3 Upja & Arise 2-month incubation program

These Programmes aim to nurture early-stage innovators and 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 the MVP (Minimum Viable Product) stage. It was launched on June 15, 2023. The program, designed to offer startups a comprehensive learning experience, featured personalized mentoring and thoughtfully crafted sessions covering design thinking principles to successful product launches. The valedictory session was organized on August 16, 2023, encapsulated key moments, culminating in 16 startups recommended for pre-seed stage and 18 startups selected for seed stage funding during the RC meeting on September 12 & 13, 2023.



11.4.4 SHITIJ

Shitij is a year-long incubation program that nurtures early-stage startups with full-throttle capacity building, infrastructure, and other resources to solve the big challenges in agriculture with innovative solutions. The deadline for this event was September 20, 2023 and 107 applications were received. The result was announced on September 29, 2023 and the final selection round was conducted on October 3–4, 2023 after which the mentoring sessions were held from October 16–31, 2023. These sessions provided comprehensive capacity building, essential infrastructure, and various resources to empower these startups in addressing significant agricultural challenges through innovative solutions. The second phase of Shitij was organized from December 19 – 22, 2023. In the second phase of Shitij, PUSA KRISHI will provide startups the unique opportunity to benefit from one-on-one mentoring sessions, providing them with invaluable guidance and support. This will equip these startups with the requisite knowledge and expertise to navigate the ever-evolving agricultural industry effectively, enabling them to create sustainable solutions and make a meaningful impact within their respective sectors.

11.4.5 Other Activities

11.4.5.1 Her Harvest

Her Harvest was a five-day online workshop series organized from February 13–17, 2023, with leading women entrepreneurs & amp; changemakers. The program provided opportunities to engage with successful women in various fields, including business, technology, social media, art, and design. Expert interactive workshops, discussions, debates, immersive activities, and a full-throttle learning experience of the startup ecosystem through the lens of women. 66 people participated in the program.

11.4.5.2 Startup showcasing in Pusa *Krishi Vigyan Mela*

Pusa *Krishi Vigyan Mela* was organized from March 2– 4, 2023. A total of 43 startups participated from our side, out of which 7 were millet-based startups who displayed their stalls in the thematic area. These startups attracted various crowds, ran their feasibility studies, tested their offerings with farmers, and got an excellent marketing and networking platform.

11.4.5.3 BEEJ

BEEJ 2023 was organized from March 13–24, 2023. It was a series of 11 masterclasses with experts from the startup ecosystem, policymaking, finance, design, technology etc. It involved two-week online Masterclasses, Expert mentors and speakers, and an e-certificate on completion. It was launched on February 27, 2023 with 103 participants.

11.4.5.4 Pusakrishi Master Class Series

As a strategic collaborator within the RKVY-RAFTAAR initiative of the Ministry of Agriculture & Farmers Welfare, Pusa Krishi initiated a transformative Masterclass series spanning from April 24 to May 18, 2023, exclusively tailored for agri-startups recommended by the CIC for funding and emanating from 12 meticulously curated incubators. This endeavor materialized after a comprehensive year-long incubation process entailing mentorship and strategic guidance. More than 300 startups applied for the programme from 50 ABICs of ICAR and 12 R-ABI of RKVY-RAFTAAR, Ministry of Agriculture.

11.4.5.5 Agri India Meet (AIM) 3.0

We organized the third edition of the Agri-India Meet. It was scheduled to have deliberations between different stakeholders and discuss several key topics within the agriculture domain. We organized the following sessions under this edition of AIM.

S. No.	Topic of the session	Date of the session
1	Agriculture Infrastructure Fund (AIF): How is AIF strengthening the Agri & Allied startups	May 3, 2023
2	Food Business Startups & FSSAI	December 5, 2023

11.4.6 The co-working space at the Pusa Krishi centre

We have established PHT, Biotechnology, and Bioinformatics labs along with the co-working space at the Pusa Krishi Centre, fostering innovation for startups. We recognize agriculture's historical significance and aim to propel it into a tech-driven future. Post-harvest technology, Bioinformatics, and Fab Labs are pivotal in this transformation, enhancing productivity and efficiency. Our initiative empowers startups to delve into these key pillars, contributing to the evolution of agriculture and ensuring sustenance and livelihoods for communities worldwide.

11.4.6.1 PHT Lab

Navigating the challenges from farm to table, Post-Harvest Technology (PHT) Lab pioneers solutions against losses of agricultural produce. Equipped with cutting-edge tools like Proofer, sealing machines, and baking ovens, it focuses on refining handling, storage, and distribution.

11.4.6.2 Biotechnology Lab

Unveiling the potential of biological systems, the Biotechnology Lab fosters advancements in agriculture through GMOs, gene editing, and innovative technologies. Gel documentation units, spectrophotometers and Real-time PCR tools empower this exploration.

11.4.6.3 Bioinformatics Lab

Positioned at the biology and data science crossroads, the Bioinformatics Lab revolutionizes agriculture with genomics and proteomics. Housing a Bioinformatics server, it stands as a hub for data-driven crop management and breeding strategies.

Pusa Krishi Centre co-working facilities

11.4.7 MoUs/Agreements Signed

In 2023, 242 MOA have been signed for 58 technologies with 189 industry partners generating a revenue of ₹ 4,70,43,684. This included two renewals. Other than this 53 incubation MOUs were signed generating a revenue of ₹ 3,90,000.

12. LINKAGES AND COLLABORATION

The Indian Agricultural Research Institute has linkages with various National and International Institutes/organizations. At the 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 Department 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 center to coordinate the accelerated crop improvement program for breeding rust-resistant wheat varieties involving 10 centers, improving maize quality, enabling several SAUs and ICAR institutes to upgrade and update themselves with new tools and techniques. Under the NAIP and NASF, IARI is the lead center to develop state-of-the-art facilities and infrastructure for food science and phonemics-led sciences. The NICRA program 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 the project of ICAR, the Institute has been encouraging linkages and professional collaborations among national institutes to work on major research focus on 'Molecular breeding' for improvement of tolerance to biotic and abiotic stress, yield and quality traits in crops, and 'Hybrid technology' for higher productivity in selected field and horticultural crops. The Institute also identified some of the priority research areas through other ICAR Consortium Research Platforms as Mega Seed platform, Genomics platform, Diagnostic and Vaccines, Energy platform, Water platform, Conservation Agriculture platform, Farm mechanization and Precision farming, etc.

In the public-private partnership mode, the role and participation of the private sector in agricultural services are increasing in different forms and capacities. This underlines the need to ensure effective public-private partnerships and linkages besides improving the institutions' structural and operational efficiency and governance to make them farmer-friendly. Keeping this in mind, the Institute has planned to forge collaboration with some of the private seed sector, which has a strong R&D base and expertise in seed quality enhancement, as well as with advanced research centers 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 program 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 program with the University of Nebraska from the 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) the Afghan National University of Agricultural Sciences and Technology, Afghanistan, and the 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 establish two IARI-like Institutions 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 centers of excellence at IARI have established linkages with different national institutions through their regular training programs and also through other programs offered through the 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 January 01- December 31, 2023 is given below:

Name of Funding Agency	Number of Projects
Within India 1. Department of Biotechnology (DBT) 2. Department of Science & Technology (DST) 3. National Committee on Plasticulture Application in Horticulture (NCPAH) 4. Council of Scientific and Industrial Research (CSIR) 5. Department of Agriculture and Cooperation (DAC) 6. Indian Meteorological Department (IMD) 7. Board of Research in Nuclear Sciences (BRNS) 8. Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), 9. Ministry of Human Resource and Development (MHRD) 10. National Bank for Agriculture and Rural Development (NABARD) 11. Ministry of Environmental, Forest and Climate Change (MoEF&CC) 12. UP Council of Agricultural Research (UPCAR) 13. Ministry of Food Processing Industries (MoFPI) 14. NTPC 15. Ministry of Steel 16. Central Pulp & Paper Research Institute (CPPRI) 17. Department of Scientific & Industrial Research (DSIR) 18. Ministry of Electronics & Information Technology (Meity) 19. Central Council for Research in Ayurvedic Sciences (CCRAS) 20. Delhi Research Implementation & Innovation Foundation (DRIIV) 21. Indian Council of Agricultural Research (ICAR)	165

Outside India 1. Bill & Melinda Gates Foundation & UK Department of International Development (DFID) 2. Bill & Melinda Gates Foundation 3. ICAR-International Rice Research Institute 4. International Fertilizer Development Centre (IFDC), USA 5. United Kingdom Research & Innovation (UKRI) 6. Heinrich Heine University (HHU), Germany 7. HarvestPlus-International Food Policy Research Institute, USA 8. Centre for Agriculture and Bioscience International (CABI), United Kingdom 9. US-National Academies of Sciences under USAID 10. Borlaug Institute of South Asia, BISA 11. Japan International Cooperation Agency, JICA 12. CIMMYT, Mexico 13. International Centre of Agriculture Research in the Dry Areas, ICARDA	16
Total	**181**

13. AWARDS AND RECOGNITION

- Dr. A.K. Singh, Director, ICAR-IARI received Professor S K Sinha Memorial Lecture Award-2023 by Indian Society of Plant Physiology
- Dr. A.K. Singh, Director, ICAR-IARI and the team Dr. Gopala Krishnan S, Dr. Ranjith K Ellur, Dr. P.K. Bhowmick, Dr. Nagarajan M, Dr. K.K. Vinod, Dr. Haritha Bollinedi received Team Certificate and Appreciation for the development of technology: Rice variety Pusa Basmati 1985, Development of first herbicide tolerant basmati rice variety in India
- Dr. Mukesh K Dhillon, Head, Division of Entomology was elected as a Fellow of the Royal Entomological Society
- Dr. M.S. Saharan, Head, Division of Plant Pathology received Dr R Prasada Memorial Award from the Indian Society of Mycology & Plant Pathology (ISMPP) and also received Prof S N Banerjee Memorial Lecture Award
- Dr. N.A. Shakil, Head, Division of Agricultural Chemicals was elected as Chair 15th IUPAC International Congress of Crop Protection Chemistry
- Dr. Alka Singh, Head, Division of Agricultural Economics elected as a Fellow of the Indian Society for Agricultural Economics
- Dr. Gyan P. Mishra, Head, Seed Science & Technology received 8th Dr Harbhajan Singh Memorial Award 2022 of ISGPB, New Delhi
- Dr. S.S. Rathore, Head, Division of Agronomy was elected as a Fellow of the Indian Association of Hill Framing for 2022 for outstanding education and research
- Dr. K.K. Pramanick, Head, Regional Station Shimla received Pandit Jawaharlal Nehru Scientist Award-2023 by STA Temperate Horticulture
- Dr. H.K. Dikshit, Professor, Division of Genetics was awarded Fellowship of National Academy of Agricultural Sciences *w.e.f.* 01.01.2023 and also received Dr. A.B. Joshi Memorial Award 2022 (Binneal) of ISGPB, New Delhi
- Dr. Robin Gogoi, Professor, Division of Plant Pathology received Prof. V P Bhide Memorial Award from the Indian Society of Mycology & Plant Pathology (ISMPP)
- Dr. Firoz Hossain, Principal Scientist & Programme Leader, Division of Genetics received Team Award: Best AICRP-Maize Centre Award for the biennium (2021-22 & 2022-23)
- Dr. D. Vijay, Principal Scientist, Division of Seed Science and Technology was elected as a Fellow of Range Management Society of India, ICAR-IGFRI, Jhansi
- Dr. Ashwani Kumar, Principal Scientist, Regional Station Karnal received a Certificate for Technology Development for 'Optimization of aperture size of bottom/ grading sieves for processing of new crop varieties'
- Dr. Atul Kumar, Principal Scientist, Division of Seed Science and Technology received the Choudhary Devi Lal Outstanding AICRP Award for AICRP NSP crops
- Dr. M. Hasan, Principal Scientist, Centre for Protected Cultivation Technology received Dr Rajendra Prasad Purasakar 2022, ICAR for Technical Book Greenhouse Farming Book in Hindi
- Dr. Y.S. Shivay, Principal Scientist, Division of Agronomy received Gold Medal from the Indian Society of Agronomy and also elected as a Fellow of the International Society of Environmental Botanists for the year 2021–22
- Dr. Anchal Dass, Principal Scientist, Division of Agronomy was elected as a Fellow of Society of Tropical Agriculture, 2022

- Dr. Ramanjit Kaur, Principal Scientist, Division of Agronomy received the ISWS Fellow Award from the Indian Society of Weed Science
- Dr. D.R. Biswas, Principal Scientist, Division of Soil Science and Agricultural Chemistry received the Award for Excellence for the Best Work done in the field of Plant Nutrition, FAI 2023 and also received the Platinum Jubilee Commemoration Award 2023 for outstanding lifetime contributions by Indian Society of Soil Science
- Dr. Kalyan Mondal, Principal Scientist, Division of Plant Pathology was elected as an NAAS Fellow in Plant Protection
- Dr. Anirban Roy, Principal Scientist, Division of Plant Pathology was elected as a Fellow of National Academy of Biological Sciences
- Dr. Supradip Saha, Principal Scientist, Division of Agricultural Chemicals was elected as a Fellow, Royal Society of Chemistry, London
- Dr. Archana Singh, Principal Scientist, Division of Biochemistry became a Fellow of the Indian Agricultural Society of Biochemists (IASB)
- Dr. R.R. Burman, Principal Scientist, Division of Agricultural Extension was elected as NAAS Fellow 2023
- Dr. Vignesh Muthsamy, Senior Scientist, Division of Genetics, received Young Scientist Award by the Indian National Science Academy
- Dr. Niharika Mallick, Sr. Scientist, Division of Genetics received NESA Scientist of the Year Award-2023
- Dr. Vishwanath Y. Senior Scientist, Division of Seed Science and Technology received the Best oral presentation award at 3rd "National Symposium on Edible Alliums" during February 11-14, 2023 at Jain Hills, Jalgaon
- Dr. Harshawardhan Choudhary, Senior Scientist, Division of Vegetable Science received a Fellowship of the Indian Academy of Horticultural Sciences for Research contributions in Horticulture
- Dr. J.K. Ranjan, Senior Scientist, Division of Vegetable Science was elected as a Fellow of the Indian Society of Vegetable Science (ISVS)
- Dr. Namita, Senior Scientist, Division of Floriculture and Landscaping received the Manmohan Attavar Award in Floriculture-2023, IAHS, New Delhi
- Dr. Neelam Upadhyay, Senior Scientist, Division of Food Science and Post-harvest Technology received Shri Somalal Vyas - SEA Innovation Award - 2023
- Dr. Subhash Babu, Senior Scientist, Division of Agronomy received the NAAS Associate Fellow Award for the year 2023; also received INYAS membership from the Indian National Young Academy of Science, INSA, New Delhi
- Dr. Amalendu Ghosh, Senior Scientist, Division of Plant Pathology was elected as NAAS Associate-2023
- Dr. T.K. Dutta, Senior Scientist, Division of Nematology was Selected for the Fulbright Fellowship (2023-24 Fulbright-Nehru Academic and Professional Excellence Fellowships) conferred by the United States-India Education Foundation (USIEF)
- Dr. Aditi Kundu, Senior Scientist, Division of Agricultural Chemicals received Dr HK Jain Memorial Young Scientist Award, (2022) from Indian Agricultural Research Institute, New Delhi
- Dr. Rajkumar U. Zunjare, Scientist, Division of Genetics received Young Scientist Award by the National Academy of Agricultural Sciences and SERB-International Research Experience Fellowship to visit Iowa State University, Ames, USA (2022)
- Dr. Ranjith K Ellur, Scientist, Division of Genetics received NAAS Associateship, National Academy of Agricultural Sciences, New Delhi
- Dr. S.S. Dey, Scientist, Division of Vegetable Science received the D.P. Ghosh Young Scientist Award of the Indian Academy of Horticultural Sciences
- Dr. Prasenjit Ray, Scientist, Division of Soil Science and Agricultural Chemistry received an Indo-US Visiting Fellowship

- Dr. Suneha Goswami, Scientist, Division of Biochemistry received the Young Women Scientist Award" in the 10th National Seminar on Agriculture and More: Beyond 4.0
- Dr. Chirag Maheshwari, Scientist, Division of Biochemistry received the Young Scientist Award at National symposium on Emerging Innovations in Plant Molecules for Achieving Food and Nutritional Security (EIPMAFNS-2022)
- Dr. V. Sangeetha, Scientist, Division of Agricultural Extension received Third prize in athletics in the ICAR Central Zonal Sports tournament

14. BUDGET ESTIMATES & UTILIZATION

Statement showing Budget Estimates (B.E.) & Revised Estimates (R.E) for the year 2023-24 under Unified Budge

											(₹ In Lakhs)
		B.E. 2023-24					**R.E. 2023-24**				
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	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	
	B. Building										
	i. Office building	2000.00	0.00	0.00	0.00	**2000.00**	550.00	0.00	0.00	0.00	**550.00**
	ii. Residential building	2700.00	0.00	0.00	0.00	**2700.00**	3992.00	0.00	0.00	0.00	**3992.00**
	iii. Minor Works	200.00	0.00	0.00	0.00	**200.00**	75.00	0.00	0.00	0.00	**75.00**
2	Equipments	600.00	100.00	40.00	150.00	**890.00**	690.00	100.00	40.00	100.00	**930.00**
3	Information Technology	220.00	0.00	0.00	0.00	**220.00**	112.00	0.00	0.00	0.00	**112.00**
4	Library Books and Journals	100.00	0.00	0.00	0.00	**100.00**	100.00	0.00	0.00	0.00	**100.00**
5	Vehicles & Vessels	100.00	0.00	0.00	0.00	**100.00**	45.00	0.00	0.00	0.00	**45.00**
6	Livestock	2.00	0.00	0.00	0.00	**2.00**	2.00	0.00	0.00	0.00	**2.00**
7	Furniture & fixtures	400.00	0.00	0.00	0.00	**400.00**	334.00	0.00	0.00	0.00	**334.00**
A	**Total – CAPITAL (Grants for creation of Capital Assets)**	**6322.00**	**100.00**	**40.00**	**150.00**	**6612.00**	**5900.00**	**100.00**	**40.00**	**100.00**	**6140.00**
1	Establishment Expenses (Salaries)										
	i. Establishment Charges	28000.00	0.00	0.00	0.00	28000.00	27000.00	0.00	0.00	0.00	27000.00
	ii. Wages	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	iii. Overtime Allowance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total – Establishment Expenses	**28000.00**	**0.00**	**0.00**	**0.00**	**28000.00**	**27000.00**	**0.00**	**0.00**	**0.00**	**27000.00**
Grants in Aid - General (REVENUE)											
1	**Pension & Other Retirement Benefits**	23800.00	0.00	0.00	0.00	**23800.00**	27000.00	0.00	0.00	0.00	**27000.00**
2	**Traveling Allowance**										
	A. Domestic TA / Transfer TA	100.00	0.00	0.00	0.00	**100.00**	100.00	0.00	0.00	0.00	**100.00**
	B. Foreign TA	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**
	Total – Traveling Allowance	**100.00**	**0.00**	**0.00**	**0.00**	**100.00**	**100.00**	**0.00**	**0.00**	**0.00**	**100.00**

3	**Research & Operational Expenses**										
	A. Research Expenses	1000.00	0.00	0.00	0.00	**1000.00**	1000.00	0.00	0.00	0.00	**1000.00**
	B. Operational Expenses	2100.00	200.00	100.00	200.00	**2600.00**	2100.00	200.00	131.70	200.00	**2631.70.00**
	Total - Research & Operational Expenses	**3100.00**	**200.00**	**100.00**	**200.00**	**3600.00**	**3100.00**	**200.00**	**131.70**	**200.00**	**3631.70.00**
4	**Administrative Expenses**										
	A. Infrastructure	3700.00	0.00	0.00	0.00	**3700.00**	4000.00	0.00	0.00	0.00	**4000.00**
	B. Communication	30.00	0.00	0.00	0.00	**30.00**	30.00	0.00	0.00	0.00	**30.00**
	C. Repairs & Maintenance						0.00	0.00	0.00	0.00	**0.00**
	i. Equipments, Vehicles & Others	400.00	0.00	0.00	0.00	**400.00**	500.00	0.00	0.00	0.00	**500.00**
	ii. Office building	650.00	0.00	0.00	0.00	**650.00**	1950.00	0.00	0.00	0.00	**1950.00**
	iii.Residential building	650.00	0.00	0.00	0.00	**650.00**	1950.00	0.00	0.00	0.00	**3950.00**
	iv. Minor Works	200.00	0.00	0.00	0.00	**200.00**	300.00	0.00	0.00	0.00	**300.00**
	D. Others (excluding TA)	920.00	0.00	0.00	49.00	**969.00**	1000.00	0.00	0.00	49.00	**1049.00**
	Total - Administrative Expenses	**6550.00**	**0.00**	**0.00**	**49.00**	**6599.00**	**9730. 00**	**0.00**	**0.00**	**49.00**	**9779.00**
5	**Miscellaneous Expenses**										
	A. HRD	30.00	0.00	0.00	79.00	**109.00**	50.00	0.00	0.00	0.00	**50.00**
	B. Other Items (Fellowships, Scholarships etc.)	1600.00	100.00	140.00	751.00	**2591.00**	1600.00	210.00	40.00	726.00	**2576.00**
	C. Publicity & Exhibitions	70.00	0.00	0.00	0.00	**70.00**	90.00	0.00	0.00	0.00	**90.00**
	D. Guest House – Maintenance	150.00	0.00	0.00	0.00	**150.00**	158.00	0.00	0.00	0.00	**158.00**
	E. Other Miscellaneous	150.00	100.00	0.00	200.00	**450.00**	280.00	100.00	10.00	200.00	**590.00**
	Total - Miscellaneous Expenses	**2000.00**	**200.00**	**140.00**	**1030.00**	**3370.00**	**2178.00**	**310.00**	**50.00**	**926.00**	**3464.00**
	Total Grant in Aid-General	**11750.00**	**400.00**	**240.00**	**1279.00**	**13669.00**	**15108.00**	**510.00**	**181.70**	**1175.00**	**16974.70**
	Total (Pension+General)	**35550.00**	**400.00**	**240.00**	**1279.00**	**37469.00**	**42108.00**	**510.00**	**181.70**	**1175.00**	**43974.00**
B	**Total Revenue (Grants in Aid - Salaries +Pension+ General)**	**63550.00**	**400.00**	**240.00**	**1279.00**	**65469.00**	**69108.00**	**510.00**	**181.70**	**1175.00**	**70974.00**
	Grand Total (Capital +General)	**18072.00**	**500.00**	**280.00**	**1429.00**	**20281.00**	**21008.00**	**610.00**	**221.70**	**1275.00**	**23114.70**

Note: Sub Head wise allocation under Revised Estimate 2023-24 is tentative and is subject to change based on final expenditure figures

15. STAFF POSITION, APPOINMENTS, PROMOTIONS AND TRANSFERS

(As on 31.12.2023)

Sl. No.	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	05	05
2)	Principal Scientist	61	47
3)	Senior Scientist/Scientist (S.G.)	128	83
4)	Scientist	373	299
	Total	**567**	**434**
B.	**TECHNICAL STAFF**		
1)	Category III	11	08
2)	Category II	275	133
3)	Category I	306	214
	Total	**592**	**355**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	30	24
2)	Group B	277	164
3)	Group C	110	72
	Total	**417**	**260**
D.	**SKILLED SUPPORT STAFF**	**730+337***	**428**

*Additional post for regularization for DPL's

SCIENTIFIC STAFF

APPOINTMENT/JOINING THE INSTITUTE

Name of the Employee	Name of the post	Place of Posting	Date of Appointment
Dr. P.S. Brahmanand	PD	WTC	February 03, 2023
Dr. Dinesh Kumar	Head	Food Science & Post Harvest Technology	May 8, 2023
Dr. Subhash Nataraja Pillai	Head	Agricultural Physics	May 09, 2023
Dr. Debasish Mandal	Head	Soil Science & Agricultural Chemistry	June 22, 2023
Dr. Brijesh Kumar Mishra	Principal Scientist	Agricultural Microbiology	May 24, 2023

Dr. Debashis Dutta	Principal Scientist	Soil Science & Agricultural Chemistry	June 20, 2023
Dr. Biraj Bandhu Bisak	Senior Scientist	Soil Science & Agricultural Chemistry	March 03, 2023
Dr. Nripendra Singh	Senior Scientist	Fruit and Horti. Technology	March 31, 2023
Dr. Ravindra Kumar	Senior Scientist	Plant Pathology	October 05, 2023
Dr. Mohammad Hasnaian	Scientist	RS, Pusa Bihar	April 11, 2023
Ms. Neelam Upadhyay	Scientist	Food Science & Post Harvest Technology	January 12, 2023
Ms. Neetu Mohan	Scientist	Genetics	December 11, 2023
Dr. Pankhur Singhal	Scientist	Plant Pathology	July 28, 2023
Dr Ratna Prabha	Scientist	AKMU	March 10, 2023
Dr. Shilpi Verma	Scientist	Soil Science & Agricultural Chemistry	March 03, 2023
Dr. Sneha Adhikari	Scientist	Genetics	March 27, 2023
Dr. Vijaya Rani	Scientist	Food Science & Post Harvest Technology	December 11, 2023

TRANSFER AND RETIREMENT

Name of The Employee	Name of The Post	Division	Date of Transfer
Dr. Man Singh	PD	W.T.C	April 30, 2023
Dr. Vikash Mandal	Incharge, Virology Unit	Plant Pathology	February 01, 2023
Dr. Neeru Bhooshan	Incharge	ZTM & BPD Unit	February 10, 2023
Dr. G.K. Jha	Nodal Officer (HRD)	Agri. Economics	July 05, 2023
Dr. S.P. Datta	Prof (SS&AC)	Soil Sci.& Agri. Chem.	February 10, 2023
Dr. Anju Mahendru Singh	Prof (Genetics)	Genetics	May 08, 2023
Dr. M.K. Verma	Principal Scientist	Fruit & Horti. Technology	January 24, 2023
Dr. Raj Verma	Principal Scientist	Vegetable Science	January 31, 2023
Dr. Rajarshi Roy Burman	Principal Scientist	Agricultural Extension	February 02, 2023
Dr. A. Nagaraja	Principal Scientist	Fruit & Hort. Tech.	March 31, 2023
Dr. Sachin Suresh Suroshe	Principal Scientist	Entomology	March 10, 2023
Dr. Shailesh Tripathi	Principal Scientist	Genetics	April 29, 2023
Dr. Vinay Kumari Kalia	Principal Scientist	Entomology	April 30, 2023
Dr. Praveen Kumar Singh	Principal Scientist	Veg.Sciences	May 08, 2023
Dr. Harender Kumar	Principal Scientist	Nematology	May 12, 2023
Dr. Shiv Pratap Singh	Principal Scientist	Agri. Engineering	June 14, 2023
Dr. K.K. Bandyopadhyay	Principal Scientist	Agri. Physics	June 28, 2023
Dr. Hari Lal Kushwaha	Principal Scientist	Agri. Engineering	July 11, 2023
Dr. A.K. Dubey	Principal Scientist	Fruit & Hort. Tech.	July 12, 2023
Dr. Dinesh Singh	Principal Scientist	Plant Pathology	July 12, 2023
Dr. A.D. Munshi	Principal Scientist	Veg.Sciences	July 31, 2023
Dr. R.N. Gadag	Principal Scientist	Genetics	July 31, 2023

Dr. Sunil Pabbi	Principal Scientist	Unit of BGA	July 31, 2023
Dr. Kalyan Kumar Mondal	Principal Scientist	Plant Pathology	August 04, 2023
Dr. Navindu Gupta	Principal Scientist	Env. Sci.	August 31, 2023
Dr. Nirmal Chandra	Principal Scientist	Agri. Extension	November 30, 2023
Dr. Sagar D.	Principal Scientist	Entomology	December 13, 2023
Dr. Raju R.	Senior Scientist	Agricultural Economics	January 04, 2023
Dr. Anirban Dutta	Senior Scientist	Agri. Chemicals	March 06, 2023
Dr. Brij Bihari Sharma	Scientist	Veg. Sciences	August 30, 2023
Dr. Archana Anokhe	Scientist	Entomology	December 20, 2023

ADMINISTRATIVE STAFF

PROMOTIONS

Name of the Employee	Name of the post	Post after Promotion	Date of promotion
Sh. Yash Pal Singh	Assistant	AAO	April, 03, 2023
Sh. Viram Singh	Assistant	AAO	June 01, 2023
Smt. Tanya Khatter	Assistant	AAO	December 27, 2023
Sh. Kapil Chopra	Stenographer Grade 'D'	Personal Assistant	January 02, 2023
Sh. Akash Patel	Stenographer Grade 'D'	Personal Assistant	January 02, 2023
Smt. Ankita	Stenographer Grade 'D'	Personal Assistant	January 02, 2023
Smt. Santosh	Stenographer Grade 'D'	Personal Assistant	January 03, 2023
Sh. Sada Sukh	UDC	Assistant	December 29, 2023
Sh. Navbahar Singh	UDC	Assistant	December 29, 2023
Sh. Vinod Poddar	UDC	Assistant	December 29, 2023
Smt. Lakshmi	UDC	Assistant	December 29, 2023
Sh. Pankaj	UDC	Assistant	December 29, 2023
Sh. Tej Pal Singh	UDC	Assistant	December 29, 2023
Sh. Shyam Sunder	UDC	Assistant	December 29, 2023
Sh. Pramod Kumar	LDC	UDC	June 01, 2023

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 2023-24, 40 physically challenged students (12 UG, 10 M.Sc./M.Tech. and 18 Ph.D.) were admitted against the seats reserved for differently abled candidates. However, in the event of there being no eligible suitable differently-abled candidates in the earmarked discipline, such unfilled seats shall be transferred to other disciplines, where eligible 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 the total number of beneficiaries as on December 31, 2023, 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	428	05	1.16

17. OFFICIAL LANGUAGE (RAJBHASHA) IMPLEMENTATION

Article 343 of the Constitution says that Hindi shall be the Official Language (OL) 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 the Director and the Committee ensures compliance with policy and rules of the Official Language Act 1963 and the O.L. rules of 1976. Joint Directors, Head of Divisions and Senior Comptroller are ex officio members of OLIC and Joint Director (Research) is The 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. Sub-committees were also constituted in different Divisions, Regional Stations, and the Directorate to ensure follow-up action on the decisions taken in these meetings.

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 Viswanathan Chinnusamy, Joint Director (Resarch). 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 of 11 OLIC inspections were conducted during the period reported upon.

17.2 AWARD SCHEMES/COMPETITIONS

During the year 2023, many competitions/award schemes were also initiated to motivate the employees of the Institute to maximize work in Hindi. Many 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 performing maximum official work in Hindi

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, was implemented as per the directives of the Department. Employees of the Institute were given cash awards for performing their maximum official work in Hindi for the entire year. For the year 2022-23, the First cash prize of ₹ 5000/- was given to Dr. Virendra Kumar, ACTO, WTC; the second cash prize of ₹ 3000/- was given each to Mrs. Kavita, UDC, Estate & Protocol section and Mrs. Sakshi, LDC, P-II section, respectively. A third cash prize of R 2000/- was given each to Mrs. Madhu Bala, Assistant, Pay Bill Section and Mr. Dilip Kumar, LDC, Housing Section, respectively.

17.2.2 Hindi vyavahar pratiyogita

Hindi Vyavahar Pratiyogita was organized amongst the different Divisions and Sections of the Directorate separately and two Divisions and Sections each were awarded shields for performing maximum work in Hindi during the entire year. In the period

2022-23, the evaluation committee constituted under the chairmanship of Joint Director (Administration) and Senior Registrar gave the prizes to Agronomy Division and Water Technology Center amongst the divisions, MOHR and Pay Bill Section amongst the Unit/Section and Regional Station Shimla, Regional station Kalimpong amongst the Regional Stations.

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, third and incentive prizes for their published articles in different journals. During the reported period, the First Prize was given to Dr. Dinesh Kumar and Dr. Yashbir Singh Shivay, Principal Scientist, Agronomy Division, for their article 'भारतीय मृदाओं में जैव पदार्थों की कमी एवं प्रबंधन'. The second prize was awarded to Dr. Shivadhar Mishra, Principal Scientist, Dr. Ranbir Singh, ACTO, Agronomy Division, and Dr. Vipin Kumar, Scientist, WTC, for their article entitled "शून्य लागत प्राकृतिक खेती बनाम जैविक खेती" The third prize was given to Dr. Ranbir Singh, ACTO, Agronomy Division, and Dr. P.K. Sahoo, Agriculture Engineering Division, for their article "रागी का प्रसंस्करण एवं मूल्य संर्वधन" I[st] Incentive prize was awarded to Dr. Vipin Kumar and Dr. Sushma Sudhashri, Principal Scientist, WTC and Dr. Ranbir Singh, ACTO, Agronomy Division for their article "कृषि में जल बचत की नवीन तकनीकियां". Second incentive prize was given to Dr. Chandu Singh, Senior Scientist; Shri Ashok Jaiswal, TA, Dr. Sanjeev Sharma, ACTO, Seed Production Unit; Dr. Ganpati Mukri, Senior Scientist, Genetics Division, Dr. V.R. Yalamalle, Senior Scientist, Seed Science and Technology Division; and Dr. Subash Babu, Senior Scientist, Agronomy Division for their article "भारत में जैविक कृषि की उपयोगिता". The third Incentive prize was awarded to Dr. Virendra Kumar, ACTO, and Dr. Man Singh, Project Director (Retd.), WTC, for their article "दलहनी एवं तिलहनी फसलों का बेहतर उत्पादन"

17.2.4 Best Rajbhasha nodal officer award competition

This award is given on the basis of work done by the Rajbhasha nodal officer to look after the implementation of the official language, Hindi, in their divisions/regional stations. Mr. Anand Vijay Dubey, ACTO, CATAT has been awarded with the cash prize of Rs.5000/-.

17.2.5 INCENTIVE SCHEMES FOR GIVING DICTATION IN HINDI BY THE OFFICERS

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, was implemented as per the directives of the Department Employees of the Institute were given cash awards to encourage them to give maximum dictation in Hindi throughout the year. During the reported period, Mr. Ajay Kumar Soni, Chief Administrative Officer, Directorate, and Mr. Nandan Kumar, AAO, Agriculture Economics Division were given cash prizes of ₹ 2500/- each.

17.2.6 Dr. RAMNATH SINGH PURASKAR FOR HINDI BOOK WRITING -BIENNIAL (2021-23)

Dr. Ramnath Singh Puraskar for Hindi Book Writing - Biennial was given jointly for two books (1) Smart Krishi written by Dr. Yashbir Singh Shivay, Principal Scientist; Dr. Ranbir Singh, ACTO and Dr. Tikam Singh, Principal Scientist, Agronomy Division and (2) *जैविक खेती के मूलभूत तत्व* written by Dr. Shivadhar Mishra, Principal Scientist; Dr. Ranbir Singh, ACTO, Agronomy Division.

17.3 HINDI *CHETNA MAAS*

The month of September (September 01-30, 2023) was celebrated as Hindi *Chetna Maas* by ICAR-Indian Agricultural Research Institute, New Delhi. The inauguration ceremony of the Hindi *Chetna Maas* program was held on September 01, 2023. Dr. Ashok Kumar Singh, Director, Dr. Anupama Singh, Dean and Joint Director (Education) graced the occasion. Mrs. Arun Kamal, Assistant Director (Official Language), DRDO and Dr. Neeraj, Professor, Jamia Millia Islamia were the special guests of this program. Administrative Heads, Hods/In-charge of Units/Sections, Scientists, and Technical and administrative staff of the Institute also attended the program. Various competitions were organized *viz-* extempore speech, story or poetry writing and recitation, general knowledge competition (Descriptive) (for MTS), Hindi typing and powerpoint competition for scientific and technical staff. All the staff of the Institute participated with great enthusiasm. Besides, many Divisions/Regional Centres of the Institute also organized Hindi Day/Competition/ Fortnight at their own establishments.

Director & Chairman (OLIC) Dr. A.K. Singh addressing the staff and dignitaries during inauguration ceremony of Hindi *Chetna Maas*

Participants of Hindi typing competition held during Hindi *Chetna Maas*

Staff participating in Story or Poetry writing competition

17.4 HINDI COMPETITIONS ORGANIZED BY DIVISIONS OF THE INSTITUTE

17.4.1 Biochemistry

On September 20, 2023, the Division organized various Hindi competitions such as Hindi calligraphy, dictation, and vocabulary knowledge competitions in which Dr. R Srinivasan, Former Professor and Project Coordinator, ICAR-NIPB, was invited as the distinguished guest. Officers/employees of the Division participated with enthusiasm and prizes were awarded to the participants.

Hindi Competition program at Division of Biochemistry

17.4.2 Agriculture Economics

The Division organized calligraphy extempore speech, quizzes, and self-introduction in Hindi competitions. All scientific, technical, and administrative officers, employees and students of the division participated with zeal. Winners were also awarded certificates by the Head of the Division and distinguished guests.

Participants, and staff of Agriculture Economics Division

Water Technology center

On the occasion of Hindi *divas* September 14, 2023, a hindi programme was organized in the WTC. Extempore speech, poem recitation, story and general knowledge questionnaire competition in hindi were organized. Officers/employees of Center participated with adour.

Hindi *divas* at WTC

Agricultural Extension

The Division Agricultural Extension organized various Hindi competitions on September 21, 2023. To make the competitions successful, all the officers, employees, students and researchers of the Division participated in various competitions with full cooperation. The program comprised competitions in various disciplines such as a calligraphy contest, poetry recitation, speech on the topic "Changing nature of science and technological development," quiz competition, antakshari competition, and Self-introduction in Hindi (only for MTS). Dr. Girijesh Singh Mehra, Rajbhasha Nodal Officer was the coordinator of the program. Dr. Rabindranath Padaria, Joint Director (Extension), was the special invitee to the occasion and Dr. Atul Kumar, Associate Dean was the special guest of the program. Dr. Dinesh Kumar Sharma, Principal Scientist, Division of Environmental Sciences, Dr. Archana Singh, Principal Scientist, Division of Biochemistry were jury of the program.

Jury and Participants during the program

Joint Director (Extension) and Jury presented mementos and certificates to the winners

Agronomy

Agronomy Division organized different events during Hindi *Chetna Maas*. A questionnaire competition was organized on September 25, 2023, an extempore speech on September 26, 2023, an antakshari competition on September 27, 2023, and an Essay writing competition on September 29, 2023. Participants were given certificates by the Head and Distinguished guests.

Glimpses of Hindi competitions at Agronomy Division

18. TRANSFER OF TECHNOLOGY

Application of the latest technologies and practices is vital for effective resource management, efficient resource utilization and enhancing crop productivity and income. Therefore, the institute lays immense emphasis on the transfer of technologies to accelerate their rate of diffusion and adoption. The institute implements various outreach programmes such as Mera Gaon Mera Gaurav (MGMG), Scheduled Caste Sub Plan (SCSP), Tribal Sub-Plan (TSP) and the North-eastern Hill Region development programme (NEH). Pusa *Krishi Vigyan Mela* and training programmes were organized for the capacity building of farmers.

18.1 Interventions under SCSP

18.1.1 Reaching out to marginalized farmers for inclusive agricultural development under SCSP programme

SCSP for the Scheduled Castes (SCs) was introduced in the Sixth Plan for channelizing the funds to the SC categories to help them to avail their due share of plan benefits and outlays. The main objective of the scheme is to give a thrust to family-oriented schemes for economic development of SC who are below the poverty line, by providing them with resources for filling the critical gaps. In this regard, ICAR-IARI, New Delhi distributed seeds of IARI improved varieties for field demonstrations in paddy, moong, pigeon pea, wheat, mustard, lentil, chickpea, onion, carrot, fenugreek and spinach. Besides, vegetable kits were also distributed during the *rabi* and *kharif* seasons for household nutritional security. Several Farmer-Scientist interface meetings and training programmes were organized across the districts. Fifteen training programmes were organized under the SCSP at different locations and detailed information about the scheme/project was given to the farmers in the different districts of Uttar Pradesh, Haryana, Delhi, Madhya Pradesh, Himachal Pradesh, West Bengal, Tamil Nadu & Bihar. A total of 9478 implements like sprayer, spade and sickle have been distributed in Rajpur, Lalgadi (Aligarh), Bhureka

Details of seeds distributed under SCSP during 2023

Crop	Varieties	Seed (q)	Location (District)
***Kharif* 2023**			
Paddy	Pusa Basmati- 1121, 1509, 1692, 1718, 1847, Pusa Sugandh -5, Pusa Samba 1850 and 1853	1300.00	Bulandshahr, Hapur, Gautam Budh Nagar, Baghpat, Ghaziabad, Mathura, Aligarh, Agra, Muradnagar, Saharanpur, Moradabad, Palwal, Hathras, Ghazipur, Mau, Varanasi, IARI RS, Bihar
Arhar	Pusa 991, Pusa 992	4.00	
Moong	Pusa Vishal, Pusa 1431 and Pusa 9531	60.00	
Vegetable Kit	Different crop varieties	10000 Nos.	
***Rabi* 2022-23**			
Wheat	HD- 3226, 3086, 3098, 3271, 3237, 3059, 2967	3100.00	Bulandshahr, Hapur, Gautam Budh Nagar, Baghpat Ghaziabad, Firozabad, Aligarh, Agra, Muradnagar, Saharanpur, Moradabad, Palwal, Hathras, Ghazipur, Mau, Varanasi, Dausa, Alwar, Meerut and Muzaffarnagar
Mustard	Pusa Vijay, Pusa Mustard- 27, 28, 29, 30, 31, 32 & 33	65.12	
Onion	Pusa Red and Pusa Madhavi	9.00	
Methi	Pusa Early Bunching	4.74	
Carrot	Pusa Rudhira and Pusa Vrishti	3.77	
Vegetable kit	Different crop varieties	9500 Nos.	
Lentil	L4717, L4727, L4729	44.00	
Chickpea	Pusa 547, Pusa 3062 and Pusa Manav	30.00	

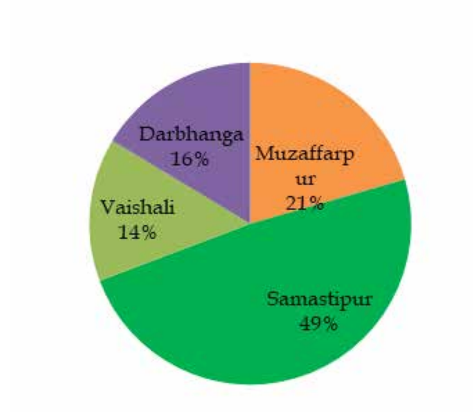
(Mathura), Baghpat, Hapur, Meerut, Muzaffarnagar and Moradabad. A total of 15 training programmes on improved cultivation of paddy, *rabi* crops, horticultural crops and agricultural residue management were conducted, benefitting 7373 farmers.

Improved cultivation of paddy– Farmers' training and seed distribution programme

18.1.2 Distribution of quality seeds under SCSP through Regional Station, Pusa, Bihar

Under the SCSP programme, a total of 6320 farmers have benefitted from advanced agricultural technologies for paddy, *Sesbania*, and pearl millet crops across four districts of Bihar- Vaishali, Darbhanga, Samastipur and Muzaffarpur.

District wise demonstration under SCSP



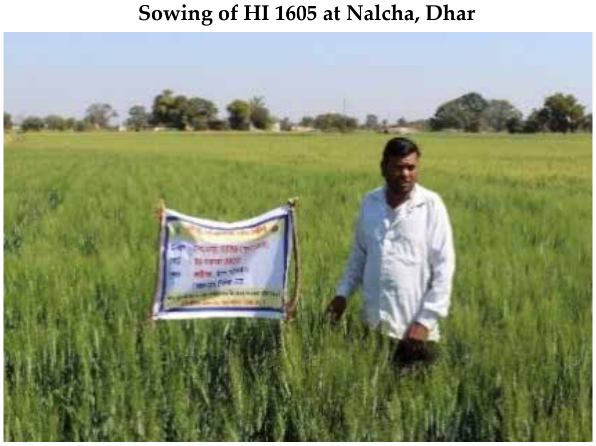
Assessment and promotion of new wheat varieties with resource-poor (SC) farmers: During 2022-23, a total of 16 demonstrations on new wheat varieties were organized in six villages of Ratlam, Ujjain and Dhar Districts of Madhya Pradesh. Demonstrations of 10 new wheat varieties (HI 1605, HI 1655, HI 8805, HI 8823, HI 8830, HI 1634, HI 1636, HI 1650, HI 8737, HI 8759) with recommended package of practices were conducted in 8.5 ha area. Overall, 10 varieties were demonstrated,

Quality seed distribution during the programme

including five bread wheat and five durum wheat. The average yield increase was 19 q/ha (53%) in these demonstrations. The highest yield increase over check (~75%) was reported in HI 8830 (Limited Irrigation, Early-Sown Durum) and the highest yield of 70 q/ha was recorded in variety HI 8737 (Irrigated, timely sown, Durum).

Tribal Farmers Training in Bercha, Indore

Sowing of HI 1605 at Nalcha, Dhar



HI 8759 demonstration in Tribal Golpura, Dhar

18.2 Interventions under NEH programme

The Institute is working in eight states *i.e.* Arunachal Pradesh, Assam, Manipur, Meghalaya, Sikkim, Mizoram, Nagaland, and Tripura, under the NEH programme. There are 30 number of KVKs directly connected with the Institute. In the year 2023, six KVKs (KVK Upper Subansiri, KVK Lower Dibang Valley, KVK Sonitpur, KVK Kohima, KVK Zunheboto, and KVK Sepahijala) were included. There are five aspirational districts covered under the programme (Churachandpur, Manipur; West Khasi hills, Meghalaya; Wokha, Nagaland; Mon, Nagaland and Dhalai, Tripura). During the Financial year 2022-23, an amount of ₹ 235 lakhs was utilized. Out of that, seed material of amount ₹ 218 lakhs were provided to the farmers of the NEH region through different KVKs of the NEH region for on-field demonstrations. Potato seed (3,40,000 kg of Kufri Jyoti/Kufri Pukhraj/ Kufri Himalini varieties) was provided to the farmers of the NEH region through 23 KVKs and the demonstration was done in an area of around 185 ha. More than 6000 farmers benefitted by receiving quality potato seed.

KVK Khowai distributed 320 q of potato seed to 1500 farmers. Mr. Hiralal Das (East Ramchandra Ghat, Khowai District of Tripura) was able to harvest an yield of 33.5 t/ha and sold the agricultural produce @ ₹ 22.0/kg in nearby market. Due to his perseverance and dedication, he proved that the IPM technology and the variety Kufri Jyoti was moderately resistant to early and late blight. This variety was also found to be resistant to leaf curl disease as the nearby fields planted with local potato were highly infested with leaf curl. The estimated net return earned by the grower was ₹ 5,37,000/- with the B: C ratio of 3.68, which was higher

Quality potato production under NEH programme

than the traditional variety. By observing the income of Mr. Hiralal Das, other farmers from that locality were also motivated to adopt the improved practices of farming.

The KVK Zunheboto received 8000 kg of Potato seeds of var. Kufri Jyoti from IARI under NEH component for Zunheboto district and 2000 kg of potato tubers var. Kufri Jyoti was distributed to 65 farm families from four villages. Mr. Hetoi Yeptho (a progressive farmer, Keltomi Village, Block: Tokiye, Zunheboto district) cultivated it in approximately two hectares of land in Jhum field. The production performance of potato var. Kufri Jyoti was good as no disease incidence was reported and yield per hectare was about 12-15 tonnes. The farmer could earn a net income of ₹ 2.2 lakhs/ha, which would help him in improving his socio-economic condition. Total 492 numbers of small tools and machinery (hand hoe, Power Winnower, Manual paddy thresher, Aqua-ferti seed drill, Mobile feed block, UMMB) were provided to farmers of NEH region through nine KVKs. Disease free planting material (2000 nos.) of Khasi mandarin and Assam lemon (1000 number) were also provided to KVK Golapara, Assam under NEH Programme in 2022-23.

18.3 Interventions under Tribal Sub Plan

18.3.1 Programs organized by ICAR-IARI, New Delhi

ICAR-Indian Agricultural Research Institute, Pusa, New Delhi organized total five *Field Day- cum-Training Program* in the different villages namely Nangal Meena, Jatwada, Balahera, Juthaheda, Balawas, Motuka in the Dausa district of the Rajasthan state under TSP-IARI Scheme with collaboration of State Agriculture Department, Dausa district, Government of Rajasthan which was attended by approximately 3000 farmers. Minor equipments like bucket, tripal, umbrella, *khasi*, tourch, dranti etc. were also distributed for their day-to-day use. One program was organized for women farmers for their capacity building and they were trained in different aspects of farming and food processing. Dr A.K. Singh, Director, ICAR-IARI, Dr. R.N. Padaria, Joint Director (Extn), ICAR-IARI, Sh. DD Verma, Senior Comptroller, ICAR-IARI, Dr. Y.R. Meena, Additional Commissioner (Extn), MoA&FW, Govt of India, Dr. S.K. Lal, Nodal Officer (SCSP), Dr. M.C. Meena, Nodal Officer (TSP) and IARI scientists from different disciplines attended the programs.

Dr. A.K. Singh, Director, ICAR-IARI, New Delhi distributed minor implements to tribal farmers

Distribution of minor implements to tribal women farmers

The vegetable kits, high yielding quality seeds of mustard and wheat were also distributed to about 500 tribal farmers in the district Dausa Rajasthan for replacing their local seeds with quality seeds. As the

Mango plant distribution to tribal farmers in Dausa district of the Rajasthan


Performance of mustard and wheat at farmers' field in Dausa district of the Rajasthan

area is suitable for horticultural crops, 1050 mango plants of IARI varieties were also distributed for establishing the fruit plants for diversification of livelihood.

18.3.2 Wheat demonstrations in Madhya Pradesh

Seed were distributed for demonstration of wheat varieties along with recommended package of practices by ICAR-IARI Regional Station Indore in the fields of tribal farmers of the Madhya Pradesh.

During 2022-23, a total of 24 wheat demonstrations (TSP) were conducted in seven tribal villages of Nalcha block, District Dhar, M.P. Demonstrations of nine new wheat varieties (HI 1605, HI 1655, HI 8805, HI 8823, HI 1634, HI 1636, HI 1650, HI 8737, HI 8759) with recommended package of practices, were conducted in 12.85 hectares area. Highest yield increase over check (~124%) was reported in variety HI 1655 (Limited Irrigation, Early sown, Bread Wheat) and Highest yield of 73.50 q/ha was recorded in variety HI 8759 (Irrigated, Timely sown, Durum) during the demonstrations.

18.4 *MERA GAON MERA GAURAV* (MGMG)

The MGMG programme aims to increase the farmer-scientist interface to reduce the delay in the delivery of information to the target group of farmers. The objective of this scheme is to provide farmers of the adopted villages with regular advisories. Linkages have been developed with Gram Panchayat, NHB, NBPGR, CPRI, ACF, NABARD, HIMCOSTE, KVK, IFFCO, YSPUHF, IIWBR, State Agril. Department which have benefitted 1786 farmers.

18.4.1 Activities organised under MGMG

S. No.	Name of activity	No. of activities	No. of farmers benefitted
1.	Visit to village by all teams	49	969
2.	Interface meeting/ *Goshthis*	19	538
3.	Training organized	8	172
4.	Demonstrations conducted	207	415
5.	Mobile based advisories	455	621
6.	Literature support provided	308	771
7.	Awareness programmes	39	2249
	Total	**1085**	**5735**

18.4.2 Facilitation under MGMG

Input	Crop/ Numbers of technology	Variety/ Name of technology	Seeds provided (in Kg/ No.)	Farmers Benefitted (No.)
i) Seeds	Vegetable kit	*Kharif* vegetable	52 (nos)	102
	Paddy	Pusa Sugandh 5	450 kg	38
	Moong	Pusa Vishal Pusa 1431	15 kg 15 kg	23 23
ii) Nutrient management				
Biofertilizer	Sugarcane	100 kg		05
	Kharif crops	6.00 l		50 (25 ha)
iii)Technology (No)	02	Cultivation of Wheat, Barley and Apple	-	52
	01	Strawberry cultivation	-	54
	04	Walnut (Pusa Khor) cultivation	-	197

18.5 PUSA *KRISHI VIGYAN MELA* 2023

Pusa *Krishi Vigyan Mela* 2023, themed "Nutritional, Food and Environmental Security through Millets" was organized at the IARI mela ground from March 2-4, 2023. Shri Narendra Singh Tomar, Hon'ble Union Minister of Agriculture and Farmers Welfare, Government of India inaugurated the mela. He appreciated the efforts made by the Pusa Institute for the welfare of the farmers and called upon the farmers to take maximum advantage of scientific innovations using new technologies. 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 sunfridge were the major attractions of the mela. More than one lakh visitors from different parts of the country, including farmers, farm women, extension workers, entrepreneurs, students and others visited the mela. Many stalls (300

Inauguration of Pusa *Krishi Vigyan Mela* by Shri Narendra Singh Tomar, Hon'ble Union Minister of Agriculture and Farmers Welfare, Government of India

IARI Innovative Farmers' Awards during Pusa *Krishi Mela* 2023

Lifetime achievement award Pusa Krishi *Mela* 2023

nos.) of ICAR Institutes/SAUs, KVKs, Govt./PSUs, agri-startups, NGOs, SHGs, FPOs, innovative farmers and other private entrepreneurs were set up. Among the stalls, 40 were of progressive farmers and startups. Seeds of high-yielding varieties of basmati rice, mungbean, bajra, pigeonpea and vegetable kits were sold through both Pusa seed sale counter and earned a revenue of ₹ 2.20 crore. IARI Innovative Farmers' Awards were bestowed upon 36 farmers during the valedictory function.

18.6 TRAINING AND CAPACITY BUILDING

The Institute has organized several National and International short-term training courses (regular, *ad-hoc* and individual) and refresher courses in specialized areas for the scientists of NARES under the programmes of "Centres of Excellence" and "Centres of Advanced Faculty Training". In addition, some special training/workshop courses were also organized for the benefit of professionals, farmers and extension workers.

Training programmes organized by Divisions and Regional Stations

Name of the training programme	Number	No. of trainees
Division of Soil Science and Agricultural Chemistry	05	95
Division of Agricultural Engineering	01	25
Division of Food Science and Post-Harvest Technology	02	65
Division of Entomology	04	109
Division of Plant Physiology	04	134
Division of Agricultural Economics	01	34
Division of Agricultural Extension	02	130
Division of Agronomy	03	524
Division of Floriculture	01	35
Division of Fruit and Horticultural Technology	02	77
Division of Agricultural Physics	02	282
ZTM & BPD Unit	12	344
AKMU	01	24
Regional Station, Kalimpong	06	290
Regional Station, Karnal	01	25
Regional Station, Wellington	01	50

19. SERVICE THROUGH QUALITY SEED & PLANTING MATERIALS

19.1 Seed Production of Field crops (January 01 to December 31, 2023)

19.1.1 Seed Production at Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seed of 62 varieties of cereals, pulses and oilseeds was 1020.00 tons, which encompasses nucleus seed (9.6 tons), breeder seed (157.48 tons) and TFL/IARI seed 869.27 tons (38.34 & 830.92 tons at the Institute farm and under farmer participatory seed production program, respectively) at Seed Production Unit, ICAR-IARI, New Delhi. Crop-wise details of the production of various seed classes are given in Table.

Seed Production of Agricultural Crops at Seed Production Unit & Farmer's Field

Crop	Number of varieties	Classes of seeds* (In tons)				Total Production (tons)
		NS (tons)	BS (tons)	IARI Seeds/(TFL) (ton)		
				At Institute	Under FPSP	
Wheat	16	7.185	148.678	18.706	423.435	590.759
Paddy	17	0.015	1.550	8.532	374.404	375.854
Chickpea	11	1.860	1.205	0.899	9.000	12.574
Pigeonpea	03	0.045	0.300	1.257	0.321	1.923
Lentil	03	0.340	3.220	2.540	6.755	12.855
Moong	03	0.125	0.720	1.282	9.422	11.424
Mustard	07	0.090	1.518	4.682	7.586	13.876
Maize	04	-	0.179	-	-	0.179
Bajra	01	-	-	0.446	-	0.446
Soybean	01	-	0.114	-	-	0.114
Total	**62**	**9.660**	**157.484**	**38.344**	**830.923**	**1020.005**

*NS-Nucleus seed, BS-Breeder Seed, TFL- Truthful Label Seed (IARI Seed), FPSP- Farmers participatory seed production

***Funds generated** = ₹ 9,25,05,652/-
(*fund generated included the seed production from field and horticultural crops)

19.1.2 ICAR- IARI Regional Station, Karnal

At ICAR-Indian Agricultural Research Institute, Regional Station Karnal, 4264.46 q quality seed of different crop varieties of cereals, pulses, oilseeds, vegetables and others (*Dhaincha*) was produced during *rabi* 2022-23 and summer/ *kharif* 2023. The total seeds produced comprised the nucleus (2162 kg), breeder (151492 kg) and IARI (271001 kg). Of the total IARI seed, 259082 kg was produced under the farmers' participatory seed production program.

Seed production of field crops during 2022-23 (*Rabi* 2022- 23 and *Summer/ Kharif* 2023)

Type	No. of Crops	No. of Varieties	Seed Production (kg)			
			Nucleus	Breeder	IARI	Total
Cereals	6	38	2,162	1,47,269	2,70,464	4,19,895
Pulses	3	8	0	4,171	0	4,171
Oil seeds	1	5	0	52	472	992
Others (Dhaincha)	1	1	0	0	65	65
Total	**11**	**52**	**2,162**	**1,51,492**	**2,71,001**	**4,25,123**

****Funds generated: ₹ 6.92 crore Approx.**

(**fund generated included the seed production from field and horticultural crops)

19.1.3 ICAR- IARI, Regional Station, Bihar

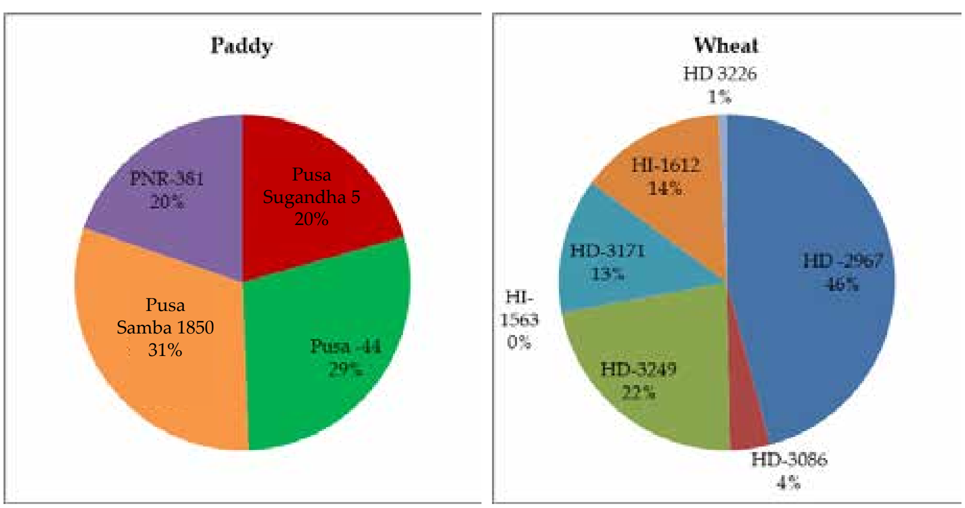
During the *kharif* 2023, summer 2023, and *rabi* 2022-23 seasons, a cumulative production of 946.89 quintals of seeds was achieved across various crops. Noteworthy contributions include paddy (247.85 q), pearl millet (5.31 q), mungbean (17 q), wheat (620.50 q), lentil (12.66 q), mustard (20.30 q), pea (2.62 q), chickpea (3.07 q) and pigeon pea (11.78 q). Additionally, tobacco (4.81 q), okra (0.68 q), marigold (0.014 q) and lathyrus (0.30 q) were produced.

S.N.	Season	Crop	Variety	Category-wise seed production (q)			
				NS	Br. Seed	TFL	Total
1	*Kharif*-2023	Paddy	Pusa Sugandh 5			51.10	51.10
			Pusa 44			71.40	71.40
			Pusa Samba 1850			76.50	76.50
			PNR 381			48.85	48.85
			Total			**247.85**	**247.85**
		Pearl millet	PC 701			2.95	2.95
			PC 1801			2.20	2.20
			PC 383			0.16	0.16
			Total			**5.31**	**5.31**
2	Summer-2023	Mung bean	Pusa Vishal			14.00	14.00
			Pusa 1431			3.00	3.00
			Total			**17.00**	**17.00**
3	*Rabi*-2022-23	Wheat	HD 2967	4.00	238.00	42.50	284.50
			HD 3086		24.00		24.00
			HD 3249	10.50	128.00		138.50
			HI 1563		0.50		0.50
			HD 3171	7.50	73.00		80.50

	Rabi-2022-23		HI 1612	1.50	86.00		87.50
			HD 3226	5.00			5.00
			Total	**28.50**	**549.50**	**42.50**	**620.50**
		Lentil	PSL 9			9.48	9.48
			PDL 1			0.12	0.12
			L 4717			3.06	3.06
			Total			**12.66**	**12.66**
		Mustard	Pusa Agrani			9.70	9.70
			Pusa 27			10.60	10.60
			Total			**20.30**	**20.30**
		Pea	Pusa Shree			0.80	0.80
			Pusa Pragati			1.82	1.82
			Total			**2.62**	**2.62**
		Chickpea	C-3043			3.00	3.00
			Pusa-256			0.07	0.07
			Total			**3.07**	**3.07**
		Pigeon pea	Pusa 9			1.71	1.71
			Pusa 151			10.07	10.07
			Total			**11.78**	**11.78**
		Tobacco	PT76			4.81	4.81
		Okra	A5			0.68	0.68
		Marigold	Pusa Narangi			0.014	0.014
		Lathyrus	BIOL-2.2			0.30	0.30
			Grand total	**28.50**	**549.50**	**368.89**	**946.89**

*****Fund generated ₹ 69,119,23**

(***fund generated included the seed production from field and horticultural crops)



Variety wise seed production share in rice and wheat crops

19.1.4 ICAR-IARI, Regional Station Dharwad

Crop	Name of variety	Classes of seeds (Tone)				Total (tones)
		NS	BS	IARI Seeds/(TFL)		
				At Institute	Under FPSP	
Chickpea	BGD 111-1	0.2				0.2
	BGD 103		0.05			0.05

Fund generated: ₹ 58, 500/-

19.1.5 ICAR- IARI, Regional Station Indore

Crop	Name of Variety	Classes of Seeds (tons)				Total Seed (tons)
		NS	BS	IARI Seeds (TFL)		
				At Institute	Under FPSP	
Wheat	HI 1544, HI 1563, HI 1605, HI 1612, HI 1620, HI 1621, HI 1628, HI 1633, HI 1634, HI 1636, HI 1650, HI 1653, HI 1654, HI 1655, HI 8663, HI 8713, HI 8737, HI 8759, HI 8777, HI 8802, HI 8805, HI 8823, HI 8826, HI 8830, HD 4728	12.35	333.5	-	-	345.85

NS-Nucleus seed, BS-Breeder seed, TFL-Truthfully labeled seed, FPSP-Farmers participatory seed production

Fund generated: ₹ 2, 25, 00, 350/-

19.2 Seed Production in Horticultural Crops (January 1 to December 31, 2023)

The production of quality seed of horticultural crops (vegetables, fruits & flowers) at the Institute farm, Regional Stations and under Farmer participatory seed production programme was carried out. The crop-wise details of the production of various classes of seeds of horticultural crops are given below:

19.2.1 Vegetable Crops

Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seed of 31 varieties of 24 horticultural crops (vegetables & flower) was 20975.30 kg, which comprised nucleus seeds (156.00 kg), breeder seeds (25.70 kg) and IARI seeds/TFL seeds 20793.60 kg (6159.70 kg & 14633.90 kg at Institute farm and under farmer participatory seed production programme, respectively). Crop-wise details of the production of various classes of seed are given below in Table:

Seed production of flowers & vegetable crops at Seed Production Unit & farmer's field

Crop	Total number of varieties	Classes of seeds*(in kg)				Total Production (kg)
		NS (kg)	BS (kg)	IARI Seeds/(TFS) (kg)		
				At Institute	Under FPSP	
Spinach	02	12.0	120.0	1403.0	1530.0	3065.00
Amaranth	01	1.0	-	215.0	-	216.0
Fenugreek	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
Coriander	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

Funds generated = *

Seed production at ICAR-IARI Regional Station, Karnal, Haryana

At IARI-Regional Station, Karnal, 725.36 kg seeds of 41 varieties of 18 vegetable crops were produced during *rabi* 2021-22 and summer/*kharif* 2022. A total of 34.24 kg nucleus, 572.77 kg breeder and 118.35 kg of IARI seed were produced.

Seed production of vegetable crops

Type	No. of Crops	No. of Varieties	Seed Production (kg)			
			Nucleus	Breeder	IARI	Total
Vegetable crops	18	41	34.24	572.77	118.35	725.36

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed (IARI Seed)

Funds generated = **

Vegetable Seed production at IARI Regional Station, Kattrain, Himachal Pradesh

Seed production (kg)			
Nucleus	Breeder	IARI-TFL	Total
122.07	71.14	2822.93	3016.14

Funds Generated ₹ 24.13 lakhs

19.2.2 Fruit Crops

The following is the detail of the multiplicity of fruit plants and the revenue generated by the ICAR- IARI, New Delhi during 2022.

Division of Fruit and Horticultural Technology

Crop & variety	Number of saplings including scion	Crop & Variety	Number of saplings including cutting
Mango		**Citrus**	
Amrapali	1463	Pusa Abhinav	82
Mallika	1102	Pusa Arun	47
Pusa Arunima	1022	**Grapes**	
Pusa Surya	427	Pusa Purple Seedless	88
Pusa Lalima	562	Pusa Navrang	853
Pusa Pratibha	488	Pusa Urvashi	114
Pusa Shrestha	220	Pusa Trishar	1116
Pusa Peetamber	559	Pusa Aditi	360
Pusa Manohari	816	Pusa Swarnika	30
Pusa Deepshikha	21	Perlette	94
Citrus		**Papaya**	
Kagzi Kalan	1231	Pusa Nanha	9
Pusa Round	176	**Guava**	
Pusa Sharad	261	Pusa Aarushi	583
Pusa Udit	76	Pusa Pratiksha	554
			Fund Generated: ₹ 14,74,400/-

ICAR- IARI Regional Station, Karnal

Propagation of horticultural crops during 2022 -23

S. No.	Crop	Cultivar	Plants propagated
1.	Mango	Amrapali, Mallika, Dashari, Arunima, Surya, Langra, Ram-kela, Shrestha, Lalima, Pitamber, Chausa, Pratibha	847
2.	Lemon	Kagzi Kalan	463
3.	Guava	Allahabad Safeda	122
4.	Rose		7
Total			**1439**

Funds generated: **

Details of planting material production in fruit crops at ICAR- IARI, Regional Station, Pusa, Bihar

During 2022, a total of 6,118 seedlings of different fruit crops and varieties were produced and distributed to various stakeholders.

Funds generated: ***

Seed Production of Fruit Crops at ICAR- IARI, Regional Station, Kalimpong

(i) Budded Darjeeling Mandarin-2,000 Nos.

(ii) Nucellus Seedling of Darjeeling Mandarin -7,000 Nos.

(iii) Rootstocks of Darjeeling Mandarin – 5,000 Nos.

(iv) Bulb, Rhizomes and Corms – 2,000 Nos.

Crop	Name of Variety	Classes of seeds			Total (No.)
		NS	BS	IARI Seeds/TFL	
				At Institute	
Fruit plants	Darjeeling Mandarin	-	-	Grafted plant	140 nos
Flower	Licoris			Bulbs	300 nos
Total					

Funds generated: ₹ 37, 500

19.2.3 Ornamental Crops

Seed Production Unit, ICAR- IARI, New Delhi

Seed production of flower & vegetable crops at Seed Production Unit & Farmer's Field

Crop	Number of varieties	Classes of seeds*(in kg)				Total Production (kg)
		NS (kg)	BS (kg)	IARI Seeds /(TFS) (kg)		
				At Institute	Under FPSP	
Marigold	01	0.5	-	15.0	125.9	141.40

Fund generated: *

ICAR- IARI, Regional Station, Karnal

Seed production of ornamental crops during 2022-23

Crop	Variety	Quantity (kg)	Centre/Location
Marigold	P. Arpita, P. Bahar, P. Deep, P. Narangi, P. Basanti	12.55	IARI RS Karnal

Fund generated: **

20. MISCELLANY

I. Scientific Meetings Organized

Workshops	29
Seminars	8
Summer/Winter School	3
Farmers' day (s)	35
Others	28
Total	**103**

II. Participation of Personnel in Scientific Meetings

India

Seminars	227
Scientific meetings	210
Workshops	116
Symposia	82
Others	33
Total	**668**

Abroad

Seminars	6
Scientific meetings	14
Workshops	16
Symposia	12
Others	9
Total	**57**

III. Ongoing Projects at IARI as on 31.12.2023

(A) Research Projects: 187

School of Crop Improvement	50
School of Plant Protection	25
School of Basic Science	29
School of Natural Resource Management	48
School of Social Science	20
School of Horticultural Science	15

(B) Number of on-going contract research /consultancy/contract service project: 13

School of Crop Improvement	-
School of Plant Protection	05
School of Basic Sciences	-
School of Natural Resource Management	06
School of Social Sciences	-
School of Horticultural Sciences	02

List of sanctioned Contract Research Project in 2023

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Fund (Rs.)
1.	Dr. S.S. Rathore, Head, Division of Agronomy	Effect of novel fertilizer formulations on productivity, biofortification and nutrient-use efficiency of major cereal rotations	Shell India Market Private Limited	04.05.2023	03.05.2023	1,25,58,348/-

2.	Dr. Ram Asrey, Principal Scientist, Division of Food Science & Post Harvest Technology	Bio-efficacy evaluation GPH1022 on stored potato	UPL SAS Pvt Ltd	10.08.2023	9.08.2024	12,70,046/-
3.	Mr. Santosh Watpade, Scientist, IARI Regional Station, Shimla	Evaluation of bio-efficacy of new agrochemical against pests in apple (Malus doemstica Borkh)	Syngenta India Limited	06.09.2023	06.09.2025	30,79,594/-
4.	Dr. Suresh Nebapure, Senior Scientist, Divsion of Entomolgy	Bio-efficacy of GF-4867 RB formulation of against fall armyworm, Spodoptera frugiptera in maize.	Corteva Crop India Pvt Ltd	15.09.2023	15.03.2025	12,64,606/-
5.	Dr. P.S. Brahamanand, PD, WTC	Investigation of impact of integrated drip cum mulch practice on crop Growth, yield and economics of rice millets.	Borouge India PVT Ltd	25.09.2023	25.09.2024	15,07,627/-
6.	Dr. Suresh Nebapure, Scientist, Division of Entomology	Baseline study of PII 8007 20% SC against brinjal shoot and fruits borer, Leucinodes orbonalis & fall armyworm, Spodoptera frugiperda	PI Industries Ltd	05.10.2023	05.10.2024	14,84,440/-
7.	Dr. Tapan Kumar Khura, Principal Scientist, Division of Agricultural Engineering	Customization of the technologies for conversion of crops residue into feed, fuel and soil amendments for eco-friendly, profitable and sustainable farming	CNH Industrial (India) Pvt. Ltd	20.10.2023	20.10.2025	30,00,000/-
8.	Dr. R.S. Bana, Senior Scientist, Division of Agronomy	Micronutrient-embedded Sulphur Fertilization in rice-wheat and maize/pearl millet-mustard systems for enhancing productivity and biofortification	Sulphur Mills Limited	20.10.2023	20.10.2025	45,00,619/-
9	Dr. Dinesh Kumar, Principal Scientist, Division of Agronomy	Agronomic field studies with nano-NPK fertilizer	Rashtriya Chemicals & Fertilizer Ltd	14.12.2023	14.12.2024	11,80,000/-

List of sanctioned Consultancy Project in 2023

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Fund (Rs.)
1.	Dr. Shrawan Singh, Senior Scientist, Division of Vegetable Science	Urban Agriculture Expert: Climate- and nutrition-smart agriculture in Nauru Island	Asian Development Bank, Manila, Philippines	6.07.2023	31.07.2023	USD 10330

2	Dr. Ravinder Kaur, Principal Scientist, WTC.	"Designing an IARI technology (Jalopchar™) based eco-friendly wastewater treatment facility for rail coach factory, Kapurthala, Punjab	Rail Coach Factory, Kapurthala, Punjab	20.12.2023	30.12.2023	4,73,816/-

List of sanctioned Contract Service Project in 2023

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Fund (Rs.)
1.	Mr. Santosh Watpade, Scientist, IARI Regional Station, Shimla	Bio-efficacy evaluation of new phytochemicals in apple (*Malus* x *domestica*)	UPL Limited	20.04.2023	20.04.2025	18,20,530/-
2.	Dr. Livleen Shukla, PS, Division of Microbiology	Testing the quality of different Biofertilizers: Biopesticides and Decomposers samples	IPL Biologicals Ltd	15.09.2023	15.09.2026	30,79,594/-

IV. All India Coordinated Research Projects in Operation during the year January 1, 2023 to December 31, 2023

Sl. No.	Name of the project	Division
Project Head Quarters		
	All India Coordinated Project on Plant Parasitic Nematodes with Integrated Approach for their Control.	Division of Nematology
	All India Network Project on Pesticide Residues	Division of Agricultural Chemicals
	All India Coordinated Research Project on Honey Bees and Pollinators	Division of Entomology
Centres functioning at IARI under AICRP		
	All India Network project on Soil Biodiversity - Biofertilizers (erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)	Division of Microbiology
	All India Coordinated Project on Long Term Fertilizer Experiments	Division of Soil Science & Agricultural Chemistry
	All India Coordinated Research Project on Soil Test Crop Response Correlations	Division of Soil Science & Agricultural Chemistry
	All India Coordinated Research Project on Floriculture	Division of Floriculture & Landscaping
	All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries	Division of Environmental Sciences
	All India Coordinated Research Project on Soybean	Division of Genetics
	All India Coordinated Research Project on Fruits	Division of Fruits & Horticulture Technology

	All India Coordinated Research Project on N.S.P.(Crops)	Division of Seed Science & Technology and IARI RS, Karnal
	All India Coordinated Research Project on Mustard	Division of Genetics
	All India Coordinated Research Project on Wheat	Division of Genetics
	All India Coordinated Research Project on Rice	Division of Genetics
	All India Coordinated Research Project on Pulses	Division of Genetics
	All India Coordinated Research Project on Vegetable	Division of Vegetable Science
	AINP on Whitegrubs and other Soil Arthropods (AINPWOSA)	Division of Entomology
	All India Coordinated Wheat & Barley Improvement Project (AICW&BIP)	K.V.K. Shikohpur, Gurgaon
	Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)	K.V.K. Shikohpur, Gurgaon
	All India Coordinated Research Project on Vegetable Crops	IARI RS, Katrain
	Adhoc Cooperating Center of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal	Division of Soil Science & Agricultural Chemistry
	All India Coordinated Research Project on Ergonomics & Safety in Agriculture (ESA)	Division of Agricultural Engineering
	All India Coordinated Research Project on Pearl Millet	Division of Agronomy
	All India Coordinated Research Project on Rapeseed-Mustard	Division of Agronomy
	All India Network Research Program on Onion & Garlic (AINRPOG)	Division of Vegetable Science
	Engineering interventions for enhanced nutritional security of pearl millet during milling and storage under AICRP on Pearl Millet	Division of Agricultural Engineering
	All India Coordinated Research Project on Fruits-PAPAYA	IARI Regional Station, Pune

V. Resource Generation

1) Consultancy & other services

Consultancy services:

Contract research: ₹ 2,54,59,833/-

Contract service: ₹30, 76, 863/-

Training: ₹8, 88, 896/-

Total (A): ₹ 29,425,592/-

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed: ₹ 5,13,29,071/-

(b) Commercialization: ₹ 61,56,574/-

(c) Prototype manufacturing: ₹ 1,37,97,374/-

Total (B): ₹ 71,283,019

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:₹ 5,21,63,244/-

(d) Receipt deposited in Director's Account No. 305/17 for theses evaluation, PDC & Misc. (does not include refund of IARI scholarship by students): **₹4,42,21,044/-**

Total (C): ₹ 9,63,84,288/-

Grand Total (A+B+C): ₹ 29,425,592+ ₹ 71,283,019+ ₹ 9,63,84,288= ₹ 197,092,899/-

VI. Important policy decisions taken for improving the standards of teaching at IARI included at the Meetings of Senior Management Personnel Academic Council (January 1, 2023 to December 31, 2023):

- Renaming of the Post Graduate School IARI as The Graduate School IARI
- To fulfill the requirement of multidisciplinary faculty and an enhanced number of students, 16 IARI regional hubs have been finalised, wherein one Institute in a particular region will be the nodal institute (planet) in the regional hub and the remaining Institutes in the region will be the satellite institutes
- Organogram of ICAR-IARI Mega University revised
- Institution of Divisional level award in memory of Dr. R.C. Gautam, Former Dean & Joint Director (Edn.), ICAR-IARI, New Delhi
- Institution of Divisional level Gold Medal in memory of Dr. K.N. Synghal

IARI Internship training programme

The internship training program of one to six months has been offered at ICAR-IARI since 2019 for students doing B.Sc/M.Sc/M.Tech in Agricultural Science or Life Science disciplines, and B.Tech (Biotechnology/Bioinformatics) degree programmes on payment basis. This program aims to provide not only an opportunity for young students to carry out research in various aspects of Agricultural Sciences, but also broadens their horizons and motivates them to take up agricultural research as one of their career options.

Year	No. of persons joined/ completed internship at IARI	Total Income Generated (₹ in Lakh)
2023	88	18.17

Institute Research Council (IRC-II) - 2023

The Institute Research Council (IRC-II) - 2023 meetings of the Institute were held from November 14-22, 2023 (with intermittent gaps) under the Chairmanship of Dr. A.K. Singh, Director, ICAR-IARI. In the IRC-II, presentations were made school-wise wherein the School Coordinator of the particular school presented the Action Taken Report of the recommendations of IRC-2022. This was followed by the project-wise presentations of all the In-house research projects (51 nos.), as well as the Flagship programs (05 nos.) of the concerned school by the respective Project Investigators of the projects. Eminent resource persons were invited for the IRC-II meetings for all the Schools, who offered valuable and critical inputs for further improvement and strengthening of the research programmes of the Institute.

IRC-II Meeting at different Divisions

RESEARCH ADVISORY COMMITTEE (RAC)

The RAC-2023 meeting of the institute was held on December 21-22, 2023 under the chairmanship of Dr. R.B. Singh. The RAC presentations were made school-wise wherein the school coordinator of the particular school presented the salient achievements of the school along with the Action Taken Report of the recommendations of RAC-2022. The RAC Chairman, Dr. R.B. Singh & members, Dr. H.C. Sharma, Dr. Mruthyunjaya, Dr. K.K. Narayanan, Dr. S.P.S. Khanuja, Dr. Praveen Rao and Dr. N.S. Bains, ADG (Crop Science), ICAR attended the meeting.

RAC Meeting 2023

QRT meeting chaired by Dr. Mangala Rai, Chairman QRT & Former Secretary, DARE & DG, ICAR on July 3-4, 2023

VII. National and International visitors to ICAR-IARI during January 1 to December 31, 2023

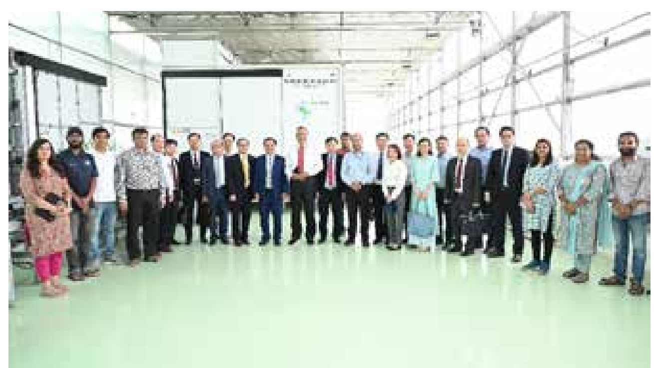
S.No.	Details of Visit	Date of Visit
1.	Hungarian delegation led by Hon'ble Vice Speaker of The National Assembly of Hungary Mr. Istvan Jakabto	February 07, 2023
2.	Guyanian Delegation led by Hon'ble Minister of Agriculture of Guyana Mr Zulfikar Mustapha	March 20, 2023
3.	Professor Gideon Henderson, Chief Scientific Advisor, Department of Environment, Food and Rural Affairs (DEFRA), UK	April 14, 2023
4.	Tanzanian delegation led by H.E. Anisa K MBEGA, High Commissioner of Tanzania	May 30, 2023
5.	Vietnamese delegation led by H.E. Le Minh Hoan, Minister of Agriculture & Rural Development, Vietnam	June 14, 2023
6.	Students of Centre for Community Medicine, AIIMS, New Delhi	August 11, 2023
7.	Dr Josephine Caffery, Associate Professor, University of Canberra, Australia	October 13, 2023
8.	Dr. Johannes Sauer, Chair for the Group of Agricultural Production and Resource Economics at the Technical University of Munich (TUM)	October 17, 2023
9.	Diplomat participants of I^{st} Global South Young Diplomats Forum at Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs	November 29, 2023

Visit of Hungarian Delegation on February 07, 2023

Visit of Guyanian Delegation on March 20, 2023

Visit of Professor Gideon Henderson, Chief Scientific Advisor, Department of Environment, Food and Rural Affairs (DEFRA), UK on April 14, 2023

Visit of Tanzanian Delegation on May 30, 2023



Visit of Vietnamese Delegation on June 14, 2023

Visit of Students of Centre for Community Medicine, AIIMS on August 11, 2023

Visit of Dr Josephine Caffery, Associate Professor, University of Canberra, Australia on October 13, 2023

Visit of Dr. Johannes Sauer, Chair for the Group of Agricultural Production and Resource Economics at the Technical University of Munich (TUM) on October 17, 2023

Visit of Diplomat participants of I[st] Global South Young Diplomats Forum at Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs on November 29, 2023

Appendix 1

Members of Board of Management of IARI

(As on 31.12.2023)

Chairman

Dr. A.K. Singh
Director, ICAR- IARI

Members

Dr. C. Viswanathan
Joint Director (Research)
ICAR-IARI

Dr. Anupama Singh
Dean & Joint Director (Education),
ICAR-IARI

Dr. R.N. Padaria
Joint Director (Extension)
ICAR-IARI

Dr. Triveni Dutt
Director, IVRI, Izzatnagar, Bareilly (U.P.)

Sh. Badri Narayan
49-Gyatri Nagar-I, Tonk Road,
Sanganer, Jaipur- 302018
Rajasthan

Dr. Sanjay Singh Rathore
Head, Division of Agronomy

Dr. Alka Singh
Head, Division of Agricultural Economics

Dr. P.K. Sahoo
Head, Division of Agricultural Engineering

Dr. Gopala Krishnan S.
Head, Division of Genetics

Dr. M.S. Saharan
Head, Division of Plant Pathology

Dr. Gyan Prakash Mishra
Head, Division of Seed Science & Technology

Dr. A.K. Singh
Vice-Chancellor, Rani Laxmi Bai Central Agricultural University, Jhansi

Dr. T.R. Sharma
Deputy Director General (Crop Science), ICAR

Dr. Dheer Singh
Director, NDRI, Karnal

Dr. P.K. Singh
Agriculture Commissioner
Deptt. of Agril. and Cooperation
Ministry of Agriculture, Krishi Bhawan, New Delhi

Dr. G.K. Koutu
Director (Research Services)
Jawahar Lal Nehru Krishi Viswavidyalya, Jabalpur (M.P.)

Dr. S.K. Pahuja
Dean, College of Agriculture,
CCS HAU, Hisar (HR)

Ms. Alka Nangia Arora
Financial Advisor, ICAR

Sh. Anil Kumar Singh, IAS
Commissioner (Development)
Development Department,
Govt. of NCT of Delhi, 5/9, Hill Road, Delhi-110054

Member - Secretary

Sh. Pushpendra Kumar
Joint Director (Admn), IARI

Appendix 2
Members of Research Advisory Committee of IARI
(As on 31.12.2023)

Chairman

Dr. R.B. Singh
Former President NAAS and Member National Commission on Farmers, New Delhi

Members

Prof. (Dr.) Nazeer Ahmad
Former 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
Chairman, ASRB, ICAR and Former Director CSIR-IHBT, 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
Joint Director (Research)
ICAR-IARI, New Delhi

Appendix 3

Members of Academic Council of IARI

(As on 31.12.2023)

Dr. A.K. Singh Director, ICAR-IARI		Chairman
Dr. Anupama Singh Jt. Director (Edn.) & Dean, ICAR-IARI		Vice-Chairperson
Deputy Director General (Agril. Edn.), ICAR	Member	Dr. R.C. Agrawal
Directors of Sister Institutes in IARI Campus and nodal coordinator Directors, ICAR-IARI hubs	Members	Dr. Rajender Parsad Director, ICAR-IASRI, New Delhi Dr. G.P. Singh Director, ICAR-NBPGR, New Delhi Dr. R.C. Bhattacharya Director, ICAR-NIPB, New Delhi Dr. C.R. Mehta Director, ICAR-CIAE, Bhopal; Nodal Coordinator, ICAR-IARI Bhopal hub Dr. S.K. Singh Director, ICAR-IIHR; Nodal Coordinator, ICAR-IARI Bengaluru hub Dr. P.K. Ghosh Director, ICAR-NIBSM, Raipur; Nodal Coordinator, ICAR-IARI Raipur hub Dr. Sujay Rakshit Director, ICAR-IIAB, Ranchi; Nodal Coordinator, ICAR-IARI Ranchi hub Dr. K. Sammi Reddy Director, ICAR-NIASM, Baramati; Nodal Coordinator, ICAR-IARI Baramati hub Dr. V.K. Singh Director, ICAR-CRIDA, Hyderabad; Nodal Coordinator, ICAR-IARI Hyderabad hub Dr. Y.G. Prasad Director, ICAR-CICR, Nagpur; Nodal Coordinator, ICAR-IARI Nagpur hub

		Dr. A.K. Nayak Director, ICAR-NRRI, Cuttack; Nodal Coordinator, ICAR-IARI Cuttack hub Dr. Gouranga Kar Director, ICAR-CRIJAF, Kolkata; Nodal Coordinator, ICAR-IARI Kolkatta hub Dr. V.K. Mishra Director, ICAR-RCNEH, Umiam, Shillong; Nodal Coordinator, ICAR-IARI Shillong hub Dr. Rasappa Viswanathan, Director, ICAR-IISR, Lucknow; Nodal Coordinator, ICAR-IARI Lucknow hub Dr. O.P. Yadav Director, ICAR-CAZRI, Jodhpur; Nodal Coordinator, ICAR-IARI Jodhpur hub Dr. Gyanendra Singh Director, ICAR-IIWBR, Karnal; Nodal Coordinator, ICAR-IARI Karnal hub Dr. Anup Das Director, ICAR-RCER, Patna; Nodal Coordinator, ICAR-IARI Patna hub
Joint Director (Res.), ICAR-IARI	Member	Dr. C. Viswanathan
Joint Director (Extn.), ICAR-IARI	Member	Dr. R.N. Padaria
Four Eminent Scientists/ (Outside Members)	Members	Dr. B.D. Singh Former Professor Emeritus, BHU Plot 123, Lane 10, Mahamanapuri Colony P.O. BHU, Varanasi-221005 Dr. B.L. Jalali Former Director of Research CCSHAU #601, Neelkanth Apartments Sector 21-C, Part-III, Faridabad-121001 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	Member	Dr. P.S. Brahmanand Water Technology Centre
Associate Dean (UG Affairs)	Member	Dr. Anil Dahuja
Associate Dean (PG Affairs)	Member	Dr. Atul Kumar
Associate Dean (International Affairs)	Member	Dr. K.K. Vinod
26 Professors of Teaching Disciplines at IARI	Members	Dr. (Ms.) Neera Singh Professor, Agricultural Chemicals
		Dr. (Ms.) Alka Singh Professor, Agricultural Economics
		Dr. A.K. Mishra Professor, Agricultural Engineering
		Dr. M.S. Nain Professor, Agricultural Extension
		Dr. (Ms.) P. Krishnan Professor, Agricultural Physics
		Dr. (Ms.) Cini Varghese Professor, Agricultural Statistics
		Dr. Y.S. Shivay Professor, Agronomy
		Dr. Anil Dahuja Professor, Biochemistry
		Dr. G.K. Jha Professor, Bioinformatics
		Dr. Alka Arora Professor, Computer Application
		Dr. (Ms.) Debjani Dey Professor, Entomology
		Dr. D.K. Sharma Professor, Environmental Science
		Dr. K.P. Singh Professor, Floriculture and Landscaping
		Dr. Manish Srivastav Professor, Fruit Science
		Dr. H.K. Dikshit Professor, Genetics and Plant Breeding
		Dr. Rajeev Kaushik Professor, Microbiology
		Dr. Debasis Pattanayak Professor, Molecular Biology and Biotechnology
		Dr. Anil Sirohi Professor, Nematology

		Dr. Sunil Archak Professor, Plant Genetic Resources
		Dr. Robin Gogoi Professor, Plant Pathology
		Dr. (Ms.) Anjali Anand Professor, Plant Physiology
		Dr. Ram Asrey Professor, Post Harvest Technology
		Dr. (Ms.) Monika Atul Joshi Professor, Seed Science & Technology
		Dr. T.J. Purakayastha Professor, Soil Science
		Dr. R.K. Yadav Professor, Vegetable Science
		Dr. (Ms.) Susama Sudhishri Professor, Water Science and Technology
Master of Halls of Residences (MOHR)	Member	Dr. Anil Sirohi
Senior Comptroller	Member	Shri D.D. Verma
Elected Faculty Representatives (2)	Members	Dr. Sandeep Kumar Lal Principal Scientist, Seed Science and Technology
		Dr. Harshawardhan Choudhary Principal Scientist, Vegetable Science
Incharge, Prof. M.S. Swaminathan Library	Member	Shri Deep Chand
Elected Students of PGSSU (2)	Members	Mr. Shivam Chaubey President PGSSU
		Mr. Tarun Students' Representative to the Academic Council
Senior Registrar & Joint Director (Admn.)	Member-Secretary	Shri Pushpendra Kumar

Appendix 4

Members of Extension Council of IARI

(As on 31.12.2023)

Chairperson
Dr. A.K. Singh, Director
ICAR-IARI, New Delhi

Members (Five Managerial Scientists representing six schools)
Dr. P.S. Brahmanand, PD, WTC and School Coordinator, Natural Resource Management

Dr. B.S. Tomar, Head, Vegetables Sciences, School Coordinator, Horticultural Sciences

Dr. Pankaj, Head, Nematology and School Coordinator, Plant Protection

Dr. Gopala Krishnan S., Head, Genetics and School Coordinator, Crop Improvement

Dr. Renu Pandey, Head, Plant Physiology & School Coordinator, Basic Sciences

Five Scientists representative of IARI

Dr. O.P. Awasthi, Head, Fruits and Horticultural Tehnology, IARI

Dr. Radha Prasanna, Head, Microbiology, IARI

Dr. J.P.S. Dabas, Incharge CATAT, IARI

Dr. G.P. Mishra, Head, Seed Science Technology, IARI, New Delhi

Dr. Gyanendra Singh, Incharge, Seed Production Unit, IARI

One Project Coordinator/Project Director

Dr. P.S. Brahmanand, Project Director, WTC, IARI

One Scientist, from IARI Regional Research Station

Dr. S.K. 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. Hans Ram Meena Head (Extension Education), 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 Agronomy Division, IARI Campus New Delhi

Dy. Director General (Agricultural Engineering), ICAR

Jt. Director (Extension), ICAR-IARI, New Delhi

Jt. Director (Research), ICAR-IARI, New Delhi

Jt. Director (Admn.), ICAR-IARI, New Delhi

Member-Secretary
Dr. Satyapriya, Head, Ag. Extension and School Coordinator, Social Sciences, IARI, New Delhi

Mr. Rajesh Aggarwal, Managing Director, (Agro Industry Representative)
Insectiside India Limited, 401-402, Lusa Tower, Azadpur Commercial Complex Delhi-33

Sh. B.K. Santosh (DD Representative)
Sr. Production Executive, DD Kisan

Sh. Shiv Nandan Lal (Additional Director General)
Representative, All India Radio, Akashwani Bhawan,
New Delhi – 110001

Sh. D.D. Verma, Sr. Comptroller, IARI, New Delhi-12

Farmers:
Shri. Pritam Singh, Panipat (Haryana)

Shri Sukhjeet Singh, Sangrur, Punjab

Appendix 5

Members of Institute Research Council (IRC)

(As on 31.12.2023)

Chairperson
Director, ICAR-IARI

Co-chairperson
Joint Director (Research)
ICAR-IARI

Members
Deputy Director General (Crop Sciences), ICAR

Project Directors/Project Coordinators of IARI

Heads of Divisions / Regional Stations of IARI

Principal Investigators of IARI

Member Secretary
In-charge, PME Cell, IARI

Appendix 6

Members of Institute Joint Staff Council (IJSC)

(As on 31.12.2023)

Chairman
Dr. A.K. Singh
Director, ICAR-IARI, New Delhi

Members (Official Side)
Joint Director (Extension), ICAR-IARI, New Delhi

Joint Director (Research), ICAR-IARI, New Delhi

Head, IARI, Regional Station, Karnal

Head, Regional Station, Shimla

Comptroller, IARI, New Delhi

Secretary (Official Side)
Joint Director (Adm.), ICAR-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, 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 31.12.2023)

Chairman
Dr. B.S. Tomar
Head & Principal Scientist, Division of Vegetable Science

Members (Official Side)
Dr. Raj Singh
Principal Scientist, Division of Agronomy

Sh. A.K. Soni
Chief Admin Officer, Directorate

Sh. Harshit Aggarwal
Sr. Admn. Officer, Directorate

Members of the Staff Side (Elected)
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 31.12.2023)

Director
Dr. A. K. Singh

Joint Director (Research)
Dr. Viswanathan Chinnusamy

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. Anjali Anand

Senior Comptroller
Mr. D.D. Verma

Chief Administrative Officer
Mr. Sanjeev Kumar Sinha

Agricultural Chemicals

Head
Dr. N.A. Shakil

Professor
Dr. (Ms.) Neera Singh

Network Project Coordinator
Dr. Vandana Tripathi

Agricultural Economics

Head
Dr. Alka Singh

Professor
Dr. Alka Singh

Agricultural Engineering

Head
Dr. P.K. Sahoo

Professor
Dr. A.K. Mishra

Agricultural Extension

Head
Dr. Satyapriya

Professor
Dr. Manjeet Singh Nain

Agricultural Physics

Head
Dr. Subhash Nataraja Pillai

Professor
Dr. P. Krishnan

Agronomy

Head
Dr. Sanjay Singh Rathore

Professor
Dr. Y.S. Shivay

Biochemistry

Head
Dr. Aruna Tyagi

Professor
Dr. Anil Dahuja

Entomology

Head
Dr. Mukesh Kumar Dhillon

Professor
Dr. Debjani Dey

Floriculture and Land-scaping

Head
Dr. Markandey Singh

Professor
Dr. K.P. Singh

Fruits and Horticultural Technology

Head
Dr. O.P. Awasthi

Professor
Dr. Manish Srivastava

Genetics

Head
Dr. Gopala Krishnan S.

Professor
Dr. Harsh Kumar Dikshit

Microbiology & CCUBGA

Head
Dr. Radha Prasanna

Professor
Dr. Rajiv Kaushik

Nematology

Head
Dr. Pankaj

Professor
Dr. Anil Sirohi

Plant Pathology

Head
Dr. M.S. Saharan

Professor
Dr. Robin Gogoi

Plant Physiology

Head
Dr. Renu Pandey

Professor
Dr. Anjali Anand

Food Science & Post Harvest Technology

Head
Dr. Dinesh Kumar

Professor
Dr. Ram Asrey

Seed Science and Technology

Head
Dr. Gyan Prakash Mishra

Professor
Dr. Monika Atul Joshi

Soil Science and Agricultural Chemistry

Head
Dr. Debasish Mandal

Professor
Dr. T.J. Purakayastha

Vegetable Science

Head
Dr. B.S. Tomar

Professor
Dr. Ramesh Kumar Yadav

Environment Science

Head
Dr. S. Naresh Kumar

Professor
Dr. D.K. Sharma

Water Technology Centre

Project Director
Dr. P.S. Brahmanand

Professor
Dr. Susama Sudhisri

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

Zonal Technology Management & Business Planning and Development (ZTM & BPD) Unit

Incharge
Dr. Akirti Sharma

IARI Library

Incharge (Library Services)
Dr. Anil Dahuja

IARI Regional Station, Amartara Cottage, Shimla

Head
Dr. Dharam Pal

IARI Regional Station, Indore

Head
Dr. Jang Bahadur Singh

IARI Regional Station, Kalimpong

Incharge
Dr. Dwijendra Barman

IARI Regional Station, Karnal

Head
Dr. Shiv Kumar Yadav

IARI Regional Station, Katrain

Head
Dr. Chandar Prakash

IARI Regional Station, Pune

Head
Dr. Anil Khar

IARI Regional Station, Pusa

Incharge
Dr. K.K. Singh

IARI Regional Station, Wellington (The Nilgiris)

Head
Dr. M. Sivaswamy

IARI Rice Breeding & Genetics Research Centre, Aduthurai

Incharge
Dr. M. Nagarajan

IARI Centre for Improvement of Pulses in South, Dharwad

Incharge
Dr. B.S. Patil

IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon

Incharge
Dr. Anamika Sharma

Annual Report 2023

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