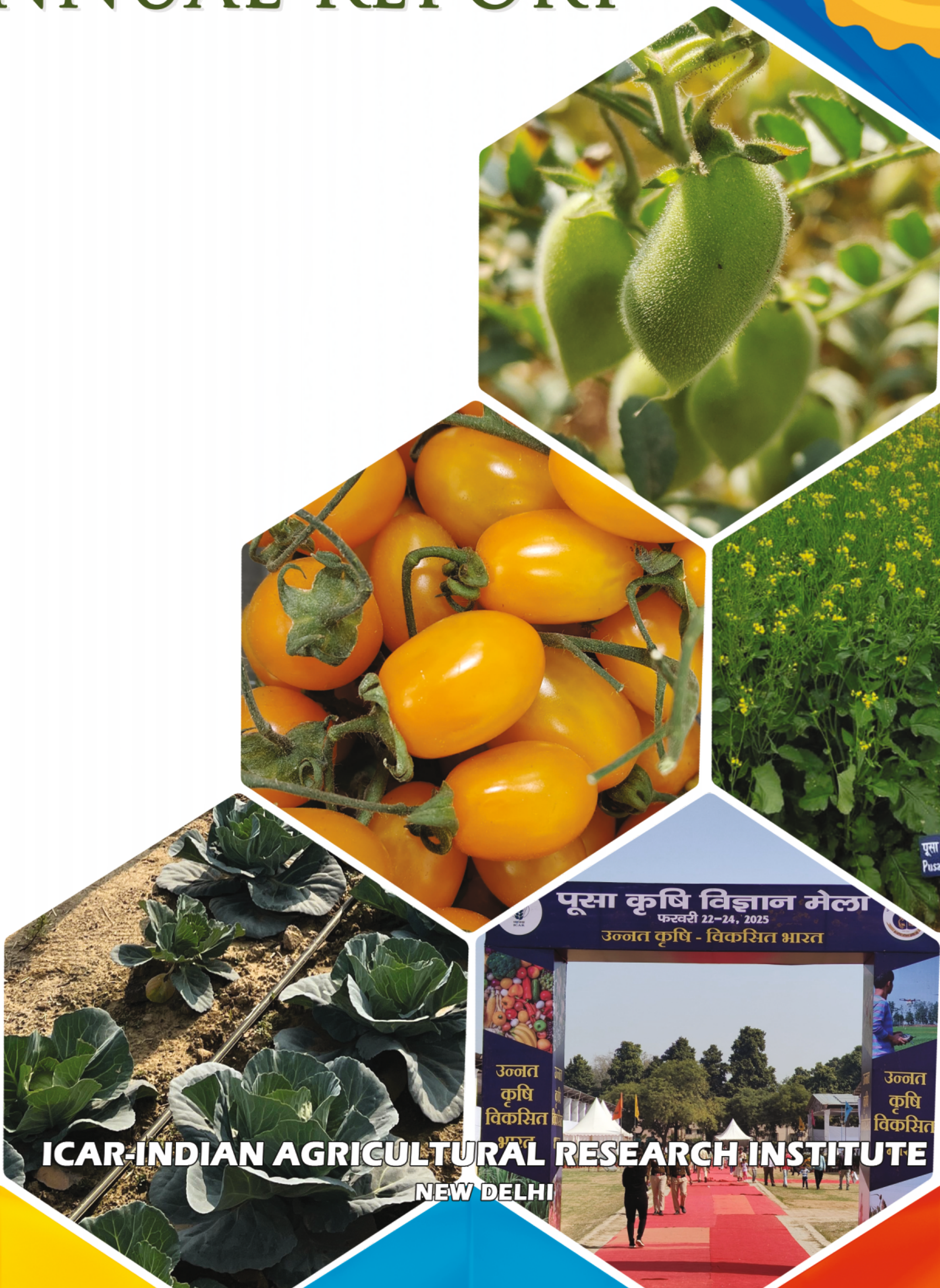
ISSN 0972-6136

2024 ANNUAL REPORT

AGRICULTURE AND ALLIED SECTORS
nirf
RANK 1



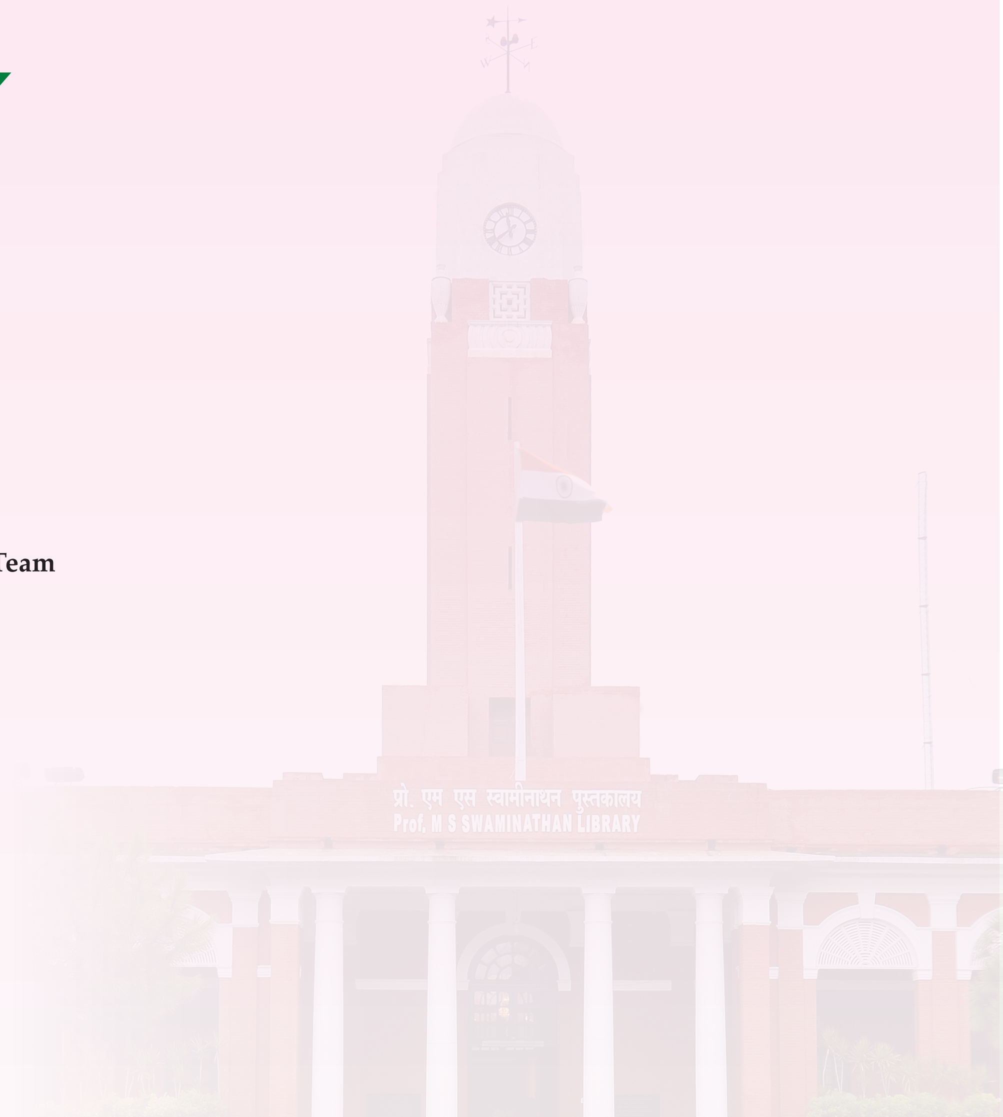
ICAR-INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI

ISSN 0972-6136

Annual Report 2024

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

Annual Report 2024



Printed: July, 2025

Supervision and Guidance
Dr. Ch. Srinivasa Rao
Director

Dr. Viswanathan Chinnusamy
Joint Director (Research)

Compilation Committee and Editorial Team

Members
Dr. C. Bhardwaj
Dr. Amish Kumar Sureja
Dr. Satyapriya
Dr. T.K. Das
Dr. S. Subramanian
Dr. Ranjeet Ranjan Kumar
Dr. K.K. Vinod

Incharge, Publication Unit
Dr. Anjali Anand

Associate Incharge, Publication Unit
Dr. Atul Kumar

Senior Technical Assistant, Publication Unit
Dr. Sunil Kumar

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

Correct citation: IARI Annual Report 2024, ICAR-Indian Agricultural Research Institute, New Delhi – 110 012, India.

ISSN 0972-6136

IARI website: www.iari.res.in

Published by the Director, ICAR-Indian Agricultural Research Institute, New Delhi -110 012, India, and printed at M/s M.S. Printers, C-108/1 Back Side, Naraina Industrial Area, Phase I, New Delhi – 110028 (Phone: 011-45104606)

PREFACE

Indian agriculture is confronted with complex and interlinked challenges including climate change, resource constraints, ecological imbalances and an increasing demand for food and nutritional security. The Indian Agricultural Research Institute (IARI) continues to address these through advanced and sustainable technological solutions, with a focus on climate-resilient and biofortified crops.

During FY 2024, basmati rice exports reached a record USD 5.2 billion, accounting for ~10% of total agricultural export earnings, with ~95% contributed by Pusa Basmati varieties. IARI maintained its leadership in food security, with IARI varieties contributing 92.2%, 36.26%, and 41.50% to total breeder seed indent of Basmati rice, wheat, and mustard, respectively. Twenty-five new cultivars were released across ten major crops viz., wheat, rice, maize, chickpea, pigeonpea, lentil, mungbean, mustard, soybean and pearl millet. Two herbicide-tolerant Basmati rice varieties (Pusa Basmati 1979 and Pusa Basmati 1985) were developed for DSR, along with two short-duration non-Basmati varieties (Pusa 1824 and Pusa 2090) to enable early harvests and reduce stubble burning.

Advancements in hybrid development were marked by the release and notification of India's first public-sector-bred two-line rice hybrid, Pusa JRH 56 and the pigeonpea hybrid, Pusa Arhar Hybrid 5. IARI also released four biofortified varieties viz., durum wheat rich in iron and zinc (HI 8840), protein-rich bread wheat (HD 3390 and HD 3410) and biofortified maize (Pusa Biofortified Maize Hybrid 5), enriched with multiple essential nutrients. The improved oilseed varieties with reduced anti-nutritional factors, such as double zero mustard (Pusa Mustard 35 and Pusa Mustard 36), and a soybean variety, low in Kunitz Trypsin Inhibitor (Pusa 21), were released and notified.

Specialty pearl millet flour, the "Divine Dough", with low-glycemic index and improved levels of protein, micronutrients, and resistant starch was developed to tailor to the nutritional requirement.

Disease-resistant hybrids, such as Pusa Tomato Hybrid-6 and Pusa Cauliflower Hybrid-102, and a cucumber variety, Pusa Parthenocarpic Cucumber Hybrid-1, suitable for protected cultivation, were released. Nutrient-rich vegetables, including Pusa Lal Bhindi-1, Pusa Purple Broccoli-1, and Pusa Sem-6 were introduced to enhance dietary diversity. Two mango rootstocks (Pusa Aam Moolvarant-1 and -2) were released to support high-density orchards. Approximately 13,000 quintals of breeder and truthfully labelled seeds of field crops as well as 37,000 kg horticultural crops were produced through participatory programs.

IARI leads a national genome editing program involving 24 crops and 178 target genes. A genome-edited rice line in the MTU1010 background, with improved drought and salinity tolerance, has been developed and is currently under evaluation at AICRPR. Tools such as a CRISPR-Cas12a dip-stick assay for chilli leaf curl virus and eco-friendly pest control products (Pusa CueFly Kit, Pusa Whitefly Attractant) were developed. Deep learning models such as YOLOv5, were adapted for automated pest identification.

Nutrient-use efficiency was improved with the use of slow-release fertilizers, urea-loaded nanoclay composites and phosphorus-enriched organic manures. The "Pusa N Doctor" mobile application aided real-time nitrogen management in maize. Bioinoculants, such as "Pusa BioGreen", were developed to mitigate methane emissions. A new wettable formulation of Pusa Decomposer enhanced the ease of crop residue management.

Remote sensing and machine learning were applied for assessment of in-season flood damage, monitoring stubble burning, and predicting groundwater quality. Engineering innovations included robotics-based farm tools, smart insect traps, electric tool carriers, and biosensors for nutrient detection. Drone-based systems were deployed for crop stress monitoring and yield forecasting.

Pusa Krishi Vigyan Mela was held in Simdega, Jharkhand, and drew a large crowd of farmers, entrepreneurs, policymakers, scientists and students. Outreach programms emphasized farmer-centric government schemes, Farmer Producer Organizations (FPOs), Kisan Credit Cards (KCC), and ecosystem service valuation.

In 2024, IARI filed twelve patents, six trademarks, and four copyright applications. Six patents and four copyrights were granted, along with seven PPVFRA registrations. Sixty technologies were licensed to 202 industries.

IARI scientists published 1199 peer-reviewed papers in reputed journals. The academic programs expanded through IARI hubs in Assam, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, and Chhattisgarh. At the 62nd Convocation, the Hon'ble President of India, Smt. Droupadi Murmu conferred degrees to 545 students.

I would like to thank Dr. Himanshu Pathak, former Secretary, DARE and Director General, ICAR; Dr. T.R. Sharma, former DDG (Crop Science) and Dr. A.K. Singh, former Director, ICAR-IARI, for their valuable guidance towards the Institute's activities during 2024. I am also grateful to Dr. M.L. Jat, Secretary, DARE and Director General, ICAR, and Dr. D.K. Yadava, DDG (Crop Science) for their constant guidance and support.

I acknowledge the funding agencies, including NASF (ICAR), AICRPs (ICAR), NAHEP (ICAR), DBT, DST, and other national and international agencies, for funding 25 projects in the financial year 2024.

The efforts of the annual report editorial team in ensuring the timely completion and publication of the report are appreciated. I look forward to more productive years ahead.

(Ch. Srinivasa Rao)

Director, ICAR-IARI

Date: July 14, 2025
Place: New Delhi

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:

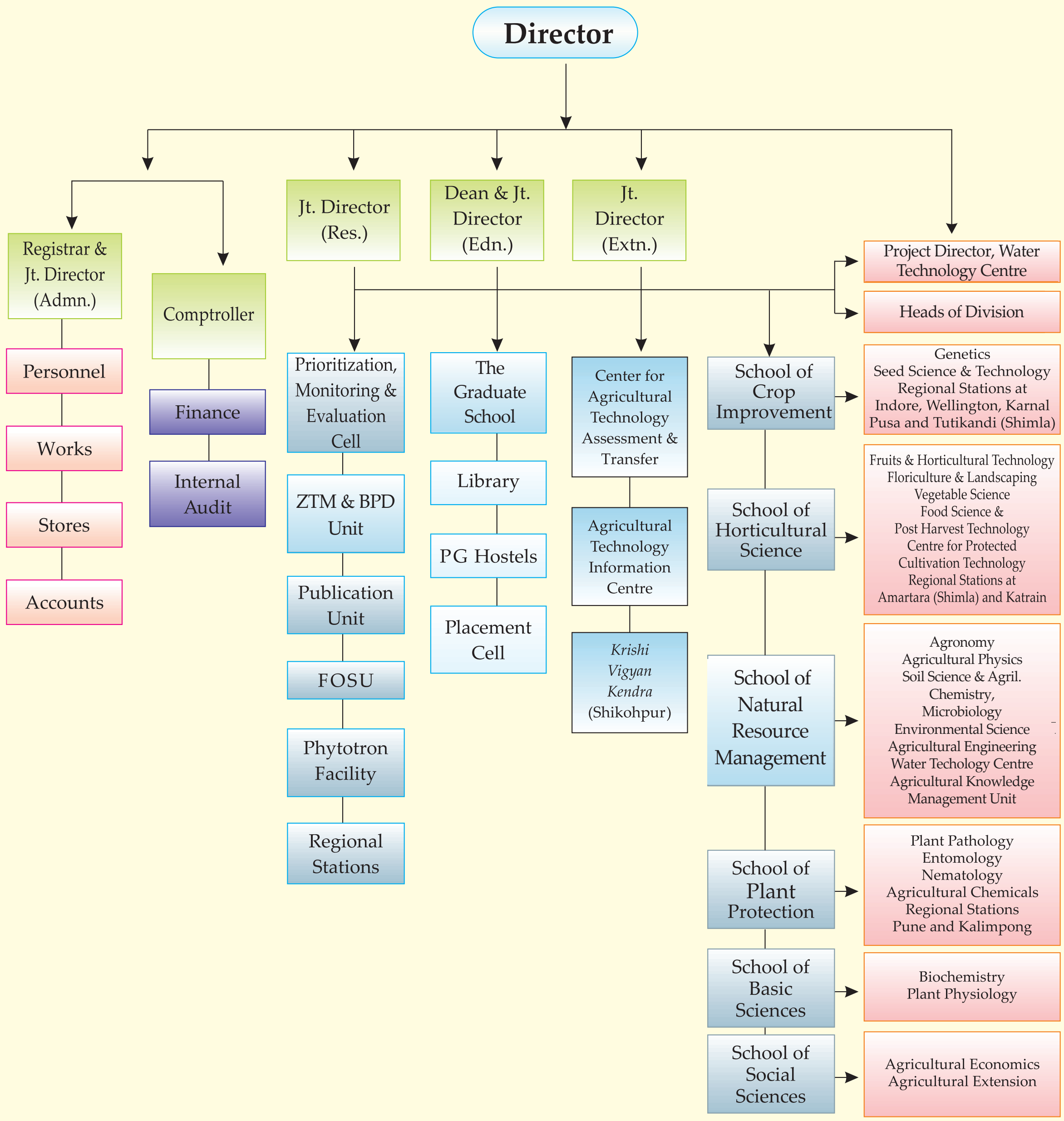
- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need-based research, that leads to crop improvement and sustained agricultural productivity in harmony with the environment
- To serve as a centre for academic excellence in 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 periods 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 2024-September 2024) ranged from 47.2 to 27.5 °C and the daily minimum temperature ranged from 13.6 to 35.2 °C. During winter (January -March, 2024 and October-December, 2024), the daily maximum temperature ranged from 37.5 C to 12.0 C and the minimum temperature ranges from 1.6 to 26.0 °C. June to September are rainy months during which 1000.5 mm of rainfall was received in 2024. During winter, 89.7 mm of 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 a sanctioned staff strength of 2278 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹ 70444.17 lakh (Unified Budget) for the year 2024-25.

Indian Agricultural Research Institute



Organizational Structure

EXECUTIVE SUMMARY

ICAR-IARI has played a crucial role in ensuring food security of the nation and livelihood security of farmers through the release of high-yielding, climate-resilient varieties and hybrids in both field and horticultural crops, and development of practical, farmer-friendly natural resource management (NRM) technologies. IARI made significant contributions to improving input-use efficiency and enhancing agricultural profitability. The salient achievements of ICAR-IARI in research, education and extension during 2024 are summarized here:

The School of Crop Improvement released 25 varieties of various crops viz., wheat- 07; rice- 04; maize-08; Pearlmillet-01; chickpea-02; Pigeonpea-01; Mustard-02, and 14 new varieties were identified in rice (04) and maize (10). Advancements in hybrid development were marked by the release and notification of India's first public-sector-bred two-line rice hybrid, Pusa JRH 56 and the pigeonpea hybrid, Pusa Arhar Hybrid 5. Four biofortified varieties viz., durum wheat rich in iron and zinc (HI 8840), protein-rich bread wheat (HD 3390 and HD 3410) and biofortified maize (Pusa Biofortified Maize Hybrid 5), enriched with multiple essential nutrients were released. Two germplasms were registered in wheat viz., HW 3654 (INGR 23082) and HW 3655 (INGR 23083) with resistance genes for stem rust (*Sr36*), leaf rust (*Lr45*) and powdery mildew (*Pm6*). Marker-assisted improvement for leaf and stripe rust resistance in wheat resulted in the identification of superior lines. Blast-resistant superior lines of wheat were developed for Northern Zones using genes from wild relatives. A targeted analysis of the Thermosensitive Genic Male Sterility (*TGMS*) gene was conducted using SSR and gene-based markers in rice. Development of multiple disease resistant wheat with herbicide tolerance is in progress with introgression of mutant allele of the *Acetolactate Synthase* (*ALS*) gene. The F5 wheat plants resistant to rusts, powdery mildew and Imazethapyr were selected for advancement. A temperate haploid inducer donor was crossed with a set of subtropical inbreds in maize. A set of newly developed inbreds were screened against fall armyworm (FAW) and tolerant lines of maize were identified. Efforts are underway to identify heat-tolerant landraces in chickpea. Two land races ILC 5911 and ILC 8666, appear promising across the locations. Two double-zero mustard varieties Pusa Double Zero Mustard 35 and Pusa Double Zero Mustard 36 were released to improve mustard cultivation for quality traits in the country. To mitigate off-flavors in vegetable soybean, a null allele of the *Lox2* gene was introduced from a donor genotype (PI596540) into the Swarna Vasundhara variety through marker-assisted backcross breeding. The fatty acid profiles in rice in differentially-aged seeds identified a strong correlation between margaric acid (C17:0), storage duration and seed viability parameters. The NIR spectroscopy differentiated the seed quality among selected rice genotypes from varying storage groups, with a strong Pearson's correlation coefficient at 1200-1400 nm spectral wavelength. Studies on cucumber seed dormancy suggested that seed coat thickness, phenolic compounds, gibberellic acid content and the ABA to GA ratio regulate dormancy.

The plant genetic resources comprising of wild relatives of crops, land races, indigenous and exotic collections and introgression lines serve as a rich reservoir of novel genes for higher productivity, biotic and abiotic stress tolerance and nutritional quality for crop improvement programs. During 2024, studies on transferring genes for tolerance to leaf rust from wild to cultivated species were attempted using triticale as a bridging species. Genetics of bronze colour and identification of germplasm for Turcicum Leaf Blight

(TLB) was taken up in maize. In chickpea, wild relatives were evaluated for their grain iron content and three lines (ICC17148, ICC17271 and ICC17149) with high iron content (110.39, 86.43 and 78.36 ppm, respectively) were identified. Donors with ultra-high protein content [ICC-13523 (33.56%), ICC-13461 (31.71%) and ICC-8397 (30.22%)] were identified in chickpea. Two germplasms were registered in lentil and a line with tolerance to black aphid was identified. In greengram, lines for Mungbean Yellow Mosaic Virus (MYMV) resistance and salinity tolerance were registered (INGR-23096, INGR-23097, respectively). In bitter gourd, two genetic stocks were registered *i.e.* with white flowers serving as a marker for genetic purity and a gynoecious line with desirable fruit traits. Purple cauliflower lines were screened for superior curd qualities. In orange cauliflower, promising lines were identified for use in hybrid breeding in early and mid-groups. Germplasm collection was strengthened with 10 lines of roses to enrich the germplasm.

In biosystematics of pest, two hundred seventy insect specimens were identified and 3350 specimens were collected, catalogued and added to the repository of the National Pusa Collection. Five new insect species viz., *Argyroptocha phalaenopa, Ophiorrhabda harmonica, O. philocompsa, Sorolopha dorsichlora* and *S. leptochlora* and two new insect genera, *Toonavora* and *Argyroptocha* were recorded from India. A catalogue for the Elateridae of the North-eastern region was compiled and two new species of *Glyphonyx* viz., *G. umiamis* and *G. kyrdemkulaiensis* were described. A deep learning based YOLOv5 detection model was developed for the identification of pests of cruciferous crops.

The soil and plant nematode communities were profiled in both mandarin and pomegranate orchards. Recombinase Polymerase Assay was developed for the diagnosis of nematodes *Meloidogyne graminicola*, *Aphelenchoides besseyi*, *Rotylenchulus reniformi* and *Globodera rostochiensis* and a LAMP technique was developed for the rapid detection of the foliar nematode, *A. besseyi.*

The School of Horticultural Sciences developed and released six vegetable varieties viz., Pusa Protected Bitter Gourd-2, Pusa Purple Cauliflower-1, Pusa Lal Bhindi-1, Pusa Sem-6, Pusa Purple Broccoli-1 and Pusa Chhota Baingan 1, and two hybrids viz., Pusa Parthenocarpic Cucumber Hybrid-1 and Pusa Cauliflower Hybrid 102, which were notified by CVRC. Two hybrids viz. Pusa Muskmelon Hybrid-2 and Pusa Tomato Hybrid-6 and tomato variety Pusa Shakti have been released by AICRP-VC and notified by CVRC.

Two tomato varieties, namely, Pusa Cocktail Tomato and a processing variety, Pusa Prasanskrit, both with *Ty-3* gene-based resistance to ToLCD, and a Pusa Cherry Tomato Hybrid-1 (with *Ty-3* gene-based ToLCD resistance and *Ph-3* gene-based late-blight resistance) were released for protected cultivation. Promising lines of sweet pepper (CPCT-03, CPCT-F4-11 and CPCT-F3-02) with big fruit size (200-350 g/fruit) and blocky shaped (3-4 lobes) fruits have been identified for protected cultivation.

ICAR-IARI Regional Station, Katrain identified the capsicum genotypes, KTGC-35, KTRC-9, KTOC-3 and KTYC-2 with superior performance. Several promising F_1 hybrid combinations of snowball cauliflower and cabbage were also identified. In greenhouse, the three-stem pruning method for big fruited tomato hybrid NS-4266, resulted in the highest fruit yield of 34.50 kg/m^2 as compared to that of the normal pruning method (23.75 kg/m^2).

The AI-based crop growth model for greenhouse vertical hydroponic system of lettuce was developed using Random Forest machine learning algorithm. In mango, half-sib genotypes, HS-24/1, HS-31/1 and HS-37/3 were developed with improved traits as compared to the parent variety Amrapali. Two lines of Kinnow mandarin, viz., Pusa Kinnow Gold and Pusa Early Kinnow and two Mosambi lines, viz., Pusa Kartiki Mosambi and Pusa Low-Seeded Mosambi have been proposed for Institute Variety Identification Committee. In guava, hybrids GH-2018-2E (white flesh) and GH-2018-7H (pink flesh) were found promising. At ICAR-IARI Regional Station, Kalimpong, promising genotypes of Darjeeling mandarin viz., PR-12, PR-13 and PR-14 were identified.

French marigold selection, Fr./R-2, was found suitable for loose flower production and bedding purposes. In gladiolus, Pusa Red Delight, a mid-season line with red florets has been developed. A mutant in gladiolus (IC-641855, INGR-24048) was registered as unique genetic stock at NBPGR, New Delhi. In annual chrysanthemum, three open-pollinated lines viz., Pusa Ivory, Pusa Dhaval and Pusa Swarna have been developed for loose flower production. In antirrhinum, KTANT-12, KTANT-17, KTANT-33 and KTANT-34 lines were found suitable for cut flower production and KTANT-42, KTANT-43, KTANT-51 and KTANT-53 were suitable for pot culture. An artificial module for day-length extension for induction of flowering in chrysanthemum has been developed, eliminating the need for staggered planting under greenhouse conditions. A green process employing moisture-assisted aging technology (MAAT) was standardized to develop black garlic from a single clove variety, Solo. Rose leaf and marigold petal extracts, at 200 mg GAE mL^{-1}, were found to be effective natural alternatives for controlling post-harvest fungal infections of *Colletotrichum gloeosporioide*s, *Rhizopus stolonifer* and *Aspergillus niger* in guava fruits.

The method for formulation of 'Nutri-prash', a convenient healthy bar, using aonla, beetroot and moringa; the extrusion processes for the development of tomato pomace-corn extrudates and pea pod powder instant noodles were optimized.

The School of Natural Resource Management focuses on development of non-invasive sensors, remote sensing, machine learning and artificial intelligence approaches to characterize soil and plant health for precision agriculture. An integrated farming system (IFS) model involving crop + dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas + vermicompost was developed for small farmers under irrigated situations in North India, which could achieve higher productivity (62.9–83.4 t/ha), production efficiency (172.3 kg/ha/day), profitability (₹7.75 lakh/ha) with increased employment (788 man-days) and a lower water footprint (112.2 L/kg REY). A long-term conservation agriculture (CA) practice in the rice-wheat system showed in higher wheat yield (20.9%), system productivity (28.5%) and soil health with higher SOC (44% at 0-5 cm, 37% at 5-15 cm) and C-sequestration, despite a 19.4% lower rice yield than the conventional method. A mobile application "Pusa N Doctor" was designed and validated for real-time nitrogen management in maize reducing N application by 18.7%, improving agronomic efficiency of N by 22.9% and minimizing N losses by 44.9 kg/ha. A maize+cowpea - wheat cropping system led to 9.31% higher maize yield, 13% higher wheat yield, 43% higher system productivity and 35% higher net return as compared to maize-wheat system. Late-sowing of wheat genotypes reduced grain filling period by 7.4 days, grain yield by 18% and dry matter accumulation by 18.8% and enhanced remobilization by 23%. Wheat varieties, DBW-187 and HD-2967 performed better under late sown conditions. In the rice-fallow system, the puddled transplanted rice with residue mulching increased grain yield by 10.8%, while zero-till direct-seeded rice with residue retention improved pulse and cereal yields by 12.6–26.5% over farmers' practices, supporting sustainable intensification. The pre-emergence tank mix application of *Pyroxasulfone* @ 127.5 g/ha + *Metsulfuron-methyl* @ 4 g/ha resulted in effective control of multiple weed flora and provided higher wheat productivity in vertisols of Central India.

A urea-loaded nanoclay biopolymer composite was developed to enhance nitrogen-use efficiency, yielding similar grain yields and ANUE of applied N fertilizer in maize and wheat crops. The ZT+ residue plots in a maize-wheat-mungbean system under conservation agriculture led to better nutrients availability and soil health in terms of soil organic carbon, nitrogen pools, soluble P and sulfur fractions as compared with the conventional tillage+residue. Phosphorus-enriched organic manure as an alternative source of phosphorus could reduce diammonium phosphate application by 50% while maintaining crop productivity in maize-wheat and soybean-wheat systems, making it a sustainable approach for phosphorus management. The aggregation dynamics and efficiency of biochar colloids were highly influenced by their interaction with rhizosphere-secreted organic acids (formic, acetic, malic), varying with electrolyte concentration and pH. It was found that the intensive cropping without applying adequate K fertilization depleted soil K reserves of major soil types and affected nutrient availability. In this situation, K fertilization effectively maintained soil K buffering capacity, ensuring better crop productivity. Ammonium acetate, barium chloride, nitric acid and Mehlich extractant were identified as most soil-moisture insensitive extractant for available K in moist soil, while sodium acetate extractant was best for air-dry soil. Iron-exchanged bentonite (7.5 g/kg) significantly reduced cadmium and lead uptake by spinach, lowered the bioconcentration factor and hazard quotient and made it an effective soil amendment for metal-contaminated soils.

Optimal water resource management in Nuh, Haryana was evaluated using a linear programming model run in LINDO software, which indicated that the proportion of 40:20:40 of water application as surface: drip: pipe method, is best for crop management practices, which provided 49% higher net return with net profit of ₹ 4,29,071 ha/year and water requirement of 14.03 ha-m. Groundwater recharge potential of Yamuna floodplain in NCT Delhi was estimated to be 6.96 MCM using MODFLOW model. Groundwater quality prediction for Karnal was conducted using Explainable AI (XAI) with Extreme Gradient Boosting (XGB) and Support Vector Machine (SVM) models. The XGB outperformed SVM with a $R^2 = 0.977$ and lower error metrics. The XAI identified calcium as the most influential factor for groundwater quality prediction, followed by total dissolved solids and sulfate. Integrated drip and mulch systems in Basmati rice and millets could improve the yield of sorghum (34%), pearl millet (31%) and Basmati rice (33%) and enhance water-use efficiency (sorghum 45%, pearl millet 38%) as compared to traditional practices. Crop water footprint of maize in north-western plains was assessed using a crop water requirement model with 20 years of data (2000-2020), which revealed that the total water footprint of maize comprised of 78% green water (1540 m^3/t) and 22% blue water (434 m^3/t). Standardized streamflow index (SSFI) was developed for the Lower Mahanadi Basin based on river discharge data (2000–2020) from the Birupa gauging site. The SSFI values below -1 indicated moderate to severe droughts, most noticeable in 1-month and 3-month indices, while the 12-month SSFI provided a smoother trend of overall water availability. A low-cost integrated sensing device for irrigation scheduling was developed and validated for maize, wheat and greenhouse capsicum, using CWSI thresholds of 0.42, 0.35 and 0.28, respectively to trigger irrigation.

A telerobotic target-specific pesticide applicator was developed for the precise application of pesticides, reducing pesticide use by 24.95% with 75% field efficiency and capacities of 0.15 ha/h for greenhouses and 0.22 ha/h for open fields. A crop disease detection for black rot detection in cauliflower using 6,000 spectral datasets with machine learning models, such as Decision Tree and Support Vector Machine (SVM) was developed with 98% accuracy for diseased samples. Sensor-based device for real time detection of groundnut bud necrosis virus classified disease severity in tomato into five categories (0 to >50%) using a machine learning model. Robot for weed detection and light tillage with a rocker-bogie mechanism was designed for weed data collection and light tillage. Robotic soil sampler with collection unit was designed for GPS-tagged soil sampling, featuring a differential steering system, two linear actuators and a DC motor-driven soil cutter. This robot takes 2.83 minutes per sample collection. Developed raised bed pneumatic precision planter-cum-fertilizer applicator, which can integrate bed making, seed planting and fertilization in one operation, reducing seed loss (missing index 1-4%, multiple index 1-3%) and labour costs by 30-60%. It operates at a suction pressure of 20-50 kg/cm^2 and has a field capacity of 0.68 ha/h, with an efficiency of 80-85%.

The development and evaluation of microbial consortia/formulations for crops revealed that rhizobacterial bioformulations maintained higher relative water content, chlorophyll, carotenoids and antioxidant activity in mustard plants under drought as compared to the control. An increase in ABA in mustard seedlings under moisture deficit stress with lowering of IAA and GA was also observed. Cyanobacterial inoculation significantly reduced drought-induced effects in wheat. For harnessing microorganisms for value-added products, a fungal consortium (*Talaromyces pinophilus*, *Penicillium oxalicum* and *Penicillium rubens*) was developed which yielded gluconic acid (58.0 g/L) from substrate potato waste (30 g/L) at pH 6.0, inoculum size 4%, temperature 30°C and 11 days fermentation. Alkali pre-treatment of corn stover led to 53 and 47% enrichment in glucan content in stover of maize hybrids PJHM 1 and PJHM2, respectively, with saccharification efficiency 85-90% at 5% substrate loading. Fermentation of the enzymatic hydrolysates with *Candida tropicalis* Y6 and *Saccharomyces cerevisiae* LN yielded the highest ethanol concentrations of 2.60 and 2.66%, respectively, within 48 h. Sixty-three root-associated rhizobial and non-rhizobial bacterial isolates from chickpea genotypes showed plant growth promotion traits, and 47% of *Rhizophagus irregularis* endobacteriome exhibited the growth-promoting activities. Among cyanobacterium-based formulations (*Anabaena laxa* C11, *Nostoc carneum* BF2 and *Anabaena laxa* RPAN8) for seed coating and soil drenching, *Anabaena laxa* was identified as best performer in terms of promoting overall growth, yield and quality of spinach.

Global climate model (GCM) ensemble data analysis revealed cold biases in northern India and hot biases in southern latitudes, which were corrected using quantile mapping to develop future climate scenarios for agricultural seasons under various SSP-RCP combinations (2015-2100). The inventory of methane and nitrous oxide emissions from agricultural soils was prepared using the IPCC inventory preparation guidelines for the base year 2021-22. Methane emissions from rice cultivation (2021-22) was estimated to be 3.57 Gg from 46.28 mha, while direct nitrous oxide emission was 231.96 Gg, with synthetic N fertilizer contributing 168 Gg and indirect N_2O emissions 58.36 Gg. Emission of GHG from rice residue burning in Punjab and Haryana in 2023 was 37.6 million tonnes of GHG (CO_2 eq.). In rice, phosphogypsum-coated urea reduced cumulative CH_4 and N_2O emissions and global warming potential by 12.5 and 6.2%, respectively, as compared to prilled urea and neem-coated urea (NCU) under alternate wetting and drying irrigation. Biochar-coated urea was found to have highest N_2O mitigation potential of 25.8 and 17.3% as compared to prilled urea and neem coated urea, respectively, in onion. The response of bread wheat variety, HD 3226 and durum wheat variety, HI 8627, to elevated CO_2 and temperature revealed that durum wheat might experience early maturation and reduction in growth, leading to lower yield loss (4.2%) than aestivum (5.5%), and elevated CO_2 partially compensated for yield decline caused by high temperature. Conservation Agriculture (CA) in a rice-wheat cropping system significantly improved soil organic carbon (SOC) sequestration after nine years, increasing total SOC by 29.9%, SOC stock by 23%, labile carbon by 27.9% and macroaggregate-associated carbon by 31%, highlighting its role in carbon sequestration and climate change mitigation. Crop yield losses due to flash floods in July in Himachal Pradesh were estimated using machine learning and remote sensing, which highlighted the most-affected areas, having highest maize loss in Solan (54.13%) and rice yield loss in Kangra (19.1%).

The School of Plant Protection focused its research on diagnostics, identification of resistant sources for biotic stresses and integrated management of important pests and pathogens of national importance.

About 50,650 fungal specimens, 4190 fungal cultures were maintained at the Indian Type Culture Collection (ITCC). Citrus concave gum-associated virus (CCGaV), Apple rubbery wood virus 1 (ARWV-1), ARWV-2 have been recorded for the first time in India. Studies on host plant resistance identified four genotypes *viz*., IC082302, IC573145, IC5099326 and IC73595 showing moderate resistance to Fusarium Head Blight (FHB). Diagnostic kits were developed for detection of citrus yellow vein clearing virus (CYVCV), citrus yellow mottle associated virus (CiYMaV), potato Leaf roll viral disease (PLRV) and rice blast disease under field conditions.

Maize parental lines, A-lines namely CML 565, AI 544 and PDIM 639, and R-lines, namely, AI 125, AI 155 and AI 1100 were found to show strong resistance to Fall Army worm (FAW) *Spodoptera frugiperda*. Two drone-compatible formulations, OD (chlorantraniliprole + emamectin benzoate) and EC (natural insecticides), were developed for FAW management in maize. Wild species such as *Lepidium sativum*, *Sisymbrium spp.*, *Eruca sativa* and *Crambe abyssinica* exhibited the least preference and population build-up of mustard aphid. An endophytic *Bacillus* with potent inhibitory activity against the rice blast pathogen was isolated and characterized. An entomopathogenic fungus, *Clonostachys rogersoniana* was found to be effective against woolly apple aphid. The mycoparasite, *Acremonium sclerotigenum* (SHZA1), effectively reduced uredospore germination of cereal rust pathogen. Cellulose-degrading gut bacterial genera viz., *Cedecea, Clostridium, Enterobacter, Klebsiella* Serratia from the gut of honey bees were identified and characterized.

Genome wide analysis led to the identification and characterization of 38 Odorant Binding Proteins (OBPs) and Chemosensory Proteins (CSP) in whitefly *Bemisia tabaci*. Two novel repellent/ovipositional deterrents have been identified for control of this pest. The plant origin compound, carvacrol exhibited strong bioactivity against pulse beetle *Callosobruchus maculatus*.

Genome-edited Arabidopsis line, AtAAP-cr-5, exhibited reduced nematode infection. Gene-edited lines of the genes KRP6-1, KRP6-2, WRKY45-1, and WRKY45-2 exhibited reduced *Meloidogyne incognita* infection and root galling. Seven chemosensory genes (*Mg-odr-1, Mg-odr-3, Mg-odr-7, Mg-tax-4, Mg-tax-4.1, Mg-osm-9* and *Mg-ocr-2*) were characterized from *M. graminicola.* Entomopathogenic nematode isolates of *H. indica* showed significant mortality of mango mealybugs. Gut-active *Photorhabdus* toxins showed insecticidal activity against *Spodoptera frugiperda* and *S. litura*.

Silencing of *BtPGRP* and *V-ATPase-B* resulted in increased mortality of whitefly, *Bemisia tabaci* and thrips, *Thrips palmi*, respectively. Using RNAi-based functional validation, two transmembrane (CAD, ABCC2) and two GPI-anchored (ALP1, APN) proteins were identified as the putative receptors for Cry1AcF protein in the gut epithelial cells. Among the 32 prenylated chalcones synthesized and tested against *M. incognita*, 2′-hydroxy-3-bromo-5′-O-prenylchalcone was found to be the most potent. Six compounds, including 3β,13β-dihydroxy-urs-11-en-28-oic acid (first-time report) were identified in the methanolic extract of *Mentha.* The essential oil contained carvone, d-limonene, 1,8-cineole and β-caryophyllene showed strong nematicidal activity of *Meloidogyne incognita* juveniles.

A robust QuEChERS-LC-ESI-MS/MS method was developed for detecting 103 pesticides in cookies. A β-cyclodextrin-based molecularly imprinted polymer (MIP) was developed for tricyclazole detection.

The School of Basic Sciences made significant achievements in exploring novel genes, QTLs, proteins and metabolites to understand and improve the physiological processes. Studies on the development of climate-smart wheat led to the identification of wheat genotypes with stay-green traits linked to heat stress tolerance. Resilience to heat stress was enhanced through the application of cytokinin and GABA in wheat. Under high night temperature, aspartate-derived amino acids accumulated in the amino acid pool of the developing grains of early-maturing wheat genotypes. GWAS analysis of sesame and lentil accessions led to the identification of drought-tolerant lines in both crops. Forty significant marker-trait associations (MTAs) related to nitrogen deficiency tolerance and nitrogen use efficiency were identified across emmer wheat lines. Haplotype analysis for the rice nitrate transporter gene *NRT1.1* led to the identification of superior rice haplotypes with improved nitrate uptake. Machine vision and deep learning helped in the selection of wheat genotypes with high early vigour. Knockout and overexpression of the matrix metalloproteinase 1 (*OsMMP1*) gene in rice generated ten single-copy overexpression events. CRISPR-Cas9 knockout of the *OsPP10* gene in rice enhanced seedling-stage tolerance to salinity and osmotic stress. Seed priming with a bioformulation of Methyl jasmonate, $FeSO_4$, and $ZnSO_4$ improved drought resilience in rice. Epigenomic studies revealed DNA methylation-regulated genes in drought-tolerant rice genotypes. Yellow rust resistance loci were mapped in *T. spelta* and *T. turgidum* derivatives using SNP chips. The rice variety, Shah Pasand, was identified as a donor for low phytic acid. Gene-based markers for anthocyanin biosynthesis, silkless traits and TLB resistance were developed in maize. In horticultural crops, promising RILs for improvement in yield and shelf life of muskmelon, QTLs linked to disease resistance in bitter gourd, heat tolerance in capsicum and genetic markers for stress resilience in okra were identified.

In quest for newer processing methods, thermal processing through autoclaving enhanced the protein digestibility in pigeonpea. In rice varieties, Swarna and BPT5204, combined treatment of microwave-autoclave-pullulanase increased the resistant starch (RS) in flour. Specialty pearl millet flour, the "Divine Dough", with low-glycemic index and improved levels of protein, micronutrients, and resistant starch was developed to tailor to the nutritional requirement.

The School of Social Sciences conducted studies on the evaluation of Farmer-centric Government Schemes and technologies, climate change adaptation, nutrition and health security, agri-preneurship and farmer-led innovation, agricultural markets and value chains, institutional initiatives such as FPOs, KCC MGNREGS and valuation of ecosystem services.

Between 2021 and 2024, e-NAM facilitated over 2.1 million transactions but showed a concentration of trade in specific commodities, such as flowers and oilseeds. India's agri-startup sector, with over 27,500 ventures, is rapidly growing and funding in this area has increased at a 49% Compound Annual Growth Rate (CAGR) from 2014 to 2021. Food technology leads this sector, bolstered by venture capital and is projected to create a $21.2 billion market opportunity by 2025. Studies on ecosystem services of Kerala's Kole Wetlands agroecosystem demonstrated a net benefit of ₹1,738.20 crores per year, out of which 85% accounts for non-marketed ecosystem services. A study in Uttar Pradesh revealed that FPO participation enhances mango commercialization, increasing farmer income by 28.5%. MGNREGA has contributed to higher consumption diversification, supporting economic resilience among rural households.

The Institute's multimedia-based extension model, Pusa Samachar, emerged as an effective tool for agricultural knowledge dissemination, with 229 episodes on YouTube and 140 episodes in regional languages, reaching 53,000 subscribers and amassing 2.3 million views. The Agricultural Technology Information Centre (ATIC) has continued to serve as a single-window platform for disseminating knowledge, providing advisory services and offering access to quality agricultural inputs. The *Pusa Agri Krishi Haat* with 60 retail outlets is a vital direct-marketing platform for farmers, promoting agripreneurship and enhancing farm incomes.

The Institute places a strong emphasis on the transfer of agricultural technologies through outreach programs. Under SCSP, improved IARI seed varieties of paddy, wheat, mustard, lentil, chickpea and vegetables were distributed to Scheduled Caste farmers, along with 10,996 farm implements across multiple districts. Additionally, 22 training programs were conducted to build farmer's capacity. The NEH program, implemented across eight north-eastern states covering 37 KVKs, provided ₹45 lakh worth of planting materials and distributed 236,700 kg of potato seeds to 4,000 farmers. The TSP initiative conducted 350 wheat demonstrations in Rajasthan and Madhya Pradesh, showing a yield increase of 15 q/ha, while mustard demonstrations in Rajasthan achieved an 80% yield improvement over local varieties. Through the Mera Gaon Mera Gaurav (MGMG) initiative, 440 scientists adopted 550 villages, benefiting over 15,000 farmers through advisory services, training and demonstrations.

Pusa *Krishi Vigyan Mela*-2024 was organized at Albert Ekka Stadium, Simdega, Jharkhand, from March

10-12, 2024, with the theme '*Krishi Uddhamita- Samridh Kisan*'. More than 4000 visitors including farmers, farm women, extension workers, entrepreneurs, students and others, visited the *mela*.

The Graduate School of IARI continued to provide national and international leadership in human resource development. A total of 1057 students were admitted for the academic session 2024-25 in IARI, New Delhi and its 16 hubs.

The 62nd Convocation of the Graduate School of the Indian Agricultural Research Institute (IARI), held on February 9, 2024, was graced by Smt. Droupadi Murmu, Hon'ble President of India as the Chief Guest. During this Convocation, 545 students (224 M.Sc., 15 M.Tech., and 306 Ph.D.) from India and other countries received their Postgraduate and Doctoral degrees.

The scientists of the Institute published 1199 research papers in scientific peer-reviewed journals with international impact factor. In addition, several other publications in the form of symposia papers, books/book chapters, popular articles, technical bulletins, regular and *ad-hoc* publications, both in English and Hindi, were brought out for the timely dissemination of the technical know-how and other important information to the respective stakeholders. Ninety national and international training courses and other capacity-building programs were conducted to benefit farmers, academicians, researchers, extension workers and other professionals. New linkages and collaborations with several national and international institutions/organizations were fostered. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions during this period.

1. CROP IMPROVEMENT

IARI, widely regarded as the "Seat of Green Revolution" in India and the crop improvement programme of the Institute is primarily aimed at enhancing the productivity and nutritional quality of various field crops. Since its inception, the School of Crop Improvement has made significant contributions to basic, strategic and applied research in genetics and plant breeding of various crops as well as model genetic organisms. The school of crop improvement serves as a cradle for farmers' seed security and the nation's food security.

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released & notified

HD 3386: A bread wheat variety with an average yield of 62.5 q/ha was released by CVRC for timely sown irrigated conditions of NWPZ. It has a high level of resistance against stripe and leaf rust and moderate resistance against leaf blight. It is heat tolerant and possesses a good combination of protein subunits with a Glu-1 score of 8/10.

Field view of HD 3386

HD 3388: A bread wheat variety released for timely sown irrigation conditions of NEPZ with an average yield of 52.0 q/ha. It is resistant to yellow and brown rust under natural and artificial epiphytotic conditions and highly resistant to 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: A bread wheat variety released for timely sown irrigated conditions of Delhi NCR with an average yield of 62.36 q/ha. It is highly resistant to all three rusts and carries the stripe rust resistance gene *Yr10*. It has a high hectolitre weight (78.2 kg/hl), good grain appearance and protein content (12%).

Field view of HD 3390

HD 3410: A bread wheat variety released for early sown irrigated conditions of Madhya Pradesh and

Field view of HD 3410

Delhi NCR. Its average yield is 70.4 q/ha under Delhi NCR and 65.91 q/ha Madhya Pradesh. It is highly resistant to multiple diseases viz., all three rust; Karnal Bunt, Powdery mildew and Foliar head blight. HD 3410 has high grain hardness (81.3) and good protein content (11.7%).

HD 3437: It is released for Delhi state and NCR under irrigated, timely sown conditions. It is a near iso-genic line of mega wheat variety HD 2967, developed through MABB with three genes *Lr19/Sr25*, *Lr34/Yr18* and *Yr10*. HD 3437 exhibits high level of resistance against leaf and stripe rusts under natural and artificial epiphytotic conditions.

Field view of HD 3437

HI 8840 (Pusa Gehun Gaurav): A durum wheat variety identified for timely sown restricted irrigation

Grains of HI 8840

conditions of the Peninsular zone. It is a high-yielding variety with an average yield of 30.2 q/ha, with a yield potential of 39.9 q/ha. It has high levels of field resistance to stem and leaf rusts under artificial conditions. It shows higher yellow pigment content (7.0 ppm), test weight (83 kg/hl), grain hardness index (95), sedimentation value (40.5 ml), zinc (41.1 ppm) and iron (38.5 ppm) content.

1.1.1.2 Development of improved cultivars

Marker-assisted improvement for leaf and stripe rust resistance: In this regard, NILs (Near Isogenic Lines) of HD 3086 with *Lr52/Yr47* were developed with >95% of RPG (Recurrent parent Genome). The BC2F3 generations with *Lr52/Yr47* and *Lr53/Yr35* in HD 3059 background were produced during the off-season by taking two generations in the phytotron facility.

Introgression of *LrSyn55* and *LrSel.G12* in superior wheat varieties: NILs were evaluated in the background of HD 3086 and HD 2932. The superior lines with phenotypic similarity to RP (Recurrent Parent) and resistance to leaf rust were identified.

Development of blast-resistant wheat varieties targeting North Eastern Plain Zone (NEPZ): The *Triticum ventricosa*-derived gene *Lr37/Sr38/Yr17* was introduced into five popular wheat varieties: DBW 39, HD 2733, PBW 343, HD 2967 and HW2045. During the 2023 *rabi* and *kharif* seasons, BC_3F_1 and F_2 plants were grown and confirmed using the Ventriup/LN2 marker for *Lr37+*. A 262 bp band confirmed the presence of *Lr37+*, while a co-dominant SSR marker, *Xstm773-2* was used to confirm *Sr36/Pm6*.

1.1.1.3 Germplasm registration

Wheat accessions HW 3654 (INGR 23082) and HW 3655 (INGR 23083) with significant resistance genes for stem rust (Sr36), leaf rust (Lr45) and powdery mildew (*Pm6*) were registered at NBPGR, New Delhi.

1.1.1.4 Introducing *ALS* gene for the development of herbicide-tolerant wheat with multiple diseases

The *ALS* gene-mediated herbicide tolerance from BCL0618 was transferred into multiple wheat varieties

HW 2436-1, HW 2436-2, HW 2436-3A, HW 2436-4, HD 3086, HD 3059, WH 1124, HD 2329, HD 2285, PBW 343, PBW 723, DBW 39 and HD 2733 with disease resistance genes, and BC_3F_4 and F_5 plants resistant to rusts, powdery mildew and Imazethapyr were

1.1.2 Barley

1.1.2.1 Barley entries in coordinated trials

The naked barley genotype, BHS 497 was promoted to AVT-II, whereas two naked barley entries, BHS 499 and BHS 500 were promoted from IVT to AVT-I under AICRP trials for Northern Hill Zone (NHZ). Two entries, BHS 498 (FB-Uncut) and BHS 498, BHS 502 (Dual Purpose) were entered in AVT-I for testing under AICRP trials. Four barley entries viz. BHS507, BHS 508, BHS 509 and BHS 510 were nominated for testing in the timely sown rainfed conditions of NHZ under AICRP trials of barley.

1.1.3 Rice

1.1.3.1 Varieties released & notified

Pusa 2090: Pusa 2090-17-20 (IET 29217) is a wide-yielding mid-early duration rice variety with seed-to-seed maturity of 125-130 days, with an average yield of 88.4 q/ha. On an overall basis, 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 in the timely harvest of paddy crops in the Delhi-NCT area, which can help provide sufficient time for after-harvest operations.

Field view of Pusa 2090

Pusa 1824: Pusa 1824-12-84-17-7-2 (IET 28442) is a high-yielding medium-duration rice variety with seed-to-seed maturity of 120-125 days, with an average yield of 95.09 q/ha. It exhibited 31.5% yield superiority over Pusa 44, the most popular non-Basmati variety grown in the Delhi-NCR region. It has a semi-dwarf, non-lodging and non-shattering habit with very high culm strength. This variety is also suitable for timely harvest in the Delhi-NCT area and provides sufficient time for after-harvest operations.

Field view of Pusa 1824

Pusa JRH Hybrid 56 (IET 27333): It is a high-yielding, short-duration, long slender grain aromatic rice hybrid with seed-to-seed maturity of 125 days, with an average yield of 61.51 q/ha. It is the first two-line hybrid developed by a public sector institution in India and has been released for the state of Madhya Pradesh.

Field view of Pusa JRH Hybrid 56

Pusa RH 60 (IET 28965): It is a high-yielding, short-duration, long slender grain aromatic rice hybrid with seed-to-seed maturity of 120 days, with an average yield of 56.02 q/ha. The hybrid is identified for release in the states of Bihar and Uttar Pradesh of Zone III.

Pusa Narendra KN 1, Pusa CRD KN 2, Pusa 2090 and Pusa 1824: SVRC released the first two as improved Kalanamak varieties for UP and the latter two for the Delhi NCR region.

1.1.3.2 Varieties identified

Pusa 1823: Pusa 1823 is a MAS-derived NIL entry from the cross of Pusa 44*3/IR81896-B-B-142 introgressed with *qDTY2.1* and *qDTY3.1* for governing tolerance to reproductive stage drought stress. It has shown a significant yield advantage under drought stress conditions over the Pusa 44. It has been identified for release in the states of Kerala, Karnataka and Tamil Nadu.

Pusa 3039: Pusa 3039 is a MAS-derived near-isogenic line of a popular rice variety, Pusa 44. It possesses bacterial blight and blast genes, *xa13* and *Pi2*, respectively. It has been identified for release in the states of Kerala, Karnataka and Tamil Nadu.

Pusa 3057: Pusa 3057 is a MAS-derived near-isogenic line of a popular Basmati rice variety, Pusa Basmati 1509, possessing bakane resistance QTLs viz., *qBK1.1* and *qBK1.2*. It has been identified for release in the states of Delhi, Punjab and Western Uttar Pradesh.

Pusa RH 60: Pusa RH 60 is a short-duration, long slender grain, two-line rice hybrid with a seed-to-seed maturity of 120 days, with an average yield of 59.24 q/ha. It has a semi-dwarf erect growth habit and is suitable for crop intensification due to its early maturity. It has been identified for release in the states of Uttar Pradesh and Bihar.

1.1.3.3 Mapping *TGMS* gene

Targeted analysis of *Thermosensitive Genic Male Sterility* (*TGMS*) gene using the SSR and gene-based markers in Chro: 2 revealed that a BAC clone-derived marker co-segregated with the trait. The sequencing of the amplified product showed that the *TGMS* gene in Pusa lines is a Class 1 HDC (Histidine decarboxylase).

1.1.4 Maize

1.1.4.1 Hybrids released

Pusa Biofortified Maize Hybrid-4: It is a provitamin-A rich (Quality Protein Maize) hybrid. It is an independently derived hybrid developed through marker-assisted selection of *crtRB1*, *lcyE* and *opaque2* genes. It provides 70.5 q/ha of grain yield with a potential of 112.1 q/ha. It contains 6.70 ppm of provitamin-A, 3.47% lysine and 0.78% tryptophan. It has been released for the North-Western Plains Zone (NWPZ), the Peninsular Zone (PZ) and the Central Western Zone (CWZ).

Ear view of Pusa Biofortified Maize Hybrid-4

Pusa Biofortified Maize Hybrid-5: It is a first triple biofortified hybrid possessing high α-tocopherol (21.60 ppm) provitamin A (6.22 ppm), high lysine (4.93%) and tryptophan (1.01%) (in endosperm protein) content. It has been developed through marker-assisted selection of *vte4, crtRB1, lcyE and opaque2* genes. It has an average yield of 70.3 q/ha with a potential yield of 110.5 q/ha. It is Suitable for NWPZ, North Eastern Plains Zone (NEPZ), PZ and CWZ zones.

Ear view of Pusa Biofortified Maize Hybrid-5

Pusa Popcorn Hybrid-1: It is a popcorn hybrid developed from germplasm adapted to Indian conditions. It has a high popping percentage (97.8%) with butterfly-type popped flakes. It has an average yield of 46.0 q/ha, with a potential yield of 97.8 q/ha. It is suitable for cultivation in NWPZ and PZ zones.

Popped seeds of Pusa Popcorn Hybrid-1

Pusa Popcorn Hybrid-2: This popcorn hybrid was also developed from germplasm adapted to Indian conditions. It has a high popping percentage (96.7%) with butterfly-type popped flakes. It has an average yield of 45.1 q/ha, with a potential yield of 96.7 q/ha and is suitable for the PZ zone.

Popped seeds of Pusa Popcorn Hybrid-2

Pusa HM4 Male Sterile Baby Corn-2: This male sterile-based baby corn hybrid was developed through

Tassels of Pusa HM4 Male Sterile Baby Corn-2

the transfer of CMS-C cytoplasm. It has an average dehusked cob yield of 19.5 q/ha and a potential yield of 32.6 q/ha and is suitable for NEPZ, PZ, and CWZ zones.

Pusa Forage Maize Hybrid-1: It has a high fodder volume with high green fodder yield (413.1 q/ha) and dry matter yield (90.3 q/ha), excellent fodder quality with crude protein content (9.2%), Acid Detergent Fiber (ADF) (41.9%), Neutral Detergent Fiber (NDF) (62.5%) and *In-Vitro* Dry Matter Digestibility (IVDMD) (56.4%). It is identified for release at NWZ zone.

Phenotype of Pusa Forage Maize Hybrid-1

Pusa Jawahar Hybrid Maize-3: It is a single-cross medium-maturity field corn hybrid released for the *rabi* season of Madhya Pradesh. It has an average grain yield of 9.0 t/ha. The tall hybrid stays green with erect leaves and semi-dent, orange-yellow seeds. It is resistant to Fusarium stalk rot and moderately resistant to Turcicum Leaf Blight (TLB), Maydis Leaf Blight (MLB), stem borer and fall armyworm.

Ear and grain characteristics of Pusa Jawahar Hybrid Maize-3

Pusa Shalimar Maize Hybrid-1: It is an early-maturing field corn hybrid released for the *kharif* season of Jammu and Kashmir. It has medium height, dark green leaves and produces bold orange grains. Its average grain yield is 8.2 t/ha. It is moderately resistant to common rust, TLB and stem borer.

Ear characteristics of Pusa Shalimar Maize Hybrid-1

1.1.4.2 Hybrids and varieties identified

APQH-4: It possesses high provitamin A (6.04 µg/g), high lysine (3.99%) and tryptophan (0.90%) (in endosperm protein) content. It has an average grain yield of 77.8 q/ha with a potential yield of 110.6 q/ha. It is suitable for NWPZ and CWZ.

APTQH-1: It possesses high α-tocopherol (21.38 µg/g) provitamin A (6.03 µg/g), high lysine (3.94%) and tryptophan (0.87%) (in endosperm protein). It has an average yield of 64.8 q/ha with a potential yield of 111.0 q/ha. It is suitable for NWPZ, NEPZ and CWZ.

ALPQH-1: It possesses 2.17 mg/g of phytate compared to 4-7 mg/g of phytate in traditional maize. It also possesses high lysine (3.75%) and tryptophan (0.80%) content compared to low lysine (1.5-2.0%) and tryptophan (0.30-0.40%) found in traditional maize. It produces an average yield of 49.7 q/ha, with a potential yield of 77.2 q/ha and is suitable for NEPZ.

AQWH-4: It possesses high amylopectin (93.9% in starch) over 70-75% amylopectin found in traditional maize. The average grain yield is 72.7 q/ha, with a potential of 87.6 q/ha. It is suitable for NWPZ.

APSKH-1: It possesses an enhanced level of provitamin-A (6.89 ppm) compared to 1-2 ppm observed in traditional sweet corn. It also possesses high lysine (0.291%) and tryptophan (0.071%) content compared to low lysine (1.5-2.0%) and tryptophan (0.30-0.40%) found in traditional sweet corn. APSKH-1 contains high brix (16%). The average dehusked cob yield is 97.0 q/ha, with a potential of 147.2 q/ha. It is suitable for NWPZ, NEPZ, PZ and CWZ.

ABHS-27: It is a male sterile-based baby corn hybrid developed through the transfer of CMS-T cytoplasm. It has an average dehusked cob yield of 14.1 q/ha, with a potential yield of 20.6 q/ha and is suitable for the CWZ zone.

AH-8323: It is an early-maturing maize hybrid for CWZ, with an average yield of 8.18 t/ha. It is resistant to TLB and Charcoal Rot.

Pusa Jawahar Hybrid Maize-1: It is identified for release as a forage maize hybrid for the Central Zone (CZ) and Hill Zone (HZ). It produces 361.9 q/ha of green fodder in the central zone and 352.2 q/ha in the hill zone.

ADC-3: It is an early-maturing composite/OPV for Northern Hills Zone (NHZ). It has an average yield of 8.81 t/ha and is moderately resistant to TLB.

1.1.4.3 Breeding for doubled haploids

A temperate haploid inducer donor was crossed with a set of subtropical inbreds and F_2 populations were genotyped for *mtl* and *dmp* genes responsible for *in vivo* haploid production. Severe segregation-distortion (SD) was observed for both *mtl* and *dmp* genes. The average haploid induction rate (HIR) among *mtlmtl*-based inducers was ~3%, while the same for *dmpdmp*- and *mtlmtl/dmpdmp*-based HI lines was <1% and ~8%, respectively.

1.1.4.4 Development of hybrids for higher bioethanol production

The traditional maize possesses 62-64% extractable starch in grains, thereby providing 370-380 litres of ethanol per one tonne of grains. Waxy maize governed by the *recessive waxy1* gene possesses high extractable starch (~70%) and can potentially produce >450 liters of ethanol. The mutant *waxy1* gene has been introgressed into five elite genetic background such that waxy kernels possessed ~96-99% amylopectin compared to ~25-35% in elite inbreds. These newly developed waxy inbreds will be used to develop hybrids with higher bioethanol recovery.

1.1.4.5 Breeding for specialty corn

Development of biofortified sweet corn with enhanced provitamin-A and vitamin-E: Two *sh2*-based sweet corn hybrids, viz. PSSC-2 and ASKH-2 were targeted for introgression of *crtRB1* and *vte4* genes through marker-assisted breeding. Reconstituted hybrids showed high provitamin-A (19.52 ppm) with a maximum of 7.8-fold increase over original hybrids (3.33 ppm). High α-tocopherol (20.75 ppm) and α/γ-tocopherol ratio (0.55) with an average enhancement of 2.3- and 1.7-fold, respectively, was recorded among reconstituted hybrids over original versions (α-tocopherol: 9.21 ppm, α/γ-tocopherol ratio: 0.31).

1.1.4.6 Breeding for plant architecture

Lowering the leaf angle for high-density planting: Traditional maize hybrids possess moderate to wide leaf angles (40-60^o). Two popular maize hybrids, 'Pusa Vivek QPM9 Improved' (PMI-PV1 × PMI-PV2) and 'Pusa Vivek Hybrid-27 Improved' (PMI-PV3 × PMI-PV4), were targeted for introgression of the recessive *leguleless1* (*lg1*) gene through marker-assisted selection. The reconstituted *lg1*-based hybrids had a narrow leaf angle of ~8-12^o against 45-50^o in the original hybrids which assumes immense significance in enhancing productivity through high-density planting.

1.1.4.7 Breeding for field corn

Identification of stable high kernel row number (KRN) genotypes: Breeding for high KRN is one of the prime objectives of genetic enhancement of grain yield in field corn. A total of five stable genotypes with 18-24 kernel rows and high general combining ability (GCA) for grain yield have been identified.

Identification of novel phenotypic variation among the HEPE mutant population: A field corn inbred line AI-544 was irradiated with a high-energy pulsed electron (HEPE) beam. The M_3:M_4 plants were characterized for various morpho-phenological traits. A novel plant phenotype, M544-13 for large leaf lamina (15 cm) was identified along with other mutants viz., M544-32 for high kernel row number (18), M544-21 for high kernel per row (48) and M544-20 for high test weight (43 g).

Phenotype of M 544-13 (L) and AI 544 (R)

1.1.4.8 Identification of inbreds tolerant to fall army worm (FAW)

The inbreds, D-36, C-46, C-79, DDM-2309, D-46 and D-102 were tolerant to FAW. Also screening of biofortified inbreds led to identification of MGU-FAW-122, MGU-FAW-231 and MGU-FAW-243 as tolerant to FAW infestation.

Leaf damage due to FAW infestation in Susceptible & Resistant inbreds

1.2 MILLETS

1.2.1 Pearlmillet

1.2.1.1 Release of hybrid

Pusa 1801: Pusa 1801 (MH 2417), a dual-purpose and biofortified pearl millet hybrid with high grain and dry stover yields was released and notified for NCT of Delhi. The average grain yield of Pusa 1801 is 3334 kg/ha and the average dry fodder yield is 175 q/ha. It matures in 83 days. The grain yield potential of Pusa 1801 is 48-50 q/ha. It stays green and contains grain iron of 70 ppm and zinc of 57 ppm content, respectively.

Pusa 1801 is highly resistant to downy mildew, blast, rust, ergot and smut.

Field view of Pusa 1801

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Variety released

Pusa Chickpea Vijay 10217: BGM 10217 (Pusa Chickpea Vijay) has been developed through hybridization (JG 11 × ICC 4958) following the pedigree method of selection and is released for the state of Uttar Pradesh for irrigated conditions. It is medium tall with a semi-erect growth habit and is highly resistant to *Fusarium* wilt. It gives an overall mean of 1853 kg/ha with a potential of 2400 kg/ha and a 7.93% higher yield than the checks. It matures in approximately 128 days and has brown colored, medium-sized seeds, with an average seed size of 18.5g per 100 seeds.

Grain view of Pusa Chickpea Vijay 10217

Pusa 3057: It is a high-yielding variety with an average grain yield of 2.01 t/ha, giving 36% more grain yield over GNG-1969 and 16% more yield than HK4. It is rich in seed protein content (24.3%). It is resistant to *Fusarium* wilt and collar rot and moderately resistant to dry root rot, *Ascochyta* blight and *Botrytis* gray mold. It is moderately resistant to pod borer. It is large-seeded and has an excellent grain colour and shape. Its 100-seed weight is 30-35 g.

Grain view of Pusa 3057

1.3.1.2 Screening and identification of heat-tolerant landraces

A set of 200 chickpea germplasm lines comprising landraces and released cultivars was screened at two locations for heat tolerance. HSI indicated that the genotypes ILC5911 and ILC8666 are common for high heat tolerance across the location. The per cent yield reduction was lower for genotypes IG5849, IG5905 (8.52 & 10.45%) under Amlaha, ILC8666, IG5900 (5.82 & 8.61%) under Dharwad and the genotype IG5851(b) and IG5857 (0.3 & 0.3) under Delhi. MGIDI showed lower values with high ranks for IG5889, ILC3887 and IG5859 (8.79, 9.28 and 9.31).

1.3.1.3 Breeding for rust resistance

Pre-breeding lines were screened against rust disease under artificial epiphytotic conditions for two years. ILCW0 was resistant to rust disease, while seven pre-breeding lines (6262, 7238, 7298, 7302, 7303, 7304, 7306) were moderately resistant.

1.3.2 Pigeonpea

1.3.2.1 Hybrid released

Pusa Arhar Hybrid-5 (PAH 5): It was notified for Delhi and NCT. The average yield of Pusa Arhar

Hybrid-5 over six years at ICAR-IARI, New Delhi was 23.35 q/ha, with a yield potential of 25.46 q/ha. It is moderately resistant to Sterility Mosaic Disease (SMD) at CZ and South Zone (SZ). It was also resistant against *Phytophthora* stem blight disease at NWPZ and NEPZ. PAH 5 had a low incidence of *Macrophomina* blight and *Alternaria* leaf spot disease at NEHZ compared to ICP 7119 (Check). The mean pollen fertility percentage was 86.7% over four years in IHT, AHT-1 and AHT-2.

Semi-erect plant of Pusa Arhar Hybrid-5

1.3.2.2 Development of new hybrids

Eight hybrids were generated using 2 newly developed R lines and 4 A-lines viz., Pusa-992A, Pusa-2001A and Pusa-2002A under isolation.

1.3.3 Lentil

1.3.3.1 Genetics of the pod coat color in lentils

A cross between lentil parents with different pod coat colors [L4717(B) NM × DPL-62)] was studied to understand pod coat color genetics. F1 showed a creamy white pod coat, indicating it as the dominant trait. In F_2, a monogenic recessive inheritance pattern was observed, with violet pod color controlled by a single recessive gene.

1.4 OILSEED CROPS

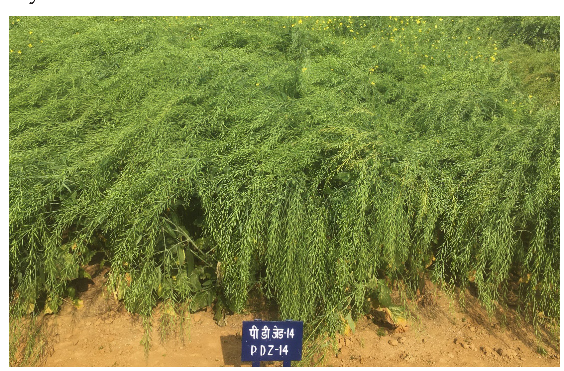
1.4.1 Mustard

1.4.1.1 Varieties released

Pusa Double Zero Mustard 35: It is a yellow-seeded double zero Indian mustard variety, low in erucic acid and total glucosinolates content, suitable for cultivation under timely sown irrigated conditions in zone-III (M.P., U.P., UK and Raj.). The average seed yield of this variety is 2148 kg/ha and it matures in approximately 132 days.

Field view of Pusa Double Zero Mustard 35

Pusa Double Zero Mustard 36: It is a yellow seeded double zero Indian mustard variety, low in erucic acid and total glucosinolates content, suitable for cultivation under timely Sown Irrigated Conditions in zone-III (M.P., U.P., UK and Raj). The average seed yield of this variety is 2148 kg/ha and it matures in approximately 132 days.



Field view of Pusa Double Zero Mustard 36

1.4.1.2 Development of herbicide-tolerant *B. juncea*

Eighty-five progenies of EMS-mutated PM 30 were raised in M_3 generation, selected against herbicide (imazethapyr @ 2 ml/l) and selfed to obtain M_4 seeds. Further, to recover the PM 30 genetic background, 13 backcrosses were attempted and to transfer the resistance in elite genetic backgrounds, a total of 48 crosses were attempted. To combine different genes imparting herbicide tolerance in PM 30 and NPJ 253 genetic background, 28 double ($F_1 \times F_1$) crosses were attempted. A point mutation in the *ALS1* gene was identified and a KASP marker was developed.

1.4.2 Soybean

1.4.2.1 Development of herbicide-tolerant soybean

Seven Indian soybean varieties viz., JS9560, JS335, JS20234, JS2069, JS2098, JS2029 and DS9712 are being made herbicide tolerant by incorporating a gene *EPSPS* from an American soybean variety S14-9017GT. The populations of JS9560 and JS2034 in BC_2F_2 generation were sprayed with herbicide (glyphosate) and the surviving plants were characterized for genotypic and phenotypic features.

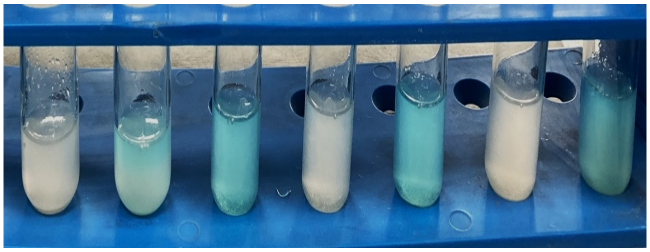
Screening of JS2034 segregating plants for herbicide tolerance

1.4.2.2 Breeding for rust resistance and tolerance to pink pod borer

During *kharif* 2024, a total of 150 soybean genotypes, including germplasm accessions, released varieties and rust differential lines were screened for reaction to rust under natural epiphytotic conditions at IARI, RRC Farm, Dharwad. The susceptible check JS 335 had >90% disease severity index. Line EC1187661 had the lowest disease severity (3.7%), followed by EC1187660 (11.11%), EC1187636 (18.52%) and EC1187659 (18.52%). The lines EC1187659, EC1187660 and EC1187661 exhibited the lowest sporulation level (0.17 × 104 uredospores/ml), followed by the line EC1187662 (0.33 × 10^4), while the susceptible check JS-335 exhibited very high sporulation (16.67 × 10^4). With respect to the number of uredinia per lesion, the line EC1187662 (0.63) recorded the lowest number of uredinia per lesion, followed by EC1187660 (1.43), EC1187661 (1.67) and EC1187636 (2.23) as against 11.57 uredinia per lesion in the case of susceptible check JS 335. Therefore, five lines (EC1187636, EC1187659, EC1187660, EC1187661, EC 1187662) were identified as resistant to soybean rust. These lines need to be further studied to confirm the resistant reaction and tested at multiple locations for utilization in the soybean breeding program.

1.4.2.3 Off-flavour-free vegetable soybean development

To mitigate off-flavors in vegetable soybean, the null allele of the lipoxygenase, *Lox2* gene (*lox2*) was introduced from a donor genotype (PI596540) into the Swarna Vasundhara variety through marker-assisted backcross breeding. Plants possessing the target allele in the genetic background of Swarna Vasundhara are currently in the BC_2F_2 generation. About eleven plants whose lipoxygenase activity was comparable to that of the donor genotype (PI596540) were identified and evaluated for phenotypic performance in the field.



Colorimetric estimation of lipoxygenase activity

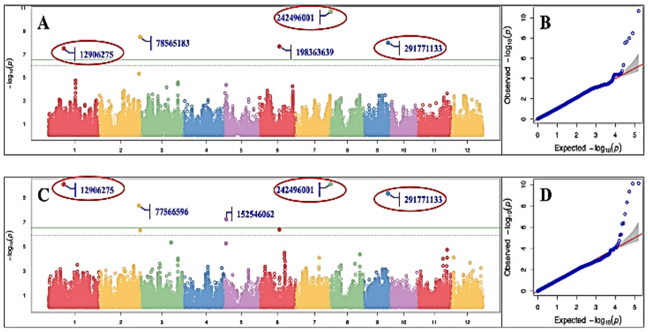
1.5 SEED SCIENCE AND TECHNOLOGY

1.5.1 Studies on Seed Quality Traits

1.5.1.1 Seed germination and vigour

The time to 50 per cent radicle emergence (TFRE), a vigour trait, was used to categorize 257 rice accessions of 3KRGP into three groups: early (<45 h), intermediate (45-50 h), and late (>50 h). The Genome-

Wide Association Studies (GWAS) revealed three MTAs (*qTFRE1*.1, *qTFRE8*.1 and *qTFRE9*.1), out of five identified each year as stable and consistent across two years of study. The *qTFRE8.1* had the highest PVE (16.7%) in *kharif* 2021 and 17.3% in *kharif* 2022.



Manhattan plot of BLINK model for TFRE. A: Kharif 2021 harvest, B: Q-Q plot of Kharif 2021 harvest, C: Kharif 2022 harvest, D: Q-Q plot of Kharif 2022 harvest

1.5.1.2 Seed dormancy

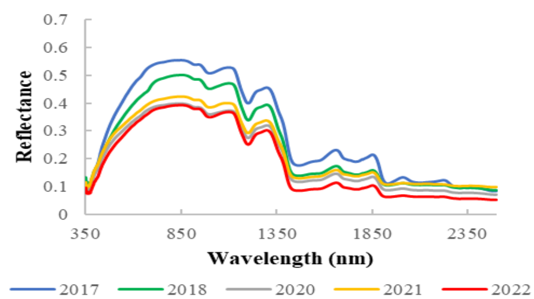
Rice: The relationship between crop duration, seed dormancy and seed longevity was studied in 295 rice genotypes comprising 83 varieties and 212 germplasm lines from the 3KRG panel. Genotype maturation duration showed a positive relationship with dormancy intensity and depth. A substantial positive relationship was recorded between the intensity of dormancy and the longevity of seeds. Thus, the early-maturing rice varieties showed less dormancy and poor longevity than late-maturing genotypes.

Cucumber: Genotypic variation in seed dormancy was observed among the various sex expression phenotypes of cucumber. The dormancy duration is minimal in exotic monoecious types (<1 month), while it is moderate in parthenocarpic and gynoecious types (1-3 months) and maximum in indigenous monoecious types (3-4 months). The seeds produced in *Kharif* had a higher intensity of dormancy than those produced in the spring-summer season. The studies inferred that seed coat thickness, phenolic compounds, gibberellic acid content, and the ABA to GA ratio regulate cucumber seed dormancy.

1.5.1.3 Seed storability/ longevity

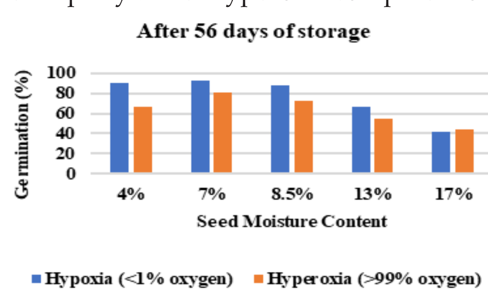
Rice: Seed longevity was assessed in 39 rice seed lots produced during 2017, 2018, 2020, 2021 and 2022 and stored under ambient conditions for different durations. The seed half-viability period (P_{50}) showed significant variation ranging from 624 days in the 'Shahbhagi' to 7321 days in the 'Jaya' genotypes. The NIR spectroscopy differentiated the seed quality among selected rice genotypes from varying storage groups, with a strong Pearson's correlation coefficient at 1200-1400 nm spectral wavelength. The fatty acid profiles in differentially aged seeds identified a strong correlation between margaric acid (C17:0) and storage duration and seed viability parameters.

The hyperspectral reflectance of dehusked grains of 39 rice seed lots showed higher values in aged seeds compared to fresh seeds. Germination prediction is achieved through Partial Least Squares Regression (PLSR), a multivariate method that identifies key spectral bands exhibiting high sensitivity. Hyperspectral imaging would be helpful in accurately and rapidly determining seed longevity status in a given seed lot.



Spectral signatures from seeds harvested in different years subjected to natural aging in a good storing rice genotype cv. Kranti

Soybean: The oxidative damage during storage was studied in 8 different soybean seed lots with varying moisture content at hypoxia (1% oxygen) and hyperoxia (99% oxygen) conditions. The total seed germination declined rapidly under hyperoxia compared to hypoxia



conditions in all the soybean seed lots. The deleterious effect of oxygen was prominent on dry soybean seeds. No significant difference in seed germination was noticed between two oxygen conditions when seeds had high moisture content.

Onion: The seed storage potential of 30 freshly harvested onion genotypes was assessed under natural (for 12 months) and accelerated ageing conditions (42°C and 75% RH). Germination ranged from 56-96% in unaged seeds, declined to 27-77, 38-93 and 18-83% after natural ageing and accelerated ageing for three and six days, respectively. Moreover, a marked decrease in vigour indices and a corresponding increase in mean germination time were observed across both ageing conditions. The biochemical changes under natural ageing conditions revealed an increase in the NADPH oxidase activity, ROS and malondialdehyde content and a decline in antioxidant enzyme activity after 6 and 12 months of ambient storage.

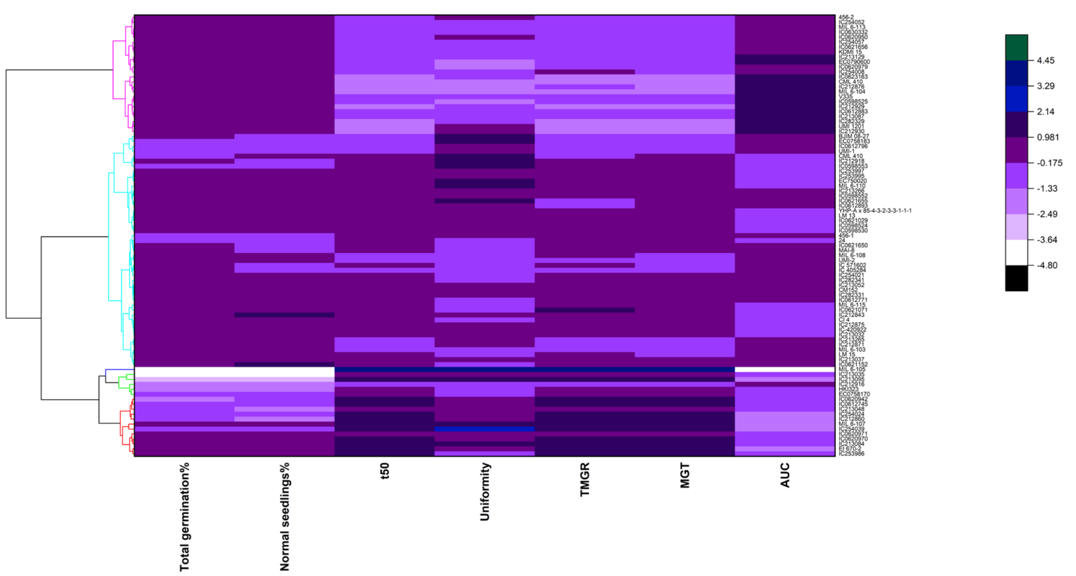
Maize: The seed storage potential of 89 maize inbreds was evaluated at ambient lab bench conditions after 12 months. Germination and vigour parameters identified two good storers (IC0623163 and IC212929) and two poor storers (MIL 6-105, IC213035). The good storers maintained significantly higher SOD and CAT activity (4.78 U and 4.04 U, respectively) after 12 months of ageing, compared to poor storers (1 U and 0.93 U, respectively). Further, poor storers recorded significantly higher hydrogen peroxide and malondialdehyde content and low amylase activity than good storers.

1.5.1.4 Genetic purity

The hyperspectral reflectance values of rice seeds were used to differentiate 16 Basmati and non-Basmati rice varieties. Sixteen effective wavelengths showing significant differences in reflectance were selected based on the Savitzky-Golay 2nd derivative at a 10 nm gap. Among the five Machine Learning models used, the LDA model achieved the highest prediction accuracy of 82 and 78%, with high kappa values of 0.81 and 0.76 for classifying all 16 rice varieties.

1.5.2 Seed Quality Enhancement

Wheat: The effect of seed coating with microbial formulations on on-field performance and seed quality attributes was studied in two timely sown (HD 2967 and HD 3086) and two late sown (HD 2851 and WR 544) wheat varieties. A total of six seed treatments viz. Vitavax and Thiram (3 g/kg seed) + 100% RDN; Vitavax and Thiram (3 g/kg seed) + 75% RDN; Cyanobacterial Consortium (BF1 – 4) + 75% RDN; Bacterial consortium (PW 1+5+7) + 75% RDN; Biofilm (An-Tr) + 75% RDN; Biofilm (An - PW5) + 75% RDN were imposed to test their efficacy. The Biofilm (An-Tr) and Cyanobacterial



consortium treatments significantly enhanced the field emergence, plant stand, dehydrogenase and nitrogenase activity in the soil, leaf nitrate reductase and glutamine synthetase activity, available soil nitrogen along with yield and yield attributes.

Specialty maize: Pusa HQPM-5 Improved and Pusa Vivek QPM-9 Improved seeds were coated with microbial consortiums BF (1-4) and *Anabaena laxa*. Seed coating with microbial formulations resulted in higher and faster germination, better seedling vigour and uniformity. The coated seeds also exhibited significantly higher field emergence, chlorophyll content, plant height and early flowering than the control.

1.5.3 Seed Production Technology

Indian Mustard: Stigma receptivity studies were conducted in three new CMS sources of *Brassica juncea.* A two-year field experiment using manual pollination up to 7 days after anthesis revealed that the peak stigma receptivity was attained in 2 to 3 days after anthesis. Among three CMS sources, *Diplotaxis berthautii* showed higher stigma receptivity than *Moricandia arvensis* and *Diplotaxis erucoides* and among the nuclear genotypes, Pusa Tarak was the most promising. The identified nucleo-cytoplasmic combinations can be used in the *B. juncea* hybrid breeding program.

Parthenocarpic cucumber: The hybrid seed production technology was standardized in the Pusa Parthenocarpic Cucumber Hybrid 1 using differential planting dates during the *kharif* and spring-summer seasons. Sowing Pusa parthenocarpic cucumber hybrid 1 during the first fortnight of February with a 4:1 ratio of female to male plants (20% male plants) and retaining 3-4 fruits/ vine was found significantly effective in enhancing the seed yield and quality.

Gynoecious Parthenocarpic cucumber: The seed production technology of Pusa Gynoecious Parthenocarpic Cucumber Hybrid-1 was standardized under protected conditions. The male parent was planted 10 days earlier for flowering synchronization with the female parent. Based on stigma receptivity and pollen viability studies, pollination up to 10 AM resulted in higher fruit and seed yield. Similarly, a fruit load of 3 fruits/vine was optimum for higher seed yield and quality. The hybrid seed quality was better in the spring-summer season than in the *kharif* season.

1.5.4 Abiotic Stresses and their Mitigation

1.5.4.1 Heat stress

Rice: The physio-chemical response of heat-tolerant (N22) and susceptible (IR64) genotypes was studied at imbibed seed, radicle, and early seedling stages. The short-and long-term acquired thermotolerances (SAT and LAT, respectively) significantly enhanced the germination and seedling length under severe heat stress in both susceptible and tolerant genotypes. The SAT and LAT enhanced the antioxidant activity and reduced MDA and H_2O_2 content in both genotypes. A significant difference in physio-chemical response was observed between genotypes, with the tolerant genotype performing substantially better.

Comparative analysis of imbibition methods revealed that 56 hours of imbibition in a -1 MPa PEG solution significantly improved seedling vigour relative to direct soaking, blotter methods (utilizing 10, 8, and 5 mL of water), or a -1.5 MPa PEG solution. The seed priming with 1 mM spermidine using the identified -1MPa PEG imbibition effectively countered the severe heat stress in rice seeds during germination.

1.5.4.2 Salinity stress

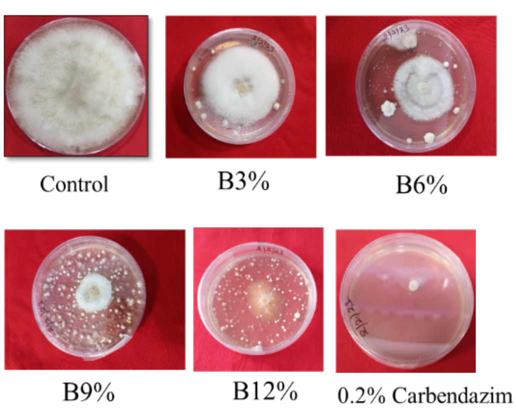
Wheat: Eleven wheat varieties, along with four genotypes each of *T. aestivum*, *T. sphaerococcum*, *T.*

durum and *T. dicoccum*, were evaluated for the second consecutive year as a pot trial at two salinity levels (4 and 6 dS/m). Significant reduction in seedling emergence, spike length, number of seeds per spike, and 1000-seed weight was observed. The seeds exhibited decreased germination and vigour indices (I and II) when produced under saline conditions. Seed priming with Ascorbic acid (100 ppm) improved salinity alleviation in *T. aestivum* and *T. sphaerococcum* wheat genotypes. Priming with 1.5 and 3% KNO_3 resulted in better responses for *durum* and *dicoccum* genotypes, respectively.

Soybean: A total of 73 genotypes with four different seed coat colours, viz., black (25), brown (6), green (5), and yellow (37) were evaluated at 0, 3, 6 and 9 dS/m salinity stress levels. Germination decreased from 0 -9 dS/m, with minimal reduction in the black group (76.33 to 30.18%) and maximum decline in the yellow group (68.0 to 9.5%). The black genotypes have higher antioxidant enzyme (CAT, POX, APX, and SOD) activity and proline content, which resulted in decreased H_2O_2 and lipid peroxidation compared to other groups. Under hydroponic conditions, jasmonic acid (20μM) primed seeds had higher leaf area index, leaf perimeter, root architecture, higher K^+ and reduced Na^+ content in the seedlings compared to the control.

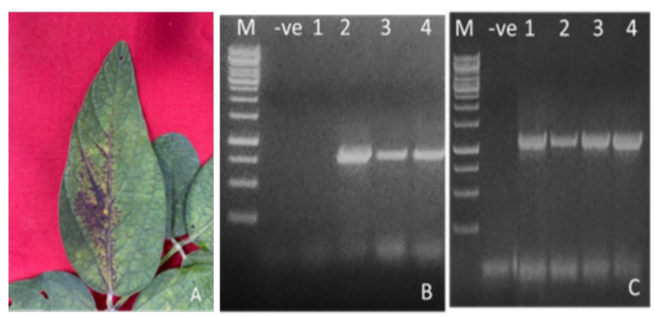
1.5.5 Seed Health

Chickpea: The study assessed the effectiveness of organic compounds, *Beejamrit*, *Jeevamrit*, and *Kunapjal*, as seed treatments to manage seed-borne fungi and enhance seed quality in ten chickpea varieties. In vitro tests revealed that Carbendazim 50% WP is most effective and inhibited mycelial growth by over 90%. However, 9 and 12% concentrations of organic compounds outperformed the control. Among the organic treatments, 12% *Beejamrit* exhibited better results, with 93% germination, 26.6 cm seedling length, and 0.39 g seedling dry weight, outperforming the control.



Inhibition of *Fusarium* by Beejamrit

Soybean: The etiology of soybean vein necrosis disease was studied from 52 infected plants through Direct Antigen Coated ELISA by using Cowpea mild mottle virus (CPMMV), groundnut bud necrosis virus (GBNV), soybean mosaic virus (SMV), tobacco streak virus (TSV) and tobacco ringspot virus (TRSV). Results indicated the association of CPMMV and GBNV with the veinal necrosis of soybean. These samples were further confirmed with RT-PCR using gene-specific primers and by sequencing the amplified products. The sequences showed 90-95% similarity with other CPMMV and GBNV isolates.



(A) Necrosis symptoms on soybean leaf samples (B) Confirmation of CPMMV with 850 bp amplification (C) Confirmation of GBNV with ~1000bp amplification (M-GeneRuler 1kb DNA ladder; -ve= Negative control; 1-4: Number of plants tested).

2. HORTICULTURAL SCIENCES

The horticulture sector in India has a significant impact on the national economy. Besides ensuring the country's nutritional security, it offers alternative employment opportunities in rural areas, diversifies farming activities and boosts farmers' income. The School of Horticultural Sciences focuses on enhancing genetic resources, genetic improvement, cost-effective production technologies, efficient input management, post-harvest procedures and the value addition of horticultural crops. Various improved varieties and hybrids in different horticultural crops have been developed. Additionally, 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

Notification and release of varieties/F_1 hybrids

Varieties/hybrids notified and released by CVRC: Pusa Tomato Hybrid-6, resistant to Tomato Leaf Curl Disease (ToLCD) was released for cultivation in Odisha, Chhattisgarh, Telangana and Andhra Pradesh. Also, tomato cv. Pusa Shakti (DT-9), having an indeterminate growth habit, high yield (35.2 t/ha) and suitability for long-distance transportation was notified for cultivation in Chhattisgarh, Odisha, Andhra Pradesh and Telangana vide notification S.O. 4917(E) dated November 13, 2024.

Varieties released and notified by the Delhi State Seed Sub-Committee: Pusa Parthenocarpic Cucumber Hybrid-1 (DPaCH-7), Pusa Protected Bitter Gourd-2 (DBGS-32-1) and Pusa Purple Cauliflower-1 were notified for release and cultivation under protected conditions in NCT Delhi. Two varieties, one each in okra cv. Pusa Lal Bhindi-1 (DOV-68) and purple-podded Indian bean cv. Pusa Sem-6 (DB-15) were released. Besides, Pusa Cauliflower Hybrid-102 (DCH-9867), broccoli cv. Pusa Purple Broccoli-1 and brinjal cv. Pusa Chhota Baingan-1 (DBOR-94) were released for cultivation in NCT Delhi.

Hybrid identified for release by AICRP-VC: Sponge gourd hybrid DSGH-132 was released during the 42^{nd} Annual Group Meeting of AICRP (Vegetable crops) for Zone VIII (Tamil Nadu, Kerala, Karnataka and Puducherry).

2.1.1 Solanaceous Crops

2.1.1.1 Tomato

Promising line for processing: Line 414-2-2-3-2-5 (SPS1) F_9, resistant to Tomato Leaf Curl Disease

Pusa Shakti (DT-9)

Pusa Sem-6 (DB-15)

Pusa Protected Bitter Gourd-2 (DBGS-32-1)

Pusa Chhota Baingan-1 (DBOR-94)

(ToLCD) was found suitable for processing purpose. It has pear-shaped fruits with less than 40 seeds per fruit. It has 85% uniform ripening, a high fruit-shape index (2.5), 18.8% pulp and 5.1 °Brix TSS.

2.1.1.2 Brinjal

Promising hybrids and line: Two F_1 hybrids (DBHR-23 and DBHL-401) and one variety (DBPiL 186-3-13-3) were found promising in brinjal. DBPiL 186-3-13-3 had long (16–19 cm), shiny pink fruits with a non-spiny green calyx, weighing 80–100 g, which yields 32.0 t/ha (23.07% higher than Pusa Purple Long, 26.0 t/ha) and is ready for harvest in 50–55 days during the *kharif* season. DBHR-23 hybrid had round, glossy purple fruits with partially pigmented peduncles and calyx, weighing 180–230 g, yielding 58 t/ha (38.09% higher than Pusa Hybrid-6, 42 t/ha) with harvest in 45–50 days. Hybrid DBHL-401 had shiny black-purple fruits, weighing 110–125 g with a non-spiny green calyx and yielding 56 t/ha (16.7% higher than Pusa Unnat, 48 t/ha) in the long fruit segment.

2.1.1.3 Capsicum

Evaluation of coloured capsicum germplasm for protected conditions: At ICAR-IARI Regional Station, Katrain, capsicum genotypes, KTGC-35 (Green) (37.72 t/ha), followed by KTRC-9 (Red) (34.96 t/ha), KTOC-3 (Orange) (34.31 t/ha) and KTYC-2 (Yellow) (32.46 t/ha) were found promising over the check cultivars viz. Pusa Capsicum-1 (Green) (29.87 t/ha) and California Wonder (Green) (27.64 t/ha).


KTGC-35


KTRC-9


KTOC-3


KTYC-2

Promising genotypes of coloured capsicum

Hybrid evaluation: At ICAR-IARI Regional Station, Katrain, 36 hybrids of capsicum, including one standard check cultivar (Asha) were evaluated for yield and contributing traits. KTYC-5 × KTRC-13 (33.40 t/ha), KTYC-12 × KTGC-24 (30.20 t/ha) and KTOC-1 × KTGC-24 (29.30 t/ha) performed better over the check cultivar Asha (27.40 t/ha).

2.1.2 Cole Crops

2.1.2.1 Cauliflower

New promising hybrids: The CMS-based F_1 hybrids DCEH-111, DCEH-126 and DCEH-181 were found most promising for October maturity (>20 t/ha) and DCEH-250, DCEH-51 and DCEH-45 for November maturity (>25 t/ha). In the mid-early group, out of 35 CMS-based F_1 hybrids, the promising hybrids (>30 t/ha) were DCMEH-54, DCMEH-961, DCMEH-67, DCMEH-57 and DCMEH-902. Out of 44 CMS-based hybrids tested in the mid-late group, the promising F_1 hybrids (>35 t/ha) were DCMLH-69, DCMLH-64, DCMLH-70 and DCMLH-84161. In orange cauliflower, the promising hybrids identified were DoCEH-1204 (SI-based), DoCEH-15419 and DoCEH-529819 in the November maturity group (>14 t/ha) and DoCMH-8419, DoCMH-46, DoCMH-1808 and DoCMH-8404 (>25 t/ha) in the December maturity group. In CMS-based hybrids of purple tropical cauliflower, DpCMH 6783 and DpCMH-6736 were promising in the November-December maturity group.

2.1.2.2 Snowball cauliflower

Evaluation of CMS and inbred parental lines-based hybrids: Sixty-eight F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI Regional Station, Katrain, during the winter season of 2023-24. Twelve hybrids performed better than the check cultivars 'Pusa Snowball Hybrid-1 (PSBH-1)', 'Pusa Hybrid-301' and 'Casper RZ' with a heterosis range of 10.53-33.76, 12.18-35.75 and 3.12-24.79%, respectively, and were found suitable for harvesting during 3rd week of February to 1st week of April.


KTCF-69A × KTCF-38B


KTCF-63A × KTCF-33B


KTCF-63A × KTCF-38B


KTCF-60A × KTCF-75B

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

Evaluation of CMS and DH parental lines-based hybrids: Thirty-two CMS and DH parental lines based F_1 hybrids were evaluated at Baragran Farm of ICAR-IARI, Regional Station, Katrain during winter 2023-24. Nine hybrids performed better than the check cultivar 'Pusa Snowball Hybrid-2 (PSBH-2)' with a heterosis range of 0.74-28.33% and were found suitable for harvesting during the 1st-3rd week of March.


KTCF-77A × KTCF DH-4B


KTCF-80A × KTCF DH-4B


KTCF-83A × KTCF DH-4B


KTCF-68A2 × KTCF DH-5B

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

Evaluation of promising snowball cauliflower hybrids in multi-location yield trials: Nine promising F_1 hybrids were evaluated along with three check cultivars at three different locations, *viz*. Katrain, New Delhi and Solan during winter 2023-24. The tested hybrids revealed a heterosis range of 7.33-34.92, 9.90-38.16 and -2.65-22.38% over the three check cultivars PSBH-1, PH-301 and Giewont, respectively. Six hybrids were superior over all the check cultivars and were suitable for harvest during the 4th week of January to the 1st week of April.


2022/KTCFH-6038


2023/KTCFH-4047


2023/KTCFH-774

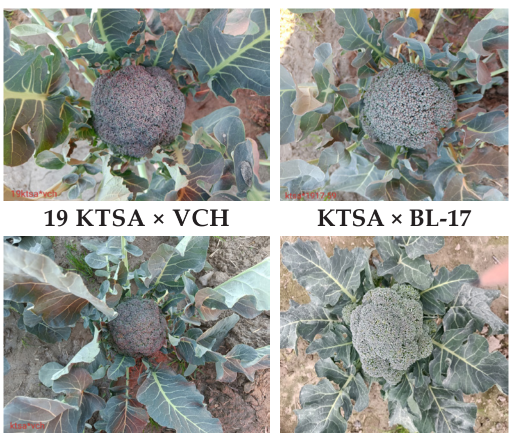
Promising snowball cauliflower hybrids in multi-location yield trials

2.1.2.3 Broccoli

Promising tropical genotypes: A new tropicalized genotype, DC-Brocco-13 (16.0 t/ha), outperformed the check variety Palam Samridhi (13.5 t/ha). Eighteen genotypes were evaluated for head formation in November. Five genotypes formed desirable heads (>350 g, medium fine buds) and attained flowering in December. New tropical broccoli lines DC-Brocco-26, DC-Brocco-36, DC-Brocco-51 and DC-Brocco-37 were promising for yield (>14.0 t/ha) and harvest in November.

Evaluation of CMS-based hybrids: At ICAR-IARI, New Delhi, 7 new F_1 hybrids were tested using two newly developed tropical CMS lines (DC-Brocco-PS-64A and DC-Brocco-15A) of sprouting broccoli. DBrH-17 (18.5 t/ha) and DBrH-20 (16.6 t/ha) were found promising for proper head size and November – December maturity.

At ICAR-IARI Regional Station, Katrain, 58 broccoli hybrids were evaluated for yield and horticultural traits against Corina F_1 and Lucky F_1 as checks. Hybrid 19 KTSA × VCH (23.38 t/ha), followed by KTSA × BL-17 L-146 (21.02 t/ha) and KTSA × VCH (20.93 t/ha), gave significantly higher yields, with an increase of 40.21, 26.03 and 25.52%, respectively, over the best check hybrid Lucky (16.68 t/ha).

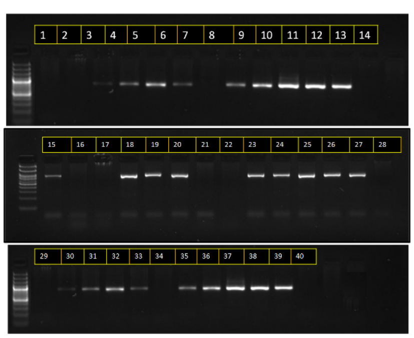


19 KTSA × VCH | KTSA × BL-17

KTSA × VCH | Lucky

Promising CMS-based F_1 hybrids of broccoli

Conversion of doubled haploids of broccoli into CMS lines: At ICAR-IARI Regional Station, Katrain, 38 doubled haploid (DH) lines of broccoli along with two checks *viz*. Pusa Broccoli KTS-1 (self-compatible) and 83-1 (self-incompatible) were tested for their self-incompatibility/compatibility reaction. Out of these, 11 lines exhibiting self-compatibility traits were identified using molecular markers resulting in identification of five horticulturally superior lines.



Self-incompatible and self-compatible doubled haploid lines of broccoli
Presence of bands indicates the existence of S alleles associated with self-incompatibility while absence indicates self-compatibility (SSR marker: SLGa)

2.1.2.4 Cabbage

Evaluation of CMS-based F_1 hybrids: At ICAR-IARI Regional Station, Katrain, among 70 F_1 hybrids of white cabbage, the promising combinations for yield over the standard check Pusa Hybrid-82 (41.46 t/ha) were Sel-5-KIRC-10A × EC-686718 (56.71 t/ha), Sel-5-KIRC-10A × EC-686771 (56.55 t/ha) and Sel-5-KIRC-10A × 51-19 (55.89 t/ha), showing an increase of 36.8, 36.4 and 34.8%, respectively.

Sel-5-KIRC-10A × EC-686718 | Sel-5-KIRC-10A × EC-686771

Sel-5-KIRC-10A × DH 51-19 | Pusa Hybrid-82 (C)

Promising CMS-based F_1 hybrids of white cabbage

In red cabbage, the hybrids RCGA × PoARC (40.39 t/ha), Primero A × PoARC (38.16 t/ha), RCA × (RCGA × RC-1) (37.71 t/ha) and RJA × PoARC (33.89 t/ha) recorded significantly higher marketable yields over the check, Pusa Red Cabbage Hybrid-1 (27.73 t/ha) with an increase of 45.64, 37.62, 36.01 and 22.22%, respectively.

RCGA × PoARC

PMA × PoARC

RCA × RCG-1

Pusa Red Cabbage Hybrid-1

Promising CMS-based F_1 hybrids of red cabbage

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

2.1.3 Cucurbitaceous Crops

2.1.3.1 Cucumber

Promising genotypes for open field and protected cultivation: During the spring-summer season of 2024, out of 89 F_1 hybrids evaluated, gynoecious hybrids DCH-143 and DCH-148 yielded 24.5 t/ha and 28.3 t/ha, respectively, as compared to the National check Pant Sankar Khira-1 (18.1 t/ha). Eighty-seven F_1 hybrids were developed using 11 gynoecious cucumber lines. Pusa Parthenocarpic Cucumber Hybrid-2 (DPaCH-11) was found promising for cultivation under protected conditions.

Entries in AICRP-VC trials: The F_1 hybrids, DCH-143 and DCH-148 were advanced to AVT-I and IMPUCH-143 and IMPUCH-148 to AVT-II.

2.1.3.2 Muskmelon

Promising hybrids and varieties for open field and protected conditions: Hybrids *viz.* Pusa Muskmelon Hybrid-2 (DMH-5), DMH-27 (24.8 t/ha) and DMH-33 (24.2 t/ha) were identified as promising for yield and fruit quality traits for open field cultivation. Specialty melon (*C. melo* var. *inodorous*) hybrids DMH-112 (5.9 t/1000 m^2), DMH-119 (5.7 t/1000 m^2), DMH-139 (5.6 t/1000 m^2), DHM-162 (5.4 t/1000 m^2), DHM-226 (5.3 t/1000 m^2) and DHM-159 (5.2 t/1000 m^2) were found promising for protected cultivation. The lines DMM-3142-8 and DMM-3142-12 were high-yielding with excellent fruit quality.

Entries in AICRP-VC trials: Muskmelon hybrids DMH-18, DMH-23 and varieties DMM-154 and DMM-159 were advanced to AVT II and DMM-207 and DMM-228 to AVT I. New varieties DMM-211 (23.4 t/ha) and DMM-31 (23.1 t/ha) were entered in IET varietal trials.

2.1.3.3 Bitter gourd

Promising hybrids: For yield traits, the best-performing hybrids were DBGH-121 (30.5 t/ha), DBGH-2143 (28.35 t/ha) and DBGH-2116 (27.32 t/ha).

Promising genotypes of *Momordica charantia* var. *muricata*: Genotypes DBGS-100-0 (1.07 kg/plant), DBG-100 (0.976 kg/plant) and CBM-12 (0.934 kg/plant) were the best-performing for yield.

Promising selection and hybrids for protected cultivation: Genotype DBGS-57 and hybrids PVGy201 × DBGS-21-06 and DBGS-21-06 × S-16-2 were found superior for earliness and yield under polyhouse and net house conditions.

Entries in AICRP-VC trials: Two hybrids DBGH-4812 and DBGH-482 were advanced to AVT-II and three hybrids DBGH-431, DBGH-21100 and DBGH-2123 were promoted to AVT-I.

2.1.3.4 Sponge gourd

Promising hybrids: Two hybrids, DSGH-211 (16.2 t/ha) and DSGH-212 (15.9 t/ha) and three hybrids, DSGH-213 (16.2 t/ha), DSGH-214 (16 t/ha) and DSGH-215 (16 t/ha) were found promising during spring-summer and *Kharif* season, respectively.

Screening for downy mildew disease resistance: Among 68 genotypes evaluated, three genotypes VRSL-1-1, VRSL-6 and VRSL-10 showed resistant reactions to downy mildew in *Kharif* 2024.

2.1.3.5 Ridge gourd

Promising selections: Among 41 accessions evaluated, the lines DRG-109 and DRG-103 showed superior performance with an average yield of more than 17.0 t/ha.

Screening for leaf curl disease resistance: Genotypes VRRGL-1-13-3 and VRRGL-1-14-3 were found resistant to the Tomato Leaf Curl New Delhi virus (ToLCNDV) in field conditions in *Kharif* 2024.

2.1.3.6 Pumpkin

Evaluation of hybrids for yield and quality: Among 47 F_1 hybrids evaluated along with check Pusa Hybrid-1, the promising hybrids based on fruit yield, shape and flesh colour were DPUH-36-15 (average fruit weight 2.15 kg, flesh thickness 2.94 cm), DPUH-15-36 (average fruit weight 2.44 kg, flesh thickness 2.98 cm), DPUH-36-101 (average fruit weight 1.84 kg, flesh thickness 2.85 cm), DPUH-15-S4 (average fruit weight-3.29 kg, flesh thickness-3.79 cm) and DPUH-36-51 (average fruit weight 1.92 kg, flesh thickness 3.06 cm).

Screening for Squash Leaf Curl China Virus (SLCCNV) resistance: Upon challenge inoculation by whitefly, out of fifty genotypes/advanced breeding lines, DPU-41, DPU-43 and DPU-133 were found to be highly resistant to SLCCNV.

2.1.4 Malvaceae Crop

2.1.4.1 Okra

Evaluation for yield and virus resistance: DOV-7, DOV-9, DOV-10, DOV-69 and DOV-92 were found most promising for yield & resistance to Bhindi Yellow Vein Mosaic Virus (BYVMV) and Enation Leaf Curl Virus (ELCV) diseases. DOV-7 recorded the earliest flowering in 38 days. DOV-9 and DOV-69 recorded fruiting at a shorter internodal length (3.5 cm) with a fruit length of 15 cm at harvest maturity. Sixty-five hybrids, along with 21 private-sector leading hybrids were evaluated for yield and resistance to BYVMV and ELCV. The most promising hybrids were DOH-6 (28.3 t/ha) and DOH-7 (27 t/ha), which showed high resistance to both BYVMV and ELCV. The fruit yield and quality of these hybrids were at par with the leading private hybrids, Radhika (26.6 t/ha) and Navya (26 t/ha).

Promising red-fruited okra selection: Pusa Lal Bhindi-1 (15 t/ha) recorded a 10% higher yield than the check, Kashi Lalima (13.6 t/ha), with maximum anthocyanin (130 μg/g) content.

2.1.5 Root Crop

2.1.5.1 Carrot

Evaluation of hybrids for yield and quality: Sixty-four CMS-based F_1 hybrids of tropical carrot were evaluated for quantitative and quality traits, of which the hybrids DCatH-88, DCatH-113, DCatH-69-O, DCatH-855 and DCatH-039 were found promising on the basis of yield, quality, root shape, surface, external & internal colour, self-core and external appearance.

Promising CMS-based F_1 hybrid DCatH-88

Evaluation of CMS-based hybrids of temperate carrot: At ICAR-IARI Regional Station, Katrain, out of 50 hybrids evaluated, KT-95 A × KS-30 (34.50 t/ha), KT-95 A × KS-60 (32.60 t/ha), KT-96 A × KS-30 (29.64 t/ha), KT-96 A × KS-17-1 (28.40 t/ha) and KT-10A × KS-60

(27.70 t/ha) were found superior than the check Pusa Nayanjyoti (25.71 t/ha).


KT-95 A × KS-30


KT-95A × KS-60


KT-96A × KS-30


KT-96A × KS-17-1


KT-10A × KS-60

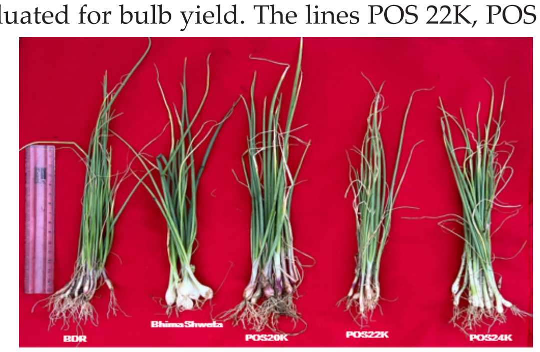
Promising CMS-based hybrids of temperate carrot

Entries in AICRP-VC trials: Two tropical carrot hybrids, DCatH-73 & DCatH-13 and four temperate carrot lines, KTTC-17, KTTC-21, KTTC-22 and KTTC-73 were advanced to AVT-II.

2.1.6 Bulb Crops

2.1.6.1 Onion

Breeding superior varieties/hybrids for *kharif* season: During *kharif* season, eight elite lines, including Bhima Shweta were evaluated for yield using onion sets. Two lines, POS 27K and POS 25K yielded significantly higher than Bhima Shweta. In another trial, using seedlings as initial material, ten entries including one hybrid were evaluated for bulb yield. The lines POS 22K, POS 20K, POS 24K and hybrid KOH-01 yielded significantly higher than Bhima Dark Red, Bhima Super and Bhima Raj. Selections PKO-22009 (26.8 t/ha), Sel. 427 (25.3 t/ha) and KP-62 (24.9 t/ha) were also found promising.



Evaluation for heat tolerance in onion genotypes

Screening for Alternaria leaf blight: KP-328 and KP-402 genotypes of onion exhibited disease-resistant reactions (PDI <10%) against *Alternaria alternata* under natural epiphytotic conditions.

Evaluation of long-day red onion germplasm: In long-day red onion, the genotypes KTON-6 (44.21 t/ha), KTON-2 (36.52 t/ha), KTON-30 (34.25 t/ha) and KTON-14 (34.10 t/ha) were found superior to the check cultivar Brown Spanish (31.42 t/ha).


KTON-6


KTON-2

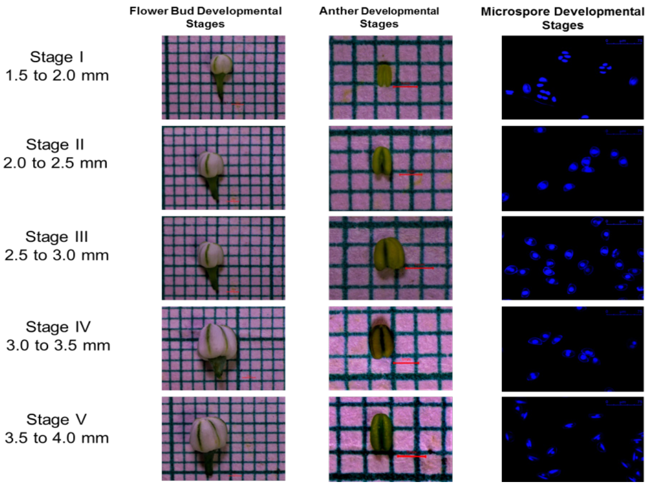

KTON-30


KTON-14

Promising genotypes of long-day red onion

Entries in AINRPOG trials: Open-pollinated long-day onion genotypes KTON-21 and KTON-27 were entered in IET, whereas KTON-51 and KTON-66 were advanced to AVT-II.

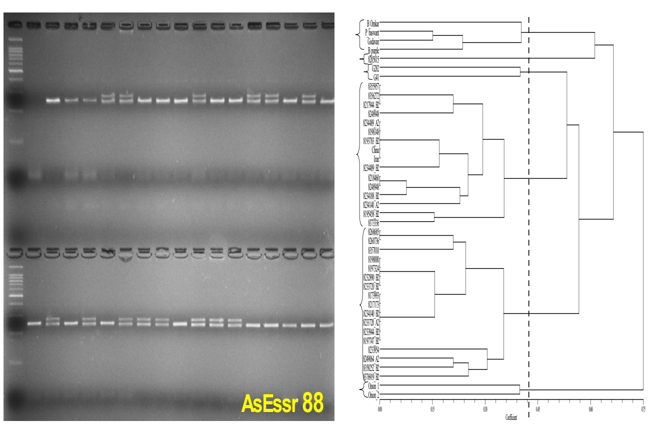
Anther culture for DH development: The relationship between flower bud, anther morphology and developmental stages of the male gametophyte in onion were analyzed for anther culture. A combination of flower bud length, diameter and the green colour intensity of anthers is proposed as easily applicable, rapid and accurate criteria for identifying microspore developmental stages.



Changes during microspore/pollen, bud, and anther development. Stage I (1.5-2.0 mm): Meiocytes and tetrads; Stage II (2.0-2.5 mm): Young microspores; Stage III (2.5-3.0 mm): Late uninucleate microspores; Stage IV (3.0-3.5 mm): Young bicellular pollen; Stage V (3.5-4.0 mm): Mid-pollen and mature pollen

2.1.6.2 Garlic

Genetic diversity assessment: Based on 19 SSR markers, 42 accessions were clustered in four groups. The accessions from India formed a separate cluster, whereas accessions from China and Iran belonged to a single group.



Genotyping of garlic accessions using SSR marker AsESSR88 and clustering-based on SSR marker characterization

Evaluation of germplasm against *Stemphylium* blight: Garlic accessions (135) were screened under artificially inoculated conditions. Gross yield ranged from 2.2-24.6 t/ha in the non-inoculated trials and 1.4-17.2 t/ha in the inoculated trials. Thirty-four accessions were moderately resistant and PGS-100, PGS-115 & PGS-051 recorded PDI <12 after 30 DAI.

2.1.7 Leguminous Crops

2.1.7.1 Garden pea

Entries in AICRP-VC trials: The line GP-2178 was entered in the heat stress trial and the early maturing line GP-2179 (11.0 t/ha) was entered in IET.

2.1.7.2 Other legumes

Promising lines identified: Three cowpea lines, CP-34, CP-61 and CP-66 were found promising for pod yield.

2.2 FRUIT CROPS

2.2.1 Genetic Improvement of Fruit Crops for Desirable Horticultural Traits

2.2.1.1 Mango

Molecular characterization of Heirloom varieties: Thirty-six heirloom mango varieties using 61 hypervariable mango simple sequence repeats (HMSSRs) were studied. Of these, 43 markers were identified as polymorphic (51%) and 18 as monomorphic (21%). The analysis revealed 97 distinct alleles with an average fragment length of approximately 400 base pairs. Each primer pair yielded an average of 2.25 alleles, ranging from 2 to 5 alleles per pair. PIC values for SSR markers ranged from 0.0570 to 0.5641, with HMSSR_593 achieving the highest and HMSSR_1219 the lowest value. Seven HMSSR loci (HMSSR_550, HMSSR_586, HMSSR_1606, HMSSR_1871, HMSSR_593, HMSSR_1478 and HMSSR_2014) had PIC values of 0.480 or greater. The major allele frequency ranged from 0.444 at HMSSR_593 to 0.969 at HMSSR_1219 and HMSSR_411.

Evaluation of maternal half-sib population of Amrapali mango: Twenty-one half-sib open-pollinated Amrapali mangoes flowered, showing considerable variation in flowering and fruiting traits. Variation was observed in inflorescence width (9.25-21.21 cm), inflorescence length (10.25-29.65 cm), number of panicles (7.0-37.0), male flowers (321-2425), hermaphrodite flowers (75.60-896.0), incidence of malformation (0.0-65.0%), fruit retention at harvest

(0.25-1.5%), fruit length (5.85-8.85 cm), fruit diameter (3.96-6.98 cm), fruit weight (87.66-215.12 g), stone length (3.76-7.12 cm), stone width (2.19-4.05 cm), stone weight (15.45-51.03 g), peel thickness (1.13-2.01 mm), pulp weight (31.12-176.45 g), peel weight (13.85-41.345 g) and pulp content (4.23-71.15%). Among these half-sibs, genotypes HS-24/1, HS-31/1 and HS-37/3 exhibited improved traits compared to Amrapali.

2.2.1.2 Citrus

New varieties of Kinnow mandarin and sweet orange proposed for release: Two varieties of Kinnow mandarin, *viz*., Pusa Gold Kinnow, Pusa Early Kinnow and two of Mosambi, *viz*., Pusa Kartiki Mosambi and Pusa Low-Seeded Mosambi were proposed for release from IVRC.

Varieties for release by IVRC - Pusa Gold Kinnow, Pusa Early Kinnow, Pusa Low-Seeded Mosambi and Pusa Kartiki Mosambi

Evaluation of interspecific acid citrus hybrids: Thirty-eight acid citrus genotypes (including hybrids and parents) were evaluated and the fruits of ACSH-7-13 and ACSH-5-5 showed thinner peel (0.95-1.33 mm) with high juice (37.44-47.89%), TSS (7.5-8.6 °Brix) and acid (5.14-5.58%) content and moderate resistance to citrus canker (10.30-18.33 PDI).

Evaluation of interspecific hybrids of sweet citrus: Among progenies of Pummelo × Mosambi, the hybrid SCSH 11-15 was most promising for fruit yield (49.63 kg/tree), peel thickness (5.26 mm), juice content (51.65%), TSS (8.50 °Brix), acidity (0.65%) and ascorbic acid content (49.55 mg/100 ml juice). No infestation of Psylla (greening vector) was observed in these hybrids.

Exploitation of natural mutants of Redblush grapefruit: Of the three vegetatively propagated mutants of Redblush (RB-1, RB-2 and RB-3), RLB-3 showed stability with lesser peel thickness (4.13 mm), seed number (2.00/fruit), higher juice (53.33%), TSS (9.40 °Brix) and ascorbic acid (62.48 mg/100 ml juice) content with more intense colour than standard Redblush.

ACSH 7-13

ACSH 5-5

SCSH 11-15

RLB-1 grapefruit mutant

Physico-chemical characterization of newly developed interspecific citrus hybrids: Fresh juice of 24 new orangelo citrus hybrids (*Citrus maxima* [Burm. f.] Osbeck × *Citrus sinensis* [L.] Osbeck) and parental genotypes was used for estimation of antioxidants and other biochemical constituents. The orangelo hybrids SCSH 17-9 (ascorbic acid 58.13 mg/100 ml) SCSH 13-13 (total phenol content 107.33 mg GAE/100g), SCSH 11-15 (total flavonoid content 59.33 mg QE/100g), SCSH 3-15 (total antioxidants 5.49 DPPH-µmol Trolox/g) were found to have superior antioxidant properties. The overall acceptability was found for SCSH 3-10 and Mosambi.

***In vitro* mutagenesis in *Kinnow* mandarin for solid mutant induction using Indirect Somatic Embryogenesis system:** Indirect somatic embryogenesis using gamma and EMS was attempted in *Kinnow* mandarin. Based on cell clumps survival, LD_{50} was calculated at 54.31 Gy in gamma and 0.1-0.5% for 1-3 hours in the EMS treatments. The embryogenesis efficiency was reduced to 85.92% and 43.67% in gamma and EMS treatments, respectively. The growth-related parameters (root length, shoot length and number of leaves/regenerant) were also significantly reduced in gamma and EMS mutants.

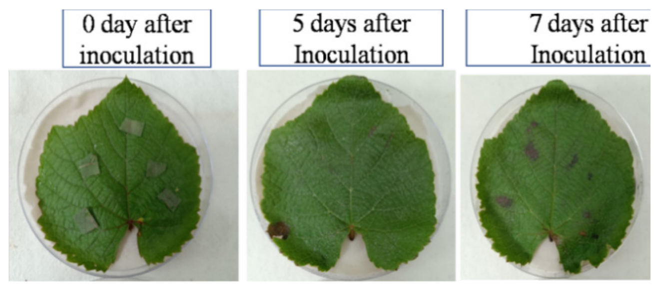
Collection and characterization of Darjeeling mandarin genotypes/clones: Among the 31 Darjeeling mandarin accessions; DL-6, DL-7, DL-8 and DL-10 recorded the smallest fruit weight but the highest total soluble solids of 15 °Brix. The accessions, PR-12, PR-13 and PR-14 recorded highest fruit weight of above 100 g and the highest yield/plant (400-450 fruits/tree).

Morphological and molecular characterization of Darjeeling mandarin: Based on the principal component and cluster analysis data of 18 fruit traits, the 31 accessions of Darjeeling mandarin were classified into six distinct clusters, emphasizing the genetic distinctiveness of accessions. Molecular characterization of the accessions using 30 SSR primers revealed the number of alleles ranging from 2.13 to 4.00. Markers CCSM 112, TAA 41 and TAA 52 recorded the highest polymorphism information content (> 0.5).

2.2.1.3 Grape

Evaluation of teinturier hybrids: Three teinturier grape hybrids, R4P7, R4P9 and R4P13 were evaluated along with Pusa Navrang for different bunch and berry-related traits. The R4P9 was found promising in terms of loose bunch with bunch length (22.69 cm), bunch breadth (11.00 cm), bunch weight (180.21 g) and had bold berries (19.38 g/10 berries) with average juice recovery of 70% and TSS 17.9 °Brix.

Evaluation of powdery mildew resistance: A total of 42 grape (*Vitis* spp.) genotypes were evaluated for their powdery mildew reactions through field and *in vitro* screening. *V. parviflora*, *V. jacquemontii*, *V. rupestris* x *V. berlandieri* (110 Richter), *V. rupestris* (St. George) and male hybrids were found to be resistant/tolerant to powdery mildew. The ultra-structural studies revealed the presence of sunken stomata in the resistant/tolerant genotypes. The indigenous Himalayan *Vitis parviflora* showed resistance to powdery mildew and its leaves had a thicker waxy epicuticular layer on the abaxial surface, thereby reducing the infection. The SSR markers VMC1A5 and VMC3d12 were the most useful for identifying powdery mildew disease-resistant genotypes.



Challenge inoculation of grape leaves

2.2.1.4 Guava

Promising hybrids

GH-2018-2E: It is a guava hybrid with yellowish white-flesh and a small seed core. It has excellent nutritional and fruit quality traits over the commercial variety Allahabad Safeda. The fruit size is large (283-323 g) with high total soluble solids (12.3 to 13.1 °Brix), ascorbic acid (177.96-186.48 mg/100 g), titratable acidity (0.51-0.64%) and total phenolic content (183.2-199.5 mg GAE/100g FW). The average fruit yield was observed to be 44 to 48 t/ha.

GH-2018-2E

GH-2018-7H: It is a large-fruited, low-seeded and pink-fleshed guava hybrid having excellent nutritional and fruit quality traits over the commercial variety Lalit. It has a large fruit size (240-277 g) and a small seed core. It has high total soluble solids (10.2 to 11.4 °Brix), ascorbic acid content (235.9-251.4 mg/100 g FW), total phenol content (203.7-215.0 mg GAE/100 g FW) and antioxidant activity (21.8-22.16 µmol TE/g). The average fruit yield is 36 to 39 t/ha.

GH-2018-7H

Evaluation of germplasm: Fifty-three germplasm samples were evaluated for fruit-related parameters such as fruit length, breadth, weight, pulp color, size, shelf life and biochemical properties. At different storage days, the Thai guava variant and GH-2018-4C genotype recorded high fruit firmness.

Induction of parthenocarpy: GA_3 spray (25 and 50 ppm) at the calyx splitting stage and after fertilization could not induce parthenocarpy in guava (Allahabad Safeda).

2.2.1.5 Papaya

Evaluation of hybrids: Ten hybrids, including the commercial variety Sapna were evaluated for physical and biochemical parameters. The minimum plant height (69.5 cm) at the first flower was observed in PN × P-9-5, the highest (167.25 cm) fruiting zone in P-7-9 × PS-3 and the lowest (127.33 cm) in PN × P-9-12. The shortest time to fruit maturity (129 days) was recorded in P-9-5 × P-7-9, while Sapna took the longest (141.25 days). The maximum fruits per plant (41.67) was observed in P-7-9 × PS-3. Hybrid PN × P-9-5 had the heaviest average fruit weight (1325 g), while Sapna had the highest TSS (13.9 ºBrix) and antioxidant activity (34.45 µmol/g). P-7-9 × PS-3 and P-9-12 × P-9-5 were found promising.

P-7-9 × PS-3

P-9-12 × P-9-5

Mutation breeding: The seeds of the papaya P-7-2 were treated with gamma rays 0.1, 0.15, 0.2, 0.25 and 0.3 kGy. Two dwarf stature mutants, *viz*., PM-04 and PM-28 were selected. The maximum number of fruits (41.2) and width of fruit (12.12 cm) was recorded in PM-04, while the maximum fruiting length (98.64 cm), fruit weight (0.960 kg) and single fruit length (21.54 cm) were recorded in the P-7-2 (control). The minimum length of fruit cavity (14.12 cm), maximum pulp thickness (3.22 cm) and TSS (10.44 °Brix) were recorded in PM-04, while minimum TSS (8.22 °Brix) was noted in the control.

2.2.1.6 Pomegranate

Survey, exploration collection and propagation of germplasm: Pomegranate genotypes (113) were collected from Uttarakhand, Himachal Pradesh and Jammu. The hardwood cutting survival for these genotypes ranged from 6.67-86.67%. A field gene bank housing 187 wild, cultivated and exotic genotypes has been established.

Characterization of germplasm: The physico-chemical properties of fruits of wild pomegranate genotypes were evaluated, and one genotype from Jhutia (Talla Ramgarh, Bhowali, Nainital) and one from Nathuakhan (Bhowali, Nainital), Uttarakhand, were found to be promising as anardana types with fruit size above 200 g and titratable acidity above 3.0%.

2.2.2 Production Technologies of Fruit Crops

2.2.2.1 Mango

Effect of integrated nutrient management on newly developed mango hybrids: A significant effect of INM treatments, mango cultivars and their interaction was found for the parameters like plant height and canopy volume. The maximum height (6.24 m) was recorded in treatment NPK 75% RDF + AMF (250 g) + *Azotobacter* (250 g). Among the cultivars, the maximum height (5.28 m) was observed in Pusa Arunima and the minimum (4.82 m) in Pusa Pratibha. The maximum number of fruits (48.74) was recorded in treatment NPK 75% + AMF (250 g) + *Azotobacter* (250 g). Among the varieties, the maximum number of fruit (54.28) and fruit weight (230.12 g) were recorded in Pusa Arunima.

2.2.2.2 Citrus

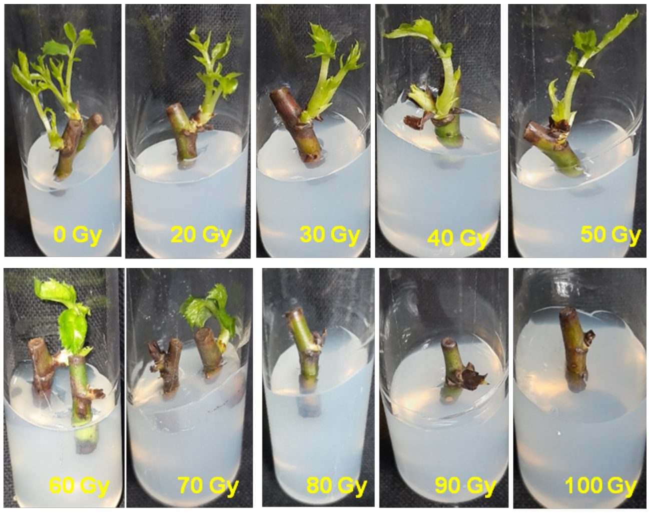
Metabolite profiling and anatomical alteration in citrus scion cultivars under NaCl stress: The metabolic responses of sweet orange cultivars Pusa Sharad grafted on eleven different rootstocks was studied at different levels of salinity stress, *viz*. control (0), 30 and 60 mM. Trehalose, pentanoic acid, raffinose, sucrose, D-galactose and myo-inositol were the pivotal metabolites contributing to salt tolerance.

Development of technologies for enhancing productivity: A study was carried out to evaluate the influence of three commercial rootstocks *i.e.*, Rangpur lime, Rough lemon and Trifoliate orange on the growth characteristics and grafting success in Darjeeling mandarin. Rough lemon recorded the highest grafting success (91.25%), followed by Rangpur lime (87.50%). Rough lemon demonstrated the highest rootstock length (22.26 cm), scion length (11.72 cm) and leaf area (39.59 cm²).

2.3 ORNAMENTAL CROPS

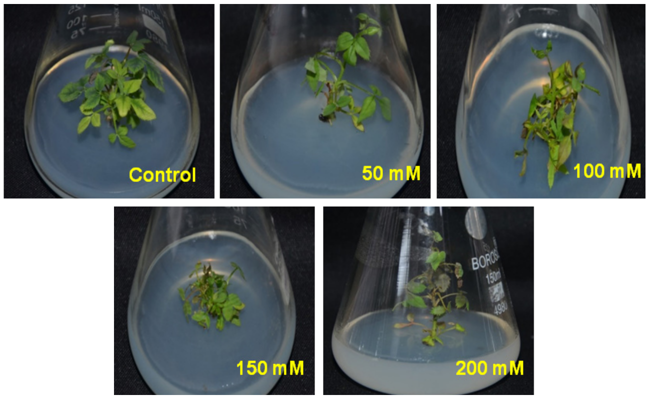
2.3.1 Rose

***In-vitro* mutagenesis to induce variability in rose varieties for the purpose of loose flowers:** Axillary buds as explants of rose cv. 'Pusa Virangana' were treated with different doses of gamma rays (20-100 Gy) and inoculated on MS media under *in vitro* conditions to induce variability for loose flower purposes. Increased doses of gamma rays lead to a decrease in bud sprouting and survival percentage. Gamma rays induced two mutants namely; PVM-3 and PVM-4 were isolated from the *in-vitro* mutated population.



Effect of gamma rays on culture establishment of rose axillary bud explants cv. 'Pusa Virangana'

Evaluation of rose genotypes for salt stress tolerance under *in-vitro* conditions: Five rose genotypes, namely 'Rose Sherbet', '*Rosa chinensis* strain (FLS-RC-1)', 'Pusa Alpana', 'Pink Parfait seedling' and 'Pusa Lakshmi' were evaluated for salt stress tolerance under *in vitro* conditions. '*Rosa chinensis* strain (FLS-RC-1)' performed better up to 200 mM NaCl concentration.



Influence of NaCl on proliferated shoots of *Rosa chinensis* (FLS-RC-1) under *in-vitro* conditions

2.3.2 Marigold

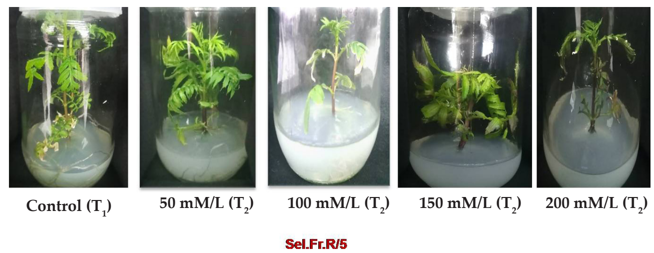
Promising Selection Fr./R-2: Plants of selection Fr./R-2 of French marigold are tall and have vigorous growth with compact flowers that are medium and dark red in colour. It mainly flowers from November to mid-December and is suitable for loose flower production and bedding purposes.

Screening marigold genotypes for drought stress: The variation for drought stress tolerance in 19 African and 21 French marigold genotypes was studied under pot culture. Among African marigold genotypes, Punjab Gainda No. 1, BRMG-113 and Arka Shubha were found tolerant to drought, whereas genotypes KAU-M1, KAU-M2 and Af/SR-15-1 White were susceptible. Among French marigold genotypes, Fr./R-2, Pusa Utsav and Gulzafari Yellow exhibited tolerance and Orange Winner, Fr/R-7 and Fr/R-10 were found to be susceptible to drought stress.

Promising Selection of French marigold - Fr./R-2

Screening for drought tolerance in marigold

Screening of marigold germplasm for salt stress under *in vitro* conditions: *In vitro* salt stress screening of five French marigold genotypes (Gulzafri Orange, Dainty Marietta, Pusa Arpita, Pusa Deep and Sel. Fr.R/5) was undertaken. Nodal segments were established in Murashige and Skoog (MS) media enriched with growth regulators such as BAP (0.5 mg/l) and NAA (0.05 mg/l). After shoot proliferation, the elongated microshoots were transferred to basal MS medium supplemented with different concentrations of NaCl (50, 100, 150 and 200 mM NaCl/L). Among all the genotypes, Sel. Fr.R/5 followed by Dainty Marietta performed better up to 200 mM NaCl compared to Pusa Deep and Gulzafri Orange.



Performance of marigold selection Sel. Fr.R/5 in different NaCl levels under *in vitro* conditions

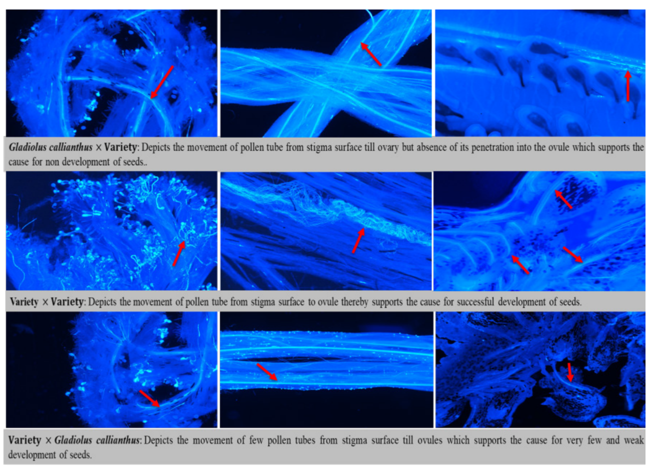
2.3.3 Gladiolus

Pusa Red Delight: It is a mid-season hybrid (Smokey Lady × Oscar) whose florets start opening from 97–103 days after planting. It produces more than 19 florets per spike. The spikes are upright and long, ranging from 104–106 cm and the rachis length is medium long 52–55 cm. Each plant produces on an average 3.11 corms and 39-42 cormels. The florets are in the red-purple group (62 B) with two spots on two inner tepals in the red group (vivid reddish orange 44 C) as per the RHS colour chart.

Mutant (IC-641855, INGR-24048) | **Vidushi (Parent variety)** | **Pusa Red Delight**

Gladiolus mutant registered at ICAR-NBPGR for unique traits (IC-641855, INGR-24048): The new mutant is entirely different from its parent variety, Vidushi, as outer tepals are in yellow-orange group 16 D and two-three spots on inner tepals are in red group 46 C. Spikes are straight and long with close arrangement of florets on spike. It has an average spike length of 118.58 cm, a rachis length of more than 67.99 cm and approximately 19.0 florets per spike. It is a high multiplier and produces 2.66 corms and 73.16 cormels from each mother corm.

Pollen-pistil interaction studies: Pollen-pistil interaction studies in the inter-varietal and inter-specific crosses in gladiolus revealed the penetration of pollen tubes into the ovules in the inter-varietal crosses, supporting the successful development of seeds in inter-varietal crosses. However, in inter-specific crosses, when *Gladiolus callianthus* was used as the female parent, the pollen tube did not penetrate into the ovule, whereas when the same was used as a male parent, growth of few pollen tubes toward the ovules led to the formation of few non-viable seeds.



Pollen-pistil interaction studies in inter-varietal and inter-specific crosses in gladiolus

2.3.4 Chrysanthemum

2.3.4.1 Promising lines in annual chrysanthemum (*Chrysanthemum coronarium*)

Pusa Ivory: It is a cream coloured open-pollinated selection developed by purification through sib mating and rigorous selection from a heterogenous population of Crown Daisy. The plant attains an average height of 62 cm with about 16 primary and 68 secondary branches. The plant is hardy and has profuse flowering, with approximately 137 flowers per plant and bears double medium-sized flowers (5.2 cm) with cream ray florets that are used as loose flowers. The flowers bloom in March-April and can stay longer under field conditions.

Flower of 'Pusa Ivory'

Field view of 'Pusa Ivory'

Pusa Dhaval: It is a white coloured open-pollinated selection developed by purification through sib mating and rigorous selection from a heterogenous population of annual chrysanthemum. The plant attains an average height of 76 cm with approximately 30 primary and 102 secondary branches. The plant is hardy and has profuse flowering, with approximately 162 flowers per plant. The flowers are double, medium-sized (5.3 cm) with white ray florets and are used as loose flowers. The flowers start to bloom in March-April and stay for a longer duration (58 days) under field conditions.

Flower of 'Pusa Dhaval'

Field view of 'Pusa Dhaval'

Pusa Swarna: It is a yellow coloured open-pollinated selection developed by purification through sib mating and rigorous selection from a heterogenous population of annual chrysanthemum. The plant attains an average height of 85 cm with approx. 26 primary and

106 secondary branches. The plant is hardy and has profuse flowering, with approximately 190 flowers per plant. It bears double medium-sized flowers (5.5 cm) with yellow ray florets used as loose flowers. The flowers bloom in March-April and stay longer (55 days) under field conditions. It is good for loose flowers and gardening purposes.

Flower of 'Pusa Swarna'

Field view of 'Pusa Swarna'

2.3.4.2 Transcriptome analysis of contrasting chrysanthemum genotypes under drought stress

Transcriptome studies identified 642 and 341 unique genes in tolerant cv. Pusa Shwet and susceptible cv. Ram Lal Dada, respectively. DEG analysis identified nine important DEGs for drought tolerance (including two down-regulated and seven up-regulated) in cv. Pusa Shwet. Five differentially expressed transcription factors (MYB family protein, FAR1 family protein, NF-YB family protein, MYB related family protein and C2H2 family protein) were upregulated in cv. Pusa Shwet. The signal transduction pathway revealed the upregulation of the *Pathogenesis-Related Protein 1* (*PR1*) gene involved in the salicylic acid pathway and the *Arabidopsis Response Regulator* (*ARR*) gene involved in the cytokinin biosynthetic pathway in tolerant cultivars under drought stress. Genes involved in lipid metabolism were also up-regulated in Pusa Shwet and down-regulated in Ram Lal Dada.

2.3.5 Lilium

Effect of PGRs/bio-stimulants on lilium bulb production: The application of seaweed extract significantly affected bulb production in lilium cv. Watch Up. The maximum bulb size (64.79 mm), weight of bulb (139.59 g) and a greater number of bulblets (4.10) were found with the foliar application of 8% seaweed extract sprayed at fortnightly intervals.

2.3.6 Ornamental Kale

Evaluation of hybrids: Out of the 30 CMS and DH lines-based hybrids developed and evaluated in ornamental kale, six performed better than the standard check 'Crane Rose' with heterosis for plant height ranging from 0.10 to 26.78% and plant spread 42.96 to 80.98%. The mean average head size and diameter of the central coloured portion varied from 18.53-26.93 cm and 7.32-11.53 cm, respectively, with a heterosis range of -23.65 to 2.39% and -11.49 to 39.42%, which indicated the superiority of hybrids over the standard check.

Best Performing CMS and DH parental lines-based hybrids

Introgression of CMS system in ornamental Kale: BC_3 population of the introgressed *Erucastrum canariense* and 'Ogura' male sterile cytoplasm into different genotypes of ornamental kale was developed.

Ornamental Kale introgressed with *Erucastrum canariense* and 'Ogura' male sterile cytoplasm (BC_3)

2.3.7 Antirrhinum

Evaluation of inbred lines for horticultural traits: The inbred lines KTANT-12, KTANT-17, KTANT-33 and KTANT-34 were found suitable for cut flower production. The genotype KTANT-34 had the maximum plant height (126.44 cm) and took the minimum number of days to flowering (33.26 days). KTANT-12 recorded the maximum number of flowers per stem (34.20). The genotypes KTANT-42, KTANT-43, KTANT-51 and KTANT-53 were found suitable for pot culture.

KTANT-12

KTANT-33

KTANT-42

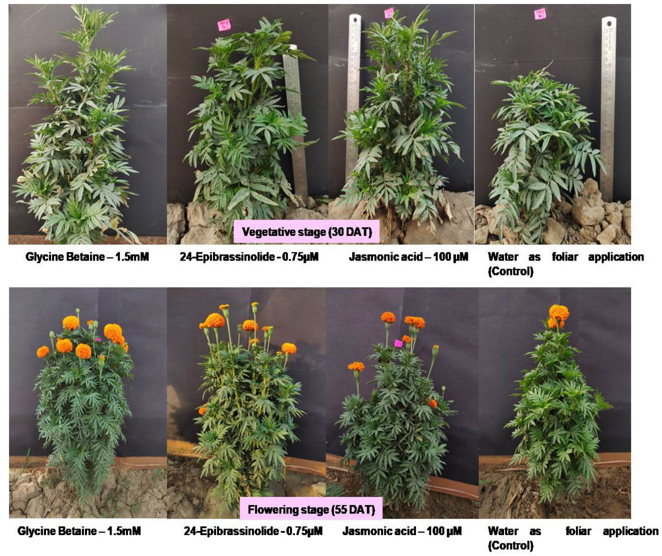
KTANT-51

Promising lines of Antirrhinum

2.3.8 Production, Post-Harvest Management and Value Addition Technology

Optimization of rooting media, rooting hormones and cutting length for root induction in floribunda and hybrid tea roses: IBA @ 1500 ppm resulted in a higher percentage of survival, increased root length and root volume in rose genotypes, namely Pusa Alpana, Pusa Lakshmi and Pink Parfait seedling. Cuttings of 15 cm length and soilless media [cocopeat + vermiculite + perlite (2:1:1)] exhibited high percent survival and root length.

Effect of different elicitors in mitigation of heat stress in African marigold under open field heat stress conditions: The efficacy of elicitors like salicylic acid, ascorbic acid, 24-epibrassinolides, jasmonic acid and glycine betaine for mitigation of heat stress in African marigold varieties 'Punjab Gainda-1' and 'Bidhan Marigold-2' was evaluated. Glycine betaine at 1.5 mM was the best treatment for morphological traits like average plant height, plant spread, stem diameter and number of primary branches, followed by 24-Epibrassinolide (0.75 μM) under heat stress.



Vegetative growth & flowering in Bidhan Marigold-2 treated with different elicitors under heat stress

Standardization of anthocyanin extraction process from rose flowers: Maximum total anthocyanin content was obtained in extractant 0.1% HCl at solid: solvent ratio of 1:5 at 25 ^{o}C.

2.4 PROTECTED CULTIVATION TECHNOLOGY

2.4.1 Tomato Varieties Suitable for Protected Cultivation

Pusa Cherry Tomato Hybrid-1: Pusa Cherry Tomato Hybrid-1 with resistance to *Ty-3* gene-based Tomato Leaf Curl Disease (ToLCD) and *Ph-3* gene-based late blight was released. This is suitable for low-cost polyhouse/protected and open-field cultivation. It has red-colored fruit, suitable for table purposes, high nutritive value (TSS 7.5 ^{o}Brix, lycopene 85 ppm, β-carotene 75 ppm) with long keeping quality (10 days). It has an indeterminate growth habit with an average of 10 flower-trusses per plant. The average fruit weight is about 18 g and the average fruit yield is 5.9 kg/plant.

Pusa Cocktail Tomato: The Pusa Cocktail Tomato, which has the Ty-3 gene for ToLCD resistance, has been released for protected cultivation in NCT Delhi. This variety's average fruit weight is about 25-30 g, and average fruit yield is 5.0 kg/plant. It has a long shelf life

(>15 days) and high nutritive value (lycopene content 7.14 mg/100g, ascorbic acid 8.3 g/100g fresh weight, acidity 0.52% and TSS 6.5 °Brix).

Pusa Cherry Tomato Hybrid-1

Pusa Cocktail Tomato

Pusa Prasanskrit: It is a newly released processing variety of tomato notified for cultivation in open fields and low-cost net house/protected cultivation in NCT Delhi. It is resistant to ToLCD due to the Ty-3 gene. The average fruit weight is 85 g, and the fruit yield is 4.0 kg/plant.

Pusa Prasankrit

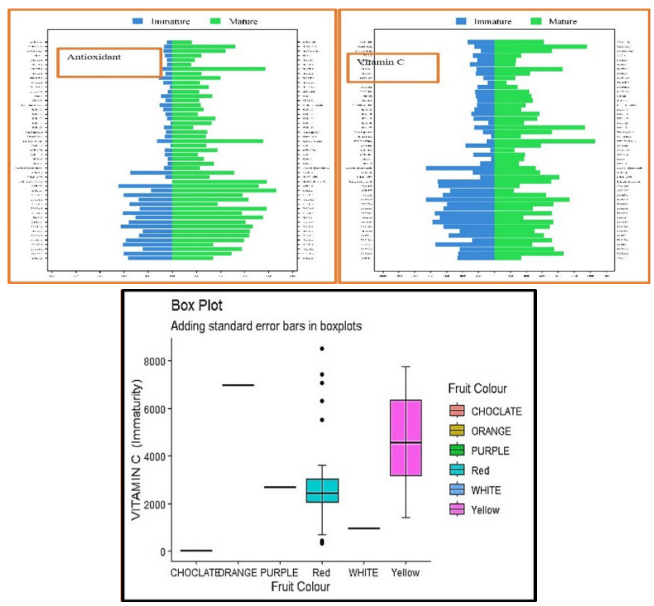
2.4.2 Effect of Pruning Methods on Yield and Economics for Greenhouse Tomato

Four types of branch pruning methods, *viz.* pruning of single stem, two stems, three stems or trishool and four stems were tested in big tomato var. NS-4266. The three-stem pruning method resulted in the highest fruit yield of 34.50 kg/m^2, followed by four-branch pruning (31.50 kg/m^2), two-branch/pruning (28.70 kg/m^2) and the normal pruning method (23.75 kg/m^2).

Response to "Trishool" method of pruning in tomato

2.4.3 High Antioxidant and Vitamin C-rich Lines of Capsicum Identified

The evaluation of forty-nine capsicum (*C. annuum* L.) genotypes was carried out for antioxidant and vitamin C. The antioxidants ranged from 0.00 to 224.53 µg/g and 78.09 to 431.34 µg/g in the immature and mature fruits, respectively. The antioxidant content was quite high in the red genotypes (AVR-152, CPCT-32C, 33B) at the mature stage. The vitamin C concentration ranged from 1487.72 to 12565.95 µg/g and 0.00 to 8511.72 µg/g in mature and immature fruits, respectively. Among different colors, *i.e.* green, red, orange, white, purple, chocolate and yellow capsicum examined for ascorbic acid content, the yellow capsicum genotypes (CPCT-31A-5, NBR-22) had a higher content of ascorbic acid at the mature stage.



Antioxidant and Vitamin C content in 49 Capsicum genotypes

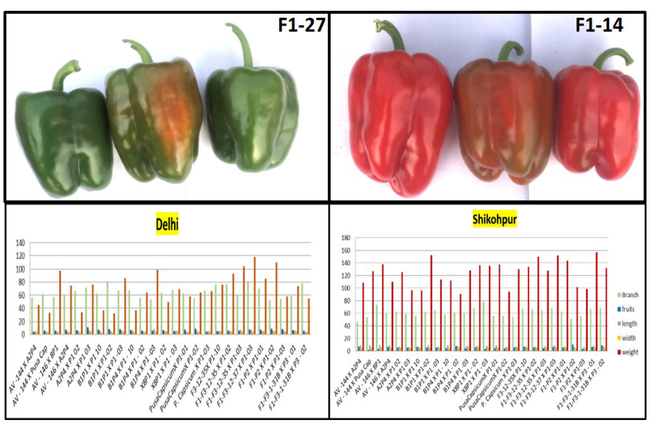
2.4.4 Large Fruit Size Lines in Sweet Pepper for Protected Cultivation

Six promising lines of sweet pepper with large fruit size and blocky shaped (3-4 lobes) fruits have been identified. These include F4-14 (180-200 g/fruit), CPCT-03 (200-350 g/fruit), CPCT 04 (150-250 g/fruit), F4-09 (180 g/fruit), CPCT-F4-11 (200-350 g/fruit) and CPCT-F3-02 (300-500 g/fruit).

Promising big fruit size lines of Sweet Pepper

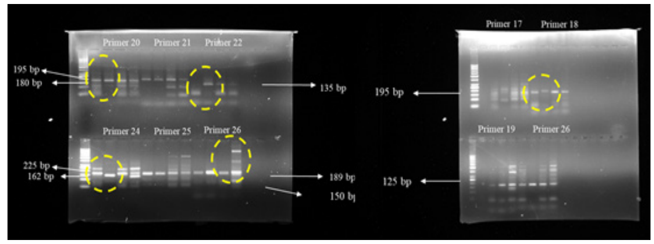
2.4.5 Identification of Hybrids of Capsicum with Suitable Fruit Size

Twenty-six F_1 crosses of capsicum were evaluated at two locations for fruit size and resistance to *Phytophthora*. Two superior F_1 hybrids, F1-27 and F1-14, exhibited desirable shape and marketable fruit sizes of 120-140 g.



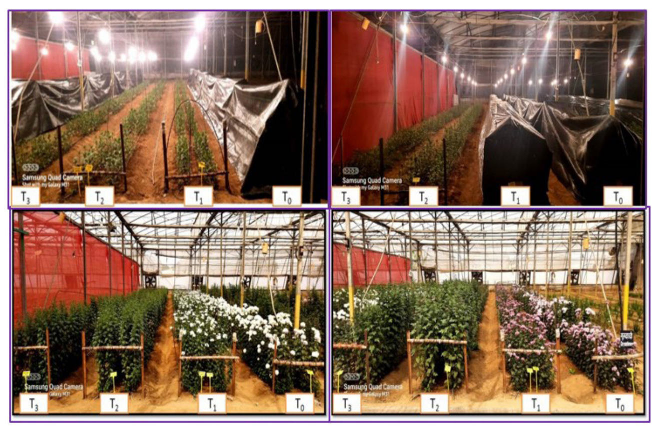
2.4.6 Polymorphic SSR markers for *Phytopthora* Blight and Root Rot Disease in Capsicum

Out of a total of 80 SSR primers screened, 15 were polymorphic and effective in distinguishing resistant and susceptible genotypes to *Phytophthora* blight and root rot disease in capsicum.



2.4.7 Development of an Artificial Module for Day-length Extension in Chrysanthemum

The effect of extending day length by four hours daily by using a light source was studied in chrysanthemum. The increase in plant height at 60 days after planting was 21.42, 40.15 and 64.78%, respectively, by extending day length by 10, 15 and 20 days. Exposure to long days for a period of 10, 15 and 20 days delayed flowering by 7, 11, and 17 days, respectively, eliminating the need for staggered planting under greenhouse conditions.



Effect of day length extension in chrysanthemum

2.4.8 PAR Influences Flower Induction and Compactness of Chrysanthemum

The seedlings of chrysanthemum were exposed to long-day PAR (120 μmol $Sec^{-1}m^{-2}$) for 7-10 days by mixing Red (80%) and Blue (20%) LEDs. The chrysanthemum varieties, *i.e.* Zembla (non-pinched), Diana Orange, Autumn Yellow, Autumn White and Bronze Turner were planted in the greenhouse after exposure to LEDs, which produced 110.5-117.2 cm long stems with more number of buds (42-53) per stem, except Zembla where the number of buds per stem was only 12. However, Zembla had the longest shelf life of 22 days compared to the control (12 days).

Effect of PAR acclimation on different chrysanthemum varieties through LEDs

2.4.9 AI-Based Crop Growth Modelling Developed for Greenhouse Vertical Farming of Lettuce

The AI-based crop growth model for greenhouse vertical hydroponic systems was developed using several machine learning algorithms, including Random Forest, Support Vector Regression, k-nearest Neighbours and Classification and Regression Trees. Random Forest emerged as the most accurate model for predicting plant growth parameters, with an R^2 value of 0.92 and a root mean square error (RMSE) of 2.5.

R^2 and root mean square error values of AI-based crop growth models for lettuce

ML-based Models	R^2	RMSE
Random Forest	0.92	2.5
Support Vector Regression	0.85	2.3
k-Nearest Neighbours	0.80	1.4
Classification and Regression Trees	0.78	1.3

2.5 FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

2.5.1 Natural Plant Extract for the Elaboration of Black Garlic from Single Clove Garlic

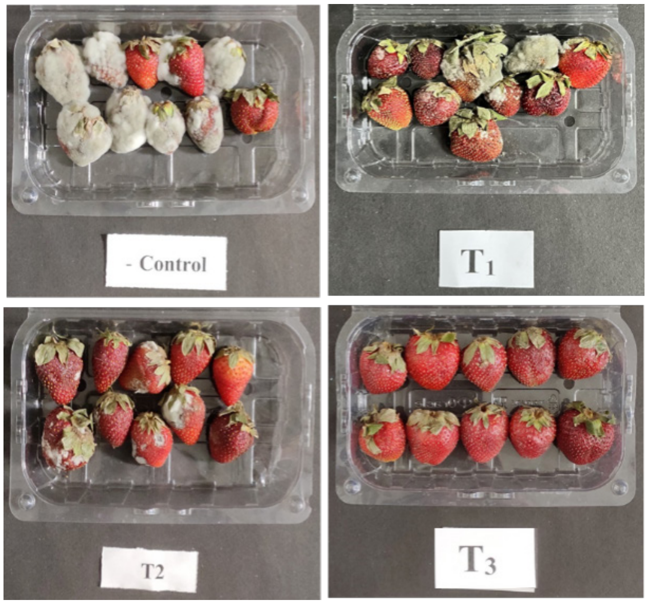
Black garlic (BG) is an important candidate product rich in Maillard reaction products (MRP) and Amadori compounds. A green process employing moisture-assisted aging technology (MAAT) was employed to develop BG from a single-clove variety (Solo) from Himachal Pradesh, India. Phenolic-rich extract from aonla/Indian gooseberry (*Emblica officinalis*) was infused through vacuum impregnation in pre-treated peeled garlic. The modified MAAT process modulated the quick transformation of fructan into fructose, increased the degree of glycation and shortened the aging time. The infusion of phenolic and ascorbic acid-rich extract accelerated the Maillard reaction (MR) and improved the functional quality of BG.

2.5.2 *In-vitro* and *In-vivo* Efficacy of Plant Extracts against Post-harvest Pathogens

The efficacy of ornamental plant extracts (leaf and petals of rose and marigold) against postharvest fungi was assessed. *In vitro* studies revealed that extracts at a total phenolic concentration of above 150 mg GAE mL^{-1}, inhibited the growth of *Colletotrichum gloeosporioide*s, *Rhizopus stolonifer* and *Aspergillus niger*, with rose leaf extract showing the highest inhibition percentage, followed by marigold petal extract. *In-vivo* experiments demonstrated that higher phenolic concentrations (200 mg GAE mL^{-1}) outperformed lower concentrations, with marigold petal extract remarkably reducing lesion diameter and decay percentage across all fungal strains. Rose leaf and marigold petal extracts, particularly at 200 mg GAE mL^{-1}, emerged as natural alternatives for controlling post-harvest fungal infections in guava fruits.

2.5.3 Mango Kernel Phenolics for Reducing Post-harvest Fungal Diseases in Strawberry

Nine different concentrations, ranging from 0-1500 ppm of mango kernel phenolics extract (MKPE) from a pickling variety of mango, were tested against three main post-harvest pathogens namely, *Botrytis cinerea, Colletotrichum gloeosporioides* and *Rhizopus stolonifera*. MKPE showed good antifungal properties against all three pathogens. *Botrytis cinerea* was found to be the most sensitive (EC50=364 ppm) to MKPE, while *Rhizopus stolonifer* (EC50=925.58 ppm) and *Colletotrichum gloeosporioides* (EC50=963.80 ppm) were more tolerant. The infection by *Botrytis cinerea* was delayed by seven and eight days upon functionalizing the MMKS edible coating with 360 ppm and 4800 ppm MKPE, respectively.



Control; STMP modified starch (T_1); STMP starch with mango kernel phenols at EC50 level (T_2); STMP starch with mango kernel phenols at EC90 level (T_3)

2.5.4 Genotype, Maturity and Processing Regime Influence GABA Content in Tomatoes

Gamma-aminobutyric acid (GABA) serves as a major neurotransmitter inhibitor in the central nervous system of humans and animals. Tomato is the richest source of GABA among vegetables. Seven tomato hybrids namely 'H-81', 'H-684', 'H-162', 'H-507', 'H-572', 'H-561' and 'Candy' were evaluated for their GABA content at six different maturity stages: immature green, green, breaker, turning, pink and ripe. In all the genotypes, GABA content was maximum at the green stage and declined as the fruit ripened. When processed into puree (approximately 14 °Brix) using hot and cold break methods, the GABA content diminished over time and followed first-order kinetics. Diffused light exposure resulted in the least, while natural light caused the maximum degradation of GABA.

2.5.5 Nutri-prash: A Convenient Healthy Bar

The method for formulation (2x3 factorial experiment) of nutri-prash using aonla, beetroot and moringa was optimized. The product contained significantly higher total phenolic content, total flavonoid content and antioxidant activity than control 2 (containing beetroot and aonla), while significantly lower than control 1 (containing only aonla). The developed product contained significantly ($p<0.05$) higher carotenoid and sensorial (flavor, color appearance and total score) than both the controls.

Control 1; Control 2 and Developed product of Nutri-prash

2.5.6 Functionalized Extruded Snacks

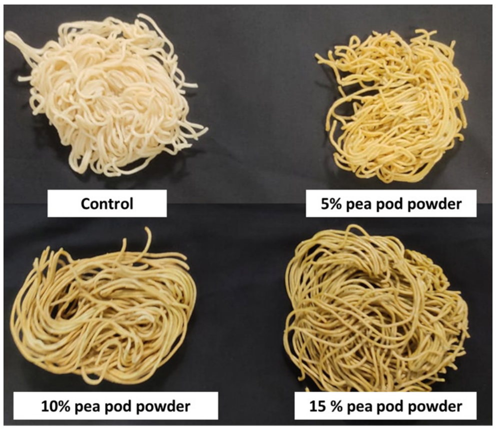
The extrusion process has been optimized for the development of tomato pomace-corn extrudates. Tomato pomace, although a food industry waste, is an excellent source of lycopene and dietary fiber. Similarly, overripe banana powder and grape pomace are excellent sources of natural sweeteners, fiber and bioactives. Utilization of these nutrient-rich wastes from agro-processing industries as a functional ingredient in commercially acceptable products such as extruded puffs can pave the way for dual benefit of waste and rejected fruit utilization as well as improved nutritional composition of commercially available snack products.

Puffed extrudates containing tomato pomace

2.5.7 Functionalized Pea Pod Powder Instant Noodles

The process of extrusion functionalization of pea pod powder for use in instant noodles was optimized.

Extrusion modifies the protein structure in pea pod powder without compromising the antioxidant capacity of the final product. The properties of noodles with functionalized pea pod powder were comparable to those of control noodles without pea pod powder. Thus, structural alteration offers a promising solution to utilize pea pod powder as a nutritious and sustainable ingredient in popular food products.



Instant noodles containing pea pod powder

2.5.8 Extraction of Nanocellulose from Pomegranate Peel

Nanocellulose was extracted from pomegranate peel using the green method and drying kinetics were determined to find the optimum moisture content for maximum cellulose content. The moisture diffusivity (D) value at drying temperatures of 50, 60 and 70°C was found to be 2.73×10^{-3} m^2/s, 3.16×10^{-3} m^2/s, and 5.25×10^{-3} m^2/s, respectively and the cellulose content was 542, 611 and 695 mg/100 g, respectively. Further, the yield of cellulose and nanocellulose was 55 and 42%, respectively.

Nanocellulose from pomegranate peel

3. GENETIC RESOURCES AND BIOSYSTEMATICS

The infrastructure for basic and applied plant science research must include plant genetic resources. These are rich sources of genes hitherto unexploited and thus need to be conserved, evaluated and utilized. They play a major role in providing genetic resources to diseases and pests and quality for breeders. Genetic resources have a pivotal role in crop improvement Programmes. The institute has a vibrant Programme for the collection, maintenance, evaluation and utilization of germplasm, insects, pathogens, nematode and other genetic resources. A large number of genetic resources maintained as crop germplasm and at insect/microbe/nematode repositories are evaluated, characterized and utilized for crop improvement and crop protection.

3.1 CROP GENETIC RESOURCES

3.1.1. Wheat

Genetic stock developed and registered: HS545 (INGR#23027) developed from a cross HD2819/HS435 has shown resistance against all the pathotypes of brown rust under the seedling resistance test (SRT). HS545 has been validated for the presence of *Lr24*/*Sr24* using molecular marker *Sr24#12*.

Registered genetic stock of barley- BHS 479 (BBM 798) (INGR23029): Resistant to all the pathotypes of leaf rust at the seedling stage. The registered genetic stock also possesses seedling resistance against all the pathotypes of stripe rust (except for 24 showing moderately resistant response). Possesses Adult plant resistance to leaf rust with the highest score of TMS. Also, have adult plant resistance to stem rust with the highest score of 0 and Adult plant resistance to stripe rust with an ACI of 5.8.

Registered genetic stock of Barley- BHS 480 (BBM 803) (INGR23066): Resistant to all the pathotypes of leaf rust at the seedling stage. The registered genetic stock is also resistant to all pathotypes of stem rust except for race 11 at the seedling stage. BHS 480 also possesses adult plant resistance to stem rust with ACI less than 15 (5MS).

Transfer of leaf rust resistance from rye into wheat using triticale as bridge species: A triticale x wheat derivative SW288 (T/W17-5) derived from the cross TL2942/HS562 was identified to carry seedling resistance to 38 pathotypes of leaf rust including 77-5, 77-9 considered as most virulent in Northern India. A broad spectrum of resistance to leaf (brown) rust shown by SW288 (T/W17-5), might be due to the accumulation of genes from both of the parents.

Developing double haploid genotypes in wheat: Among 26 doubled lines screened for rust resistance, DH-4 and DH-19 showed seedling resistance to yellow rust and DH23 to both yellow and brown rust. Seven new DH wheat plants were developed *via Imperata cylindrica* mediated doubled haploidy approach. Scanning electron microscopy was also done to study the development of haploid embryo.

3.1.2 Barley

3.1.2.1 Genetic stocks developed and registered with NBPGR

BHS 491 (BBM 880): The registered genetic stock is resistant to all the pathotypes of leaf rust and stripe rust at the seedling stage and also possesses adult plant resistance to stripe rust and leaf rust.

BHS 488 (BBM 861): This genetic stock carry seedling resistance to all the pathotypes of leaf rust except for *H1* race. It is moderately resistant to leaf blight.

BHS 489 (BBM 863): Naked barley possessing seedling and adult plant resistance to all the pathotypes of yellow rust. Also possesses adult plant resistant leaf rust.

3.1.3 Rice

Pre-breeding - evaluation of wild rice accessions: A set of 95 different accessions of wild rice collections of *O. rufipogon, O. nivara, O. longistaminata, etc.* were evaluated and data has been recorded for different traits. These lines were also utilised 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 1638 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* 2024.

Blight (TLB) and 50 inbreds against Maydis Leaf Blight (MLB) were screened under artificial epiphytotics and 16 pre-screened-inbreds were evaluated against fall armyworm (FAW). The inbreds, C 28, C 79, C 85, C 81, D 2282, D 2287, PDI 3004, were resistant to TLB, while D 2282, D 2287, C 85, PDI 3004 were resistant to MLB. The pre-screened inbreds against FAW such as D 36, C 46, C 79, DDM-2309, D 46 and D 102 were tolerant to FAW.

Genetics of turcicum leaf blight (TLB) resistance and validation of molecular markers: The genetic analysis of cross PDI 638 (R) x PDI 881 (S) through six-generation mean analysis revealed the involvement of both additive and dominance gene action with duplicate gene interaction in controlling the TLB resistance in maize. Further, the number of effective genes controlling the TLB resistance was 4 genes as estimated by all three methods, viz., East's hypothesis, Castle and Wright's method and Burton's formula.

Variation in grain types among rice landrace accessions

3.1.4 Maize

Genetic stocks for *bronze1* (*bz1*) gene: The recessive *bz1* provides bronze colour in the endosperm, while the wild-type allele, *Bz1* leads to the formation of cyaniding, which provides purple/ black colour depending upon the genetic background. The genetic stock (MGU-bz1-101) bearing *bz1bz1* genetic constitution when crossed with *Bz1Bz1* line, the F_2 seeds segregate in a ratio of 3 (purple/black): 1 (bronze). This shows that *Bz1* is completely dominant over *bz1* allele.

Breeding for biotic stress tolerant inbred lines: Screening and identification of tolerant lines: A set of 150 newly developed inbreds against Turcicum Leaf

The molecular marker validation in 200 F_2s of the cross using 10 SSR markers previously reported to be showing association with TLB resistance revealed a significant association of three markers (dupssr24, bnlg1316, umc1864) in this F_2. However, only the marker, dupssr24 explained >10% (16.12%) variation in TLB resistance implying its possible utility in the marker-assisted selection of TLB resistance. Besides, analysis of F_2s of straight and reciprocal crosses revealed a maternal effect in controlling TLB resistance, wherein the F2 distribution of TLB reaction in the F2s with resistant (PDI 638) female parent was skewed towards resistance, whereas the one with susceptible (PDI 881) female parent showed skewness towards susceptibility.

3.1.5 Chickpea

Evaluation of chickpea crop wild relatives for nutritional traits: A set of 88 chickpea crop wild relatives (CWRs) involving *Cicer. reticulatum, C. judiaicum, C. bijugam, C. pinnatifidum, C. echinospermum, C. yamashitae* were multiplied in open field and pots. Amongst them, chickpea accessions ICC17148, ICC17271 and ICC17149 had the highest grain iron content i.e. 110.39, 86.43 and 78.36 mg/kg respectively.

Crossing of high grain protein content donors to elite chickpea *desi* and *kabuli* genotypes: Identified ultra-high grain protein donors *viz*., ICC-13523 (33.56%), ICC-13461 (31.71%) and ICC-8397 (30.22%) were crossed with 10 elite chickpea *desi* and *kabuli* lines aiming to combine yield and high protein content in chickpea.

3.1.6 Lentil

Germplasm registered: Two genotypes were registered at NBPGR, New Delhi. L4717-NM: A natural mutant in lentil for seed color variation (INGR-23093), and PSL-17 for salinity tolerance in lentil (INGR 23095).

Screening for the black aphids in lentil: A screening of 350 advanced lentil breeding lines identified a natural response to the black aphid problem, a new pest probably migrating from mustard. Susceptible lines displayed more on light foliage, than dark foliage. PLL-23-53 with dark foliage was identified as a tolerant line, while PLL-23-62 was susceptible to black aphids.

3.1.7 Mungbean

Germplasm registered: Two genotypes were registered at NBPGR, New Delhi. PMR-1 with MYMIV resistance in mungbean (INGR-23096), and PMS-12 for salinity tolerance in mungbean (INGR-23097).

3.1.8 Mustard

A total of 947 germplasm lines including *Brassica juncea* (686), *B. rapa* (16), *B. carinata* (170), *B. nigra* (13), *B. napus* (15) and 47 accessions of wild /related species were raised and maintained. Also multiplied and maintained 562 accessions of core set and identified 25 accessions with white rust resistance at IARI, Regional Station, Wellington. Two RIL populations derived from RDV 29 x PMW 18 and Pusa Mustard 28 x Pusa Karishma were also maintained and phenotyped.

3.1.9 Soybean

Germplasm registration: Loss of seed viability and vigor is a serious issue in soybean. Through rigorous screening over 3 consecutive years, we have identified a soybean germplasm SEL-EC1023, which maintains longer viability in ambient storage. It has been registered (No. INGR 24033) with the National Bureau of Plant Genetic Resource, New Delhi as a germplasm with a special trait (high viability).

3.1.10 Genetic Resources Developed in Vegetable Crops

3.1.10.1 Genetic stocks registered

***DBGS-21-06 (INGR24066)*:** This genetic stock of bitter gourd is a highly stable predominantly gynoecious line with desirable fruit traits. Fruits are long (16-18cm), green, spiny surface with broken and discontinuous ridges which are highly preferred by consumers. It is an excellent combiner for fruit yield and related traits.

***DBGS-54-18 (INGR24065)*:** This is a unique white flowered bitter gourd genotype. White flower trait can serve as an important morphological marker for genetic purity testing in F_1 hybrid development.

3.1.10.2 Genetic stocks developed

Purple cauliflower: Out of 55 $F_{4:5}$ progenies from two crosses Pusa Ashwini×PPCF-1 (24) and Pusa Kartiki×PPCF-1 (31) were evaluated for curd traits and October to November maturity. The most promising progenies were DPC-6704-35, DPC-2304-36, DC-2304-64 and DPC-6704-87. CMS conversion of PC-6704-35 and PC-2304-36 was advanced to BC_3F_1 for developing *Ogura* based CMS lines in purple cauliflower. Curd surface had maximum anthocyanin in both purple (271.4 mg/100g FW) and intermediate purple (248.0 mg/100g FW) plants. Stalk level-1 from both purple (111.5 mg/100g FW) and intermediate purple (138.6 mg/100g FW) also had anthocyanin.

Pyramiding of *Or* and *Pr* genes in Indian cauliflower: Wide variation was found in anthocyanin (3.7 mg/100g fw) and β-carotene (4.7-13.3 µg/g fw) estimation in orange-purple F_2 plants from orange cauliflower (Or 84-18-19) (*OrOr*) x Purple cauliflower (Pr-36) (*Prpr*). Further, total 446 $F_{2:3}$ progenies evaluated for plant traits, curd traits and curd maturity. Eight $F_{2:3}$ progenies identified using the trait-specific markers for further use.

Orange cauliflower: Eleven genotypes of orange cauliflower namely OrCF-4, OrCF-5, OrCF 325, OrCF-84-18-19, OrCF-1-1, OrCF-1204-7, OrCF-vv04-7 and OrCF-9505-12, OrCF-244, OrCF-308 and OrCF-1204-32 were found promising for curd size and plant traits. OrCF-4, OrCF-5, OrCF-244 and OrCF 84-18-19 were found promising for flower production and used in hybrid breeding in early and mid-groups.

Cucumber: During spring summer season of 2024, 231 germplasm/advance breeding lines including 15 new collections and 16 tropical gynoecious lines were evaluated and promising lines were maintained. Tropical gynoecious line DGC-102, DGC-103, DGC-1301, DGC-1302 and DGC-1308, showed stable performance at an average day temperature of 40-45^{0}C. The genotypes DC-77, DC-70 and DC-91 were found to be highly resistant to downy mildew both under field condition and artificial inoculation. The genotypes DC-77 and DC-70 are being used in developing mapping population with highly susceptible genotypes.

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

Onion (Long day): 45 advanced breeding lines of long day onion (red, yellow, white) were purified and maintained at ICAR-IARI RS, Katrain.

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

Temperate Flowers: Fifty two cultivars including five species and 20 F_1 hybrids of lilium, 22 species/varieties of iris, 15 varieties of dahlia, 12 genotypes of alstroemeria, 70 breeding lines of gladiolus, 77 lines of ornamental kale and other bulbous crops like torch lily, wattsonia, canna, Amaryllis, crinum, Freesia, zinger lily, Lycoris and some wild ornamentals are being maintained and used for crop improvement program at the station.

Rose varieties namely Annand Rao, Akash Deep, Dr. Purohit, Diversity, Coffee Country, Blue Bird, Bichitra, Chandana, Nilkanti and Tunga Bhadra were collected from secondary sources to enrich the existing germplasm.

3.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

3.2.1 Insect Biosystematics

Identification service and National Pusa Collection (NPC) augmentation: Two humdred seventy specimens belonging to different Orders of Coleoptera (50), Hymenoptera (11) and Lepidoptera (209) were identified for different stakeholders. Collections of these orders were made from different locations in Andhra Pradesh, Arunachal Pradesh, Gujarat, Himachal Pradesh, Karnataka, Kerala, New Delhi, Odisha and Tamil Nadu. Approximately, 2,500 specimens of various orders and families were collected, processed, pinned, studied and stored in NPC.

Biosystematic studies on the micromoth family Gelechiidae (Lepidoptera: Gelechioidea): Field collections were conducted across diverse locations in India, including Andhra Pradesh, Arunachal Pradesh, Gujarat, Himachal Pradesh, Karnataka, Kerala, New Delhi, Odisha and Tamil Nadu. Among the collected specimens, three taxa, namely *Hypatima rhomboidiella*, *Teleiodes* sp. and *Agnippe* sp., represent new distribution records for India. DNA barcoding was carried out for approximately 30 specimens, representing 12 species. These include several economically important pests, such as the groundnut leaf miner (*Aproaerema modicella*), pink bollworm (*Pectinophora gossypiella*), potato tuber moth (*Phthorimaea operculella*), sapota bud borer (*Eustalodes achrasella*), tomato leaf miner (*Phthorimaea absoluta*), mango leaf miner (*Palumbina* *glaucitis*), *Mesophleps ioloncha* and Angoumois grain moth (*Sitotroga cerealella*).This integrative approach combining morphological and molecular techniques has contributed significantly to understanding the diversity and distribution of gelechiid moths in India.

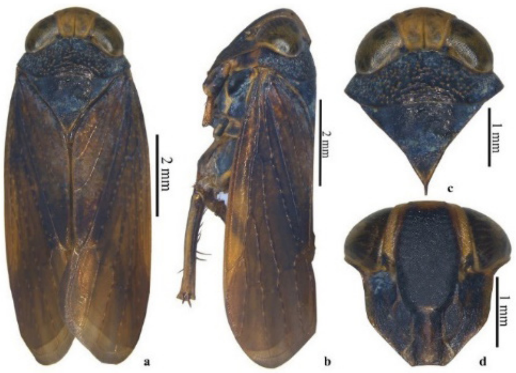
Systematic Studies on Micromoth Subfamily Olethreutinae (Lepidoptera: Tortricidae) from India: Moth collections were conducted across diverse locations in several Indian states, including Arunachal Pradesh, Uttarakhand, Himachal Pradesh and Karnataka. Nearly 65 morphospecies of Olethreutinae were sorted based on distinct morphological characters. For taxonomic studies, more than 100 high-quality illustrations were prepared from genitalia dissections and wing venation slides, facilitating precise identification and redescription of several species. Among the collected specimens, a detailed revision of the genus *Ophiorrhabda* Diakon off was

New species and new records of the family Tortricidae from India

achieved, including identification keys and a checklist. Significant findings included the discovery of five species *Argyroptocha phalaenopa, Ophiorrhabda harmonica, Ophiorrhabda philocompsa, Sorolopha dorsichlora* and *Sorolopha leptochlora* and two genera, *Toonavora* Horak, 2006 and *Argyroptocha* Diakonoff, 1968, newly recorded from India. Additionally, three new species were described: *Toonavora valvaspinosa* sp. nov., *Gypsonoma ovata* sp. nov. and *Microsarotis spatulata* sp. nov. DNA barcodes were generated for representative samples, enhancing molecular identification and supporting systematic studies of Olethreutinae.

Deep learning-based accurate detection of insects and damage in cruciferous crops using YOLOv5: We propose a deep learning approach using a YOLOv5-based single-stage object detection model for the identification of agriculturally important insects of crucifers and some of their damage symptoms. A total of 2,730 images were captured from different fields and polyhouses using different smartphones and an SLR camera. The specimens were taxonomically identified by experts and the images were curated, annotated, resized, augmented, split and trained, validated and tested through five variants of YOLOv5 *viz*., nano (n), small (s), medium (m), large (l) and extra-large (x). After all the experiments, YOLOv5l was found to be the best-performing model, acquiring an average accuracy, precision, recall and F1-Score of 99.5%, 92.0%, 83.0% and 0.873, respectively in the test images. To strike a balance between complexity and performance, YOLOv5l has emerged as the most viable option to integrate with AI-based insect identification applications. Our findings reveals that deep learning is reliable for quick detection of insects under complex backgrounds. Further, we demonstrate that use of damage symptoms produced by insects will also be explored for pest detection. The integration of the present model with mobile applications will help the farmers and stakeholders in the detection of insects and suggest effective management.

Biosystematic studies on the family Cicadellidae (Order: Hemiptera): A new species of leafhopper, *Singillatus multispinatus* sp. n., (Hemiptera: Cicadellidae: Coelidiinae) from Arunachal Pradesh, India (NPC Museum), is described and illustrated along with distribution, checklist and key to the species from the Indian subcontinent.



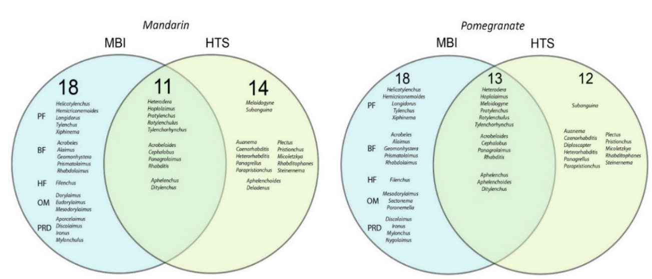
Habitus of *Singillatus multispinatus* sp. n.

Taxonomic studies of Order Coleoptera: Identification of invasive small hive beetle, *Aethnia tumida* Murray (Nitidulidae: Coleoptera) from the samples received from Nagaland and Arunachal Pradesh, India. Heavy infestation of flea beetle, *Sinocrepis sp*. (Coleoptera: Chrysomelidae) infestation on *Abutilon indica* (L.) Sweet from New Delhi, India. 850 specimens belonging to different groups of Coleoptera were augmented to NPC. A catalogue for the Elateridae of the North-eastern region was compiled and it was found that 250 species under seven subfamilies, 20 tribes and 48 genera are known from the north-eastern region. Two new species of *Glyphonyx viz., G. umiamis* and *G. kyrdemkulaiensis* from Meghalaya. Both species can be differentiated based on the external morphology and based on bursa sclerites.

Damage caused by flea beetle, *Sinocrepis* sp on *Abutilon indicum* and *Sinocrepis* sp adult

3.2.2 Nematode Biosystematics and Identification Services

A systematic survey was carried out to collect 115 soil samples from maize in the districts of Bhilwara, Chittorgarh, Udaipur, Rajsamand, Banswara and Dungarpur of southern Rajasthan for the isolation of entomopathogenic nematodes (EPNs). Five samples were found to be positive for EPNs. Identification at genus level classified two isolates as *Steinernema* sp. and three as *Oscheius* sp. based on morphological and morphometrics characterization, with a total of 12 nematode genera have been observed. Among them, seven belong to plant parasitic nematode, three to bacterivores and two to predatory nematodes. The soil and plant nematode communities were profiled in both mandarin and pomegranate orchards using conventional morphological and High Throughput Sequencing (HTS) by Illumina sequencing methods in both drip and conventional irrigation systems. The HTS method detected 70 and 68 nematode genera in mandarin and pomegranate orchards, respectively and identified more than half of the detected nematode genera as animal parasites. The morphological analysis showed a higher proportion of plant parasitic nematodes while the HTS method depicted a larger proportion of bacterivore nematodes. Therefore, metagenomic analysis can reveal nematode species that are difficult to identify using morphology, while morphological analysis rapidly identifies common soil and plant nematode species. Development of a Recombinase Polymerase Assay for diagnosis of rice root-knot nematode *Meloidogyne graminicola*, *Aphelenchoides besseyi*, *Rotylenchulus reniformis*, *Globodera rostochiensis* was carried out. Development and Evaluation of the Loop-Mediated Isothermal Amplification Technique for the Rapid Detection of the Foliar Nematode, *A. besseyi* was also done.



Taxonomic profiling of nematode diversity in surface and drip irrigation systems in citrus and pomegranate by High Throughput Sequencing (HTS) and morphological analysis

4. CROP AND NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

The School of Crop and Natural Resource Management pursues research towards integrated management of crop, soil, water and environment for higher farm productivity, profitability and sustainability while concurrently resorting to conservation of natural resource base, improving the use efficiency of inputs and reducing environmental footprints. Significant research achievements/ breakthroughs have culminated into several farm technologies/ techniques. Integrated farming system models for small and marginal farmers, conservation agriculture-based efficient cropping systems, sustainable crop diversification practices, precision water and nutrient management involving sensors, mobile application, nano-fertilizers and micro-irrigation have been developed and demonstrated on-farm towards improving crop yield, farmers' income, soil health and climate resilience. Several novel products were also developed such as urea-loaded nano-clay biopolymer composite, phosphorus-enriched organic manure, potassium-supplementing bio-mineral fertilizer and phosphogypsum-coated urea for mitigation of methane in rice. Developed/ fabricated telerobotic target-specific pesticide applicator, crop disease detection and target spray system, robotic soil sampler, raised bed pneumatic precision planter-cum-fertilizer applicator for use by the farming communities. Assessed the groundwater recharge potential of Yamuna floodplain and integrated drip-cum-mulch technology for higher water-use efficiency of sorghum, pearl millet and basmati rice. Chickpea root-associated bacterial isolates having plant growth promotion traits, fungal consortium yielding gluconic acid from potato waste, rhizobacterial bioformulations for improved water retention in mustard and cyanobacterial inoculation reducing drought-stress effects in wheat were identified. An inventory of methane and nitrous oxide emissions from agricultural soils and estimated greenhouse gasses emission from rice residue burning in Punjab and Haryana and crop yield losses upon flash floods using machine learning and remote sensing were prepared.

4.1 AGRONOMY

4.1.1 Integrated Farming System Model for Small Farmers under Irrigated Situations in North India

The integrated farming system comprising of crop + dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas unit + vermicompost provided the highest system productivity (62.9 t/ha) and system

Integrated farming system model for small farmers

production efficiency (172.3 kg/ha/day) compared to other systems under study. The water footprint (112.2 L/kg rice equivalent yield) was also significantly lower in this system.

4.1.2 Integrated Farming System Model for Marginal Farm Holders

An integrated farming system module integrating field crops, open field vegetables, protected vegetable cultivation, mushroom production, beekeeping and vermicomposting resulted in significantly higher system productivity (83.40 t/ha), profitability (gross returns of 1452 x 10^3 ₹/ha, net returns of 774.9 x 10^3 ₹/ha, profitability of 2123 ₹/ha/day) and employment generation (788 man-days) compared to other farming system modules.

Integrated farming system model for marginal farmers

4.1.3 Phosphorus Management in Maize-based Systems

A study on three conservation agriculture (CA)-based cropping systems and six phosphorus management practices revealed that the maize+cowpea-wheat cropping system led to 9.31% higher maize yield, 13.04% higher wheat yield, 43% higher system productivity and 35% higher net returns compared to the sole maize-wheat system. The application of 50% recommended dose of phosphorus (RDP) + phosphate-solubilizing bacteria (PSB) to maize + cowpea resulted in 15 and 29% higher recovery efficiency of phosphorus than 100% RDP applied to maize + cowpea and 75% RDP + PSB to maize, respectively.

CA-based maize+cowpea-wheat cropping system

4.1.4 Improved Productivity and Soil Health under Long-term Conservation Agriculture (CA)-based Rice-Wheat System

A long-term 14-year-old experiment on conservation agriculture revealed that a zero till (ZT) triple cropping system involving ZT-DSR (direct seeded rice) with summer mungbean residue, ZT wheat with rice residue and ZT summer mungbean with wheat residue was superior to conventional puddled transplanted rice (PTR)- conventional till wheat (CTW) system in terms of wheat yield, system productivity and net returns. This CA system provided 19.4% lower rice yield but 20.9% higher wheat yield and 28.5% higher system productivity than the conventional PTR-CTW system. It also led to the building up of 44 and 37% higher soil organic carbon (SOC), respectively, at 0-5 and 5-15 cm soil layers and higher C-sequestration than the PTR-CTW system.

4.1.5 Late-sown Stress Afflict Post-anthesis Dry Matter and Nutrient Partitioning and Remobilization in Wheat Genotypes

Five potential wheat genotypes, viz. HD 2967, HD 3086, HD 3249, DBW 187 and HD 3226 were evaluated under field conditions as well as in PVC tubes for root-system traits. Timely sown wheat had a grain yield advantage of 18%. DBW-187 and HD 2967 gave the highest grain yield under timely and late sown conditions, respectively. The days to anthesis and grain filling period under the late sown were hastened by 5.2 days and shortened by 7.4 days, respectively. Timely sowing enhanced the post-anthesis dry matter accumulation and remobilization to the tune of 18.8 and 23%, respectively.

4.1.6 Designing an Environmentally Clean Agricultural Production Model for Balancing Productivity, Economics and Environmental Outcomes

In a study, two land configurations viz., flat-bed (FB) and permanent raised bed and furrow (PRBF) were integrated with four cereal-legume systems such as maize-wheat (M-W), maize + black gram + soybean-wheat + chickpea (M+Bg+S-W+C), maize + cowpea + soybean-wheat + lentil (M+Cp+S-W+L) and maize + cowpea + soybean-wheat + mustard (M+Cp+S-W+Ms) to develop a robust production model. The PRBF resulted in ~6% higher productivity over FB, while the cereal-legume system improved system productivity by 2-2.5 times over the M-W system. The PRBF system provided significantly higher energy use efficiency (8.29%) and energy productivity (1.54 kg MJ^{-1}) than FB. The M+Cp+S–W+Ms gave 2.26 times higher energy productivity and 41.35 times less specific energy over the M-W system.

4.1.7 Design and Validation of a Mobile Application for Real-time Nitrogen Management in Maize

Among the parameters evaluated, the dark green colour index (DGCI) at 35 days after sowing (DAS) (r = 0.80) and 45 DAS (r = 0.82) showed the highest correlation with N concentration. N concentration served as the absolute indicator of leaf N status, while DGCI, normalized difference vegetation index (NDVI), soil plant analysis development (SPAD) and leaf colour chart (LCC) were relative indicators. Calibration of N concentration against relative indicators revealed DGCI as the most reliable predictor of leaf N concentration (R^2 = 0.69; MAPE = 16.96%). The DGCI-based "Pusa N Doctor" app was validated against GreenSeeker (GS) using an N prescription algorithm incorporating INSEY (35 and 45 DAS) and grain yield. The application of 50% recommended N and full dose of P and K along with the dose of N from the App reduced N application by 18.7%, increased agronomic N efficiency by 22.9% and recorded the lowest N losses (44.9 kg ha^{-1}) compared to the recommended dose of fertilizer (RDF).

Pusa N Doctor app

4.1.8 Tillage and Residue Management Options and Crop Rotation for Sustainable Intensification of Rice Fallows in Eastern India

In this study, the puddled transplanted rice (PTR) + residue mulching increased grain yield by 5.21, 8.03 and 10.85% compared to zero till direct-seeded rice (ZTDSR)-residue, ZTDSR+ residue retention and ZTDSR+ residue mulching, respectively. The ZTDSR + residue retention provided 22.35, 25.58, 12.57, 26.47, 16.80 and 17.18% higher grain yield of chickpea, lentil, mustard, linseed, wheat and maize compared to farmers' practice.

4.1.9 Efficacy of Herbicides against Diverse Weed Flora of Wheat

The pre-emergence tank mix application of *Pyroxasulfone* @ 127.5 g/ha + *Metsulfuron-methyl* @ 4 g/ha resulted in effective control of multiple weed flora and provided higher, most economical and energy-efficient wheat productivity in vertisols of Central India.

4.2 SOIL MANAGEMENT

4.2.1 Urea-loaded Nano Clay Biopolymer Composites (NCBPC) for Higher Nitrogen Use Efficiency

The combined application of urea-loaded nano clay biopolymer composites (NCBPC: 50% N as urea-loaded NCBPC+ remaining 25% as top dress) + Zn solubilizer + P solubilizer gave similar grain yield, apparent nitrogen recovery and agronomic nitrogen use efficiency in both maize and wheat crops with the recommended dose of N. The application of 75% N as urea-loaded NCPBC using mango kernel flour, *i.e.* NCBPC-A + P solubilizer and Zn solubilizer resulted in 7.61 and 6.09% higher maize and wheat grain yield, respectively, over 100% of the recommended dose of nitrogen through urea.

4.2.2 Nutrient Release from Seaweed Extract-based Products in Wheat Crop

The nutrient release of two seaweed extract-based products, *i.e.* seaweed extract-based Sagarika Z^{++} granules (SG) and Sagarika liquid (SL) was studied under greenhouse experiments. The application of 75% recommended NPK along with SG @ 10.67 mg/kg soil and SL @ 5 ml/L of water showed bio-stimulatory effects and yield of wheat at par with 100% NPK. In acidic soils, the application of SG indicated an ameliorative effect without any visible sign of nutrient mining.

4.2.3 Potassium Supplying Capacity of Major Soil Types

The quantity/intensity (Q/I) relationship of K was studied for five soils, *viz.* alkaline alluvial (New Delhi), acidic alluvial (Coochbehar), calcareous alluvial (Samastipur), red (Hazaribagh) and black (Bhopal) soils using sorghum-sudan grass hybrid as test crop in a pot experiment. Soil K supplying capacity assessed through quantity, intensity and buffering power showed a noticeable deterioration under exhaustive cropping without adequate K input, which could largely be prevented or improved by K fertilization.

4.2.4 Enriched Organo-mineral Fertilizer as an Alternative Source of Phosphorus

A phosphorus-enriched organic manure was evaluated under maize-wheat and soybean-wheat cropping systems. The study revealed that phosphorus-enriched organic manure application effectively reduced 50% of the diammonium phosphate application while maintaining crop productivity in both cropping systems.

4.2.5 Rhizosphere Metabolites Modulate Aggregation Behavior of Biochar Colloids

The interaction between biochar and low molecular weight organic acids (LMWOAs: formic acid, acetic acid, malic acid) secreted by crops as rhizo-secretions at different pH (4.5, 5.5 and 6.5) was studied on the aggregation behavior of biochar colloids. The hydrodynamic diameter of biochar colloids increased as the electrolyte concentration (NaCl) increased from 10 to 210 mM, with greater variability at 210 mM. Attachment efficiencies (α) of biochar colloids with formic acid, acetic acid and malic acid at pH 4.5, 5.5 and 6.5 increased with rising ionic strength until reached critical coagulation concentration values (α=1). Biochar colloids exhibited negative electrophoretic mobility (EPM) values from pH 4.5 to 6.5. Thus, the efficiency of the use of biochar for different types of amendments in soil is highly dependent upon the pH of the soil and the type of crops.

4.2.6 Land Use System Affects Soil Carbon Dynamics

To elucidate the variations in soil carbon pools and their fractions, seven principal plantation systems in the Western Himalayan region were analyzed at soil depths of 0-20 cm and 20-60 cm. At both depths, apricot soils exhibited the highest total organic carbon (15.3 g TOC kg^{-1}) while walnut soils had the highest total carbon (17.2 g TC kg^{-1}). In contrast, walnut and plum systems contained the highest levels of inorganic carbon. The carbon sequestration rate was maximized in apricot (0.54 and 0.45 Mg C ha^{-1} yr^{-1}) and walnut plantation systems (0.53 and 0.43 Mg C ha^{-1} yr^{-1}) in the 0-20 cm and 20-60 cm soil layers, respectively. These findings suggest that soil degradation in the region can be mitigated by adopting apricot, walnut and peach plantations instead of apple plantations in the northwestern Himalayan region.

4.2.7 Nutrient Dynamics under Conservation Agriculture

In a maize-wheat-mungbean cropping system, the zero tillage +residue (ZT+R) plot showed significantly higher very labile, labile, less labile and non-labile soil organic carbon pools. Nitrogen pools, *i.e.* NH_4^+-N, NO_3^-- N, Alkali-$KMnO_4$, Microbial biomass N (MBN), potentially mineralized N (PMN) and total N compared to conventional tillage + residue (CT+R) plots. Among inorganic P fractions, only soluble and loosely bound P was found to be higher in ZT+R. The ZT+R plot had significantly higher available-S, heat soluble-S, total water-soluble-S, sodium bicarbonate extractable-S, inorganic-S and organic-S pools in comparison to CT+R plots.

4.2.8 Modified Bentonites for Uptake of Heavy Metals by Spinach

All the modified bentonite clays (modified using humic acid, iron exchange and goethite + humic acid) demonstrated superior metal remediation efficiency compared to normal bentonite. Iron-exchanged bentonite @ 7.5 g/kg application significantly reduced the metal uptake (Cd and Pb), metal bioconcentration factor and hazard quotient in spinach grown in metal-contaminated soil.

4.2.9 Removal of Arsenic from Groundwater

Adsorption of arsenic (As) species, As(V) and As(III) by sulfur-modified nano zero-valent iron (S-nZVI) (200 mg/L) indicated a complete removal of both As(III) and As(V) from contaminated water (up to 5 mg/L). The S-nZVI worked in a wide pH range from 3.5 to 8.5. Rapid reduction (>99% in <10 min) of As(III) and As(V) (initial concentration, C_0=100 mg/L) was achieved with the S–nZVI (200 mg/L). The electrostatic interaction and surface complexation contributed to ultra-high arsenic removal by S–nZVI compared to nano zero-valent iron.

4.2.10 Molecular Mechanism in Rice (*Oryza sativa*) in Response to Arsenic Stress

Illumina sequencing was used to acquire information on EukmRNA regulation in rice grown in hydroponics with As(III) and iron nanomaterials. The 199 genes were uniquely expressed in As-treated plants compared to control at 6 h, whereas 126 genes were uniquely expressed in As-treated plants at 24 h. In all, 6052 differential genes were up- and down-regulated in response to As(III) stress at 6 h. At 24 h, 4035 genes were identified as up- and down-regulated in response to As(III) application. Our findings highlight the significance of jasmonate signaling and lipid metabolism in response to As(III) stress and their regulation by EukmRNA.

4.2.11 Nutrient Management

4.2.11.1 Soil-moisture insensitive extractant for available potassium

Among the seven extractants studied, ammonium acetate, barium chloride, nitric acid and Mehlich extractant showed a better correlation with plant K uptake in moist soil than in air-dry soil. Sodium acetate extracted K was better correlated with plant K uptake in air-dry soil than in moist soil. The other two extractants, *i.e*. the cold sulphuric acid and organic acid mixture, showed the same correlation with plant K uptake in air-dry and moist soils. The 0.01 M organic acid mixture emerged as the least soil moisture-sensitive extractant of plant available K.

4.2.11.2 Potassium supplementing bio-mineral fertilizer from low-grade minerals

The potassium-supplementing bio-mineral fertilizer (BMF) formulations have been developed from K solubilizing microbes (KSM) and waste mica powder. Among the various protocols for formulating BMF, mixing of spores with talc in 1:10 ratio followed by thorough mixing with waste mica powder in a 1: 5 ratio, maintaining moisture at 40% of the water holding capacity and storing in darkness at ambient conditions were found to maintain the highest viable microbial cell count of KSM.

4.2.11.3 Molybdenum chemistry and bio-availability in soils

A highly significant negative correlation was observed between soil pH and Mo adsorption parameters, while a significant positive correlation was found between SOC and adsorption parameters. Soils with low pH (~4.5) to slightly alkaline (~7.5) recorded the Mo adsorption, while with alkaline soils (pH >8), negative adsorption was observed. Thus, molybdenum sorption in soil is a spontaneous endothermic entropy-driven reaction. A significant positive correlation was observed between Gibbs free energy change and soil pH, while a significant negative correlation was observed between equilibrium constant (K) and soil pH. Finally, acid soils recorded a higher desorption index compared to neutral and alkaline soils.

4.3 WATER MANAGEMENT

4.3.1 Optimal Water Resource Management Plan in Nuh Watershed, Haryana

After the revival of the waterbody in Nuh and creating an extra water availability of 22792 m^3, water resource management was investigated for 64.3 ha through the utilization of a range of irrigation methods such as surface, drip and pipe networks irrigation methods at different ratios 60:10:30, 50:10:40, 40:20:40, respectively, to optimize water utilization and crop management practices (intercropping, agroforestry, cropping pattern and farming system). A linear programming model was run in LINDO software to obtain the area allocation for the command area to develop the optimal plan. It was found that the 40:20: 40 ratio was the best, which provided 49% higher net return with a net profit of ₹ 4,29,071 ha/year and a water requirement of 14.03 ha-m.

4.3.2 Assessment of Drought-Vulnerable Zones in the Indo-Gangetic Plains Using Machine Learning

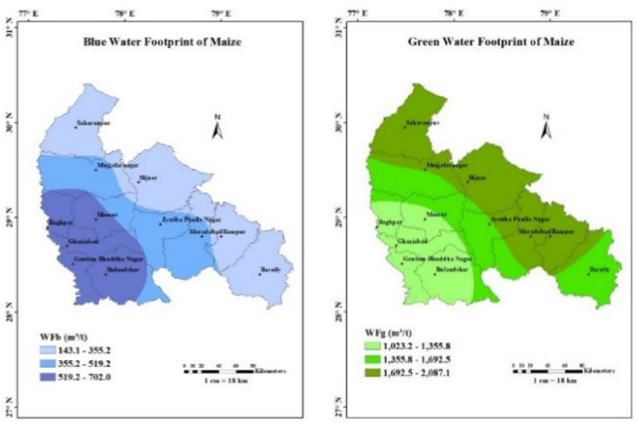
Drought prediction was carried out for the Agra and Budaun districts of Uttar Pradesh using the standardized precipitation evapotranspiration index (SPEI). SPEI values across various time scales (SPEI-1, SPEI-3, SPEI-6, SPEI-9 and SPEI-12) were calculated using the SPEI R package in RStudio. The predictions were assessed using the highest coefficient of determination (R^2) for both districts. For Agra, R^2 values were 0.70 (SPEI-1), 0.73 (SPEI-3), 0.70 (SPEI-6), 0.61 (SPEI-9) and 0.99 (SPEI-12). Similarly, for Budaun, R^2 values were 0.70 (SPEI-1), 0.68 (SPEI-3), 0.65 (SPEI-6), 0.62 (SPEI-9) and 0.71 (SPEI-12).

4.3.3 Assessing the Groundwater Recharge Potential in Yamuna Floodplain (NCT Delhi) Using A Groundwater Model

Yamuna Flood Plain (YFP) in NCT, Delhi has substantial potential for groundwater recharge. Dewatering aquifers in flood plain during non-monsoon would create space in aquifer which can be filled with water through recharge during monsoon season. Pumped water can be supplied to water scarce areas. Recharge potential in YFP was assessed using groundwater model MODFLOW. The groundwater recharge in YFP is 6.96 MCM. Increasing the pumping levels by 20%, 40%, 60% and 2 times of current pumping rate during non-monsoon period would result in decline of water table by 0.43 m, 0.53 m, 0.61 m and 0.78 m; respectively, which will increase recharge potential to 9.05, 11.31, 12.86 and 16.59 MCM/year, respectively.

4.3.4 Assessment of the Crop Water Footprint of Maize in the North-Western Plain Agro-Climatic Zone

A study was conducted to assess the green and blue water footprint of maize in the north-western plains using the crop water requirement model. The study utilized 20 years' weather and yield data for the region, spanning from 2000 to 2020. The results of the study revealed that the green and blue water footprints of maize were found to be 1540 and 434 m^3/t, contributing 78 and 22% of the total water footprint of maize, respectively.



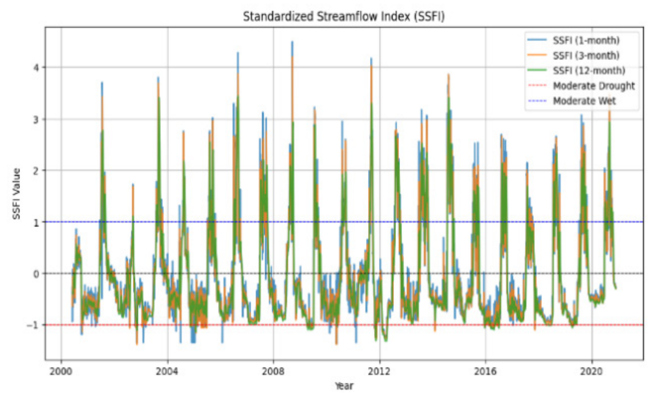
Spatial-variability map of blue and green water footprint in maize

4.3.5 Groundwater Quality Prediction for Karnal using Explainable AI Models

Automatic groundwater quality was estimated using Explainable Artificial Intelligence (XAI) for the Karnal district of Haryana. Two machine Learning models, Extreme Gradient Boosting (XGB) and Support Vector Machine (SVM) were compared to predict the quality of groundwater. The XGB outperformed the SVM in predicting the water quality index. The XAI revealed that the most significant feature contributing to prediction results in the case of XGB is calcium, with a SHAP value ranging from -1.5 to 1.5, followed by TDS and Sulphate.

4.3.6 Standardized Streamflow Index (SSFI) Developed for Lower Mahanadi Basin

The standardized streamflow index (SSFI) for the lower Mahanadi basin was developed using daily river discharge data collected from the Birupa gauging site during 2000-2020, provided by the Department of Water Resources, Government of Odisha. It revealed that periods with SSFI values falling below -1, across any time scale were identified as indicating moderate or more severe drought conditions. These drought events were most noticeable in the 1-month and 3-month SSFI curves. Wet conditions were particularly prominent in the 1-month and 3-month SSFI curves, which highlighted short-term variability, while the 12-month SSFI curve smoothened these extreme events, providing a more gradual depiction of overall water availability trends.



Standardized Streamflow Index for Lower Mahanadi Basin

4.3.7 Integrated Drip-cum-Mulch Practice in Basmati Rice and Millets

Three field trials evaluated the impact of the combination of drip cum mulch on yield and water-use efficiency of basmati rice (Pusa Basmati 1885), sorghum (CSH-41) and pearlmillet (Pusa 1201). The response of sorghum, pearlmillet and basmati rice to integrated mulch-cum-drip was found better and the grain yield of sorghum, pearlmillet and basmati rice increased by 34, 31 and 33%, respectively, compared to farmers' practice. Similarly, the water-use efficiency of sorghum and pearlmillet was higher by 45 and 38% compared to farmers' practice.

4.3.8 Enhancing Crop Water Productivity Using Sensors and Smart Irrigation Techniques

To enhance crop water productivity, real-time soil moisture sensor-based irrigation scheduling was done in wheat when soil moisture depletion reached or exceeded 50% in soil moisture sensor-based treatment. It showed that a total of 188 mm and 243 mm of irrigation were applied in sensor-based and conventional irrigation plots. Nearly 23% of water was saved under sensor-based irrigation scheduling in wheat. The water productivity in sensor and conventional plots was 1.84 and 1.42 kg m^{-3}, respectively.

4.3.9 Impact of Jalopchar Technology-based Wastewater Treatment Systems on Antibiotic Bacterial Resistance

Keeping in view the emerging global concern for increased antibiotic resistance, the impact of varied Jalopchar technology-based treatment systems was evaluated for microbial resistance against the antibiotics ciprofloxacin, amoxicillin and sulfamethoxazole. It indicated that Acorus Calamus-based treatment systems imparted the lowest antibiotic bacterial resistance and hence, were the safest treatment systems. This was perhaps due to significantly higher entrapment of antibiotic microbial strains by the laterally spreading meshy roots of the *Acorus calamus* as compared to those by the vertically spreading *Phragmites* and the *Typha*.

4.3.10 Integrated Sensing Device for Irrigation Scheduling

A low-cost integrated sensing device for irrigation scheduling (ISDI) was developed by integrating a canopy temperature sensor, air temperature sensor, humidity sensor and soil moisture sensor. Field experiments with maize in net houses and open fields, wheat in open fields and capsicum in greenhouses under different irrigation regimes were carried out for the validation of the device. The ISDI was calibrated using the gravimetric method for soil moisture measurement and the crop water stress index (CWSI) for crops was calculated. The scheduling of irrigation was recommended when the CWSI values were ≥ 0.51, 0.42, 0.35 and 0.28 for net house maize, open field maize, open field wheat and greenhouse capsicum, respectively.

4.3.11 Survey of NCT of Delhi to Know and Delineate Different Existing Water Bodies/Wetlands

The critical analysis of water supply and water demand for domestic, irrigation and industrial needs including the inventorization of water bodies both in terms of water quantity and quality was done under the Delhi Research Implementation and Innovation Project of the Government of India. A detailed survey was conducted in NCT of Delhi to know and delineate different existing water bodies/wetlands and their functional problems through primary and secondary sources *viz*. historical satellite images (Sentinel-2A), Normalized difference water index (NDWI), Google image and ArcGIS software. At the same time, rainfall patterns and runoff were estimated using Indian Meteorological Department (IMD) data and the Geospatial Curve Number method. About 467 Water bodies were identified in the NCT of Delhi during the non-monsoon season and 488 water bodies were identified during the monsoon season. Twenty-one water bodies dried during the lean period of rainfall in the NCT of Delhi. Water bodies occupied 2092 ha area, which is 1.40% of NCT of Delhi. North West District of Delhi has more water bodies (109), whereas East Delhi has very small number of water bodies (4).

4.4 AGRICULTURAL ENGINEERING

4.4.1 Telerobotic Target-Specific Pesticide Applicator

A telerobotic target-specific pesticide applicator (robot) was designed and developed for the real-time, judicious application of chemicals for greenhouses

Telerobotic Target-Specific Pesticide Applicator

and open fields. Pesticide use during greenhouse field evaluation was reduced by 24.95% with activation sensors than without activation of sensors. The theoretical field capacity, effective field capacity and field efficiency in greenhouse conditions with a vertical boom are 0.20 ha h-1, 0.15 ha h-1 and 75%, respectively, whereas with horizontal booms in open fields are 0.30 ha h-1, 0.22 ha-1 and 75%, respectively.

4.4.2 Robot for Weed Detection and Light Tillage

The rocker-bogie mechanism-based robot was designed and developed for light tillage and collecting information on weed. The length, width and height of the robot were 65, 48 and 45 cm, respectively. The robot comprises of a rocker-bogie mechanism-based chassis, motors (6 numbers, 12 V DC), wheels (6 number, 12 cm diameter), control box (18 cm x 26 cm x 8 cm), batteries (2 number 12VD, weeding unit (30 cm width, 3 number of furrow opener), linear actuator (100 cm, 12 V DC), controller and remote control. The robot was found suitable for crossing the bund height of 25 cm.

Weed Detection and Light Tillage Robot

4.4.3 Robotic Soil Sampler with Soil Sample Collection Unit

A robotic soil sampler with a soil sample collection unit was developed to collect the soil samples with

Robotic Soil Sampler

GPS tagging to facilitate the variable rate technology (VRT) application. The opening and closing time of the soil cutter was measured and found to be 28.78 and 28.91 seconds, respectively. The total time for a sample collection was found to be 2.83 min.

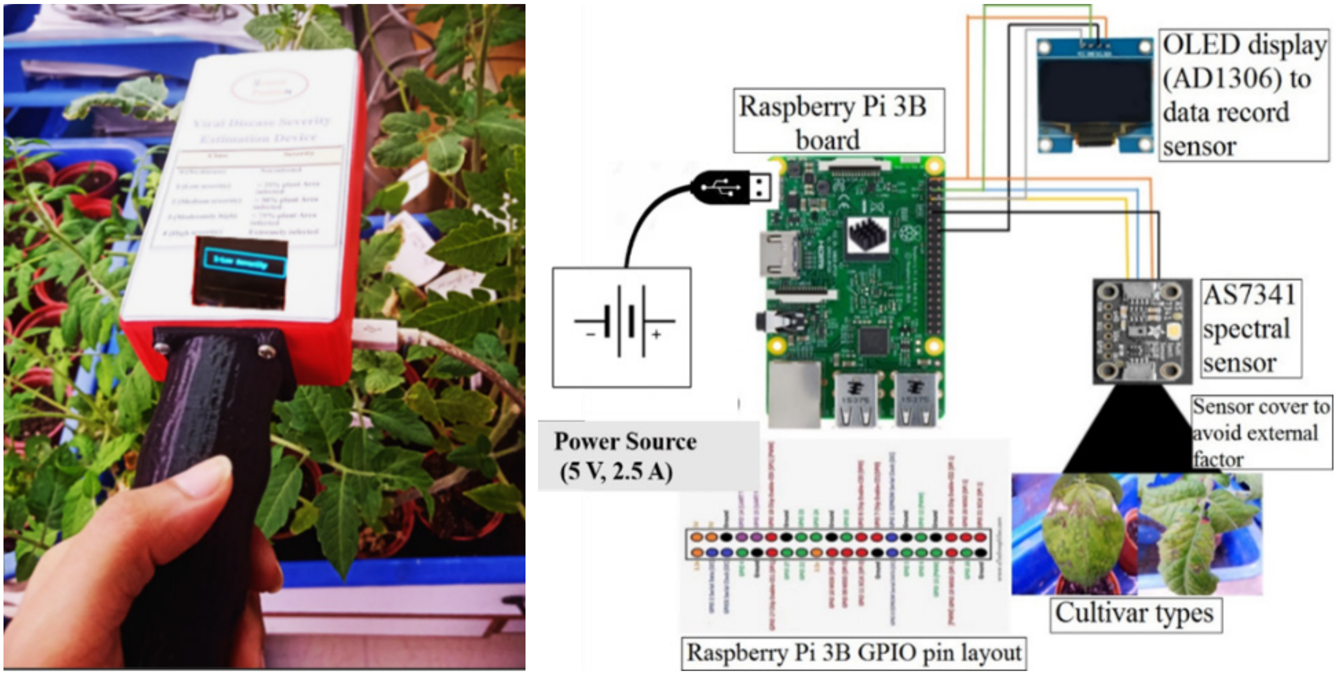
4.4.4 Raised Bed Pneumatic Precision Planter cum Fertilizer Applicator for Field and Vegetable Crop

The developed raised bed pneumatic precision planter-cum-fertilizer applicator can perform raised bed-making and planting of seeds in a single operation. It helps to improve the singulation of the seed and reduces the seed losses by reducing the missing index by 1-4% and multiple indexes by 1-3%. It reduces the labor cost by 30 to 60%. The pneumatic suction pressure can range from 20-50 kg/cm^2 depending upon the seed size of the crop. It has a field capacity of 0.68 ha/h and a field efficiency of 80-85%.

Raised Bed Pneumatic Precision Planter

4.4.5 Sensor-Based Device for Real-Time Detection and Severity Estimation of Groundnut Bud Necrosis Virus in Tomato

A machine learning-based approach was followed for developing a device for detection and estimation of groundnut bud necrosis virus (GBNV) severity in tomato plants. The developed machine learning model could categorize disease severity into five major classes, *i.e.* 0, 1-10, 11-25, 26-50 and >50%. Based on the model accuracy of the decision tree, a spectral sensor-based device was developed for disease detection and severity estimation.

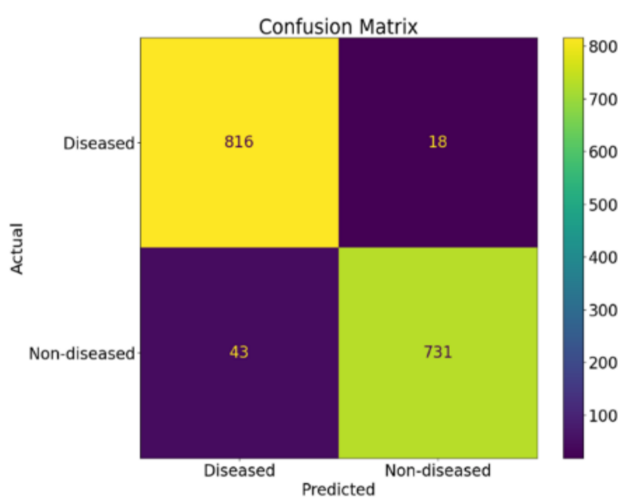


(a) (b)

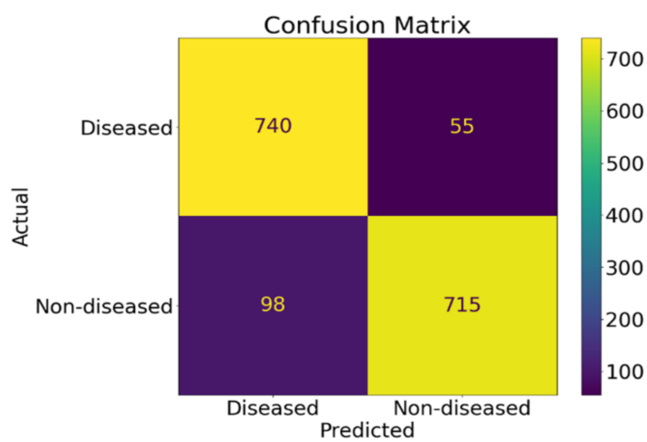
Device for GBNV disease severity under (a) Field evaluation (b) Internal circuit

4.4.6 Crop Disease Detection and Target Spray Application System

A novel multimodal approach was developed for detection and targeted pesticide application for black rot disease, particularly of cauliflower. Twenty models were assessed, comprising eight decision tree (DT) models and 12 support vector machine (SVM) models.



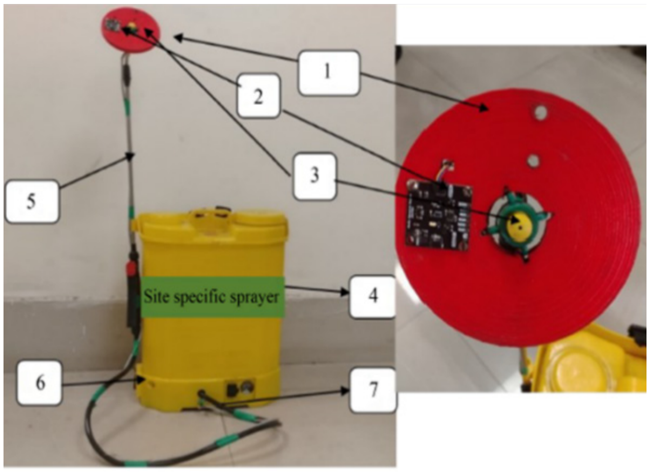
Confusion matrix of detecting black rot disease of cauliflower by decision tree model



Confusion matrix of detecting Black rot disease of cauliflower by support vector machine model

Of the total 1608 samples evaluated, the DT model accurately identified 740 cases as diseased and 715 cases as healthy. In contrast, the SVM model correctly classified 98% of the samples as diseased and 94% of the samples as healthy.

After selecting the precise components, a target sprayer was developed. The sprayer demonstrated the ability to detect 75% of diseased regions, recommend chemical application and accurately identify 87.5% of the healthy areas, where it remained inactive.



1. Sensor controlled discharge unit
2. Spectral sensor (AS7341)
3. Hollow cone nozzle
4. Battery-oprated knapsack sprayer
5. Spray lance
6. Switch
7. Elecrical connections for the sensor

Target sprayer

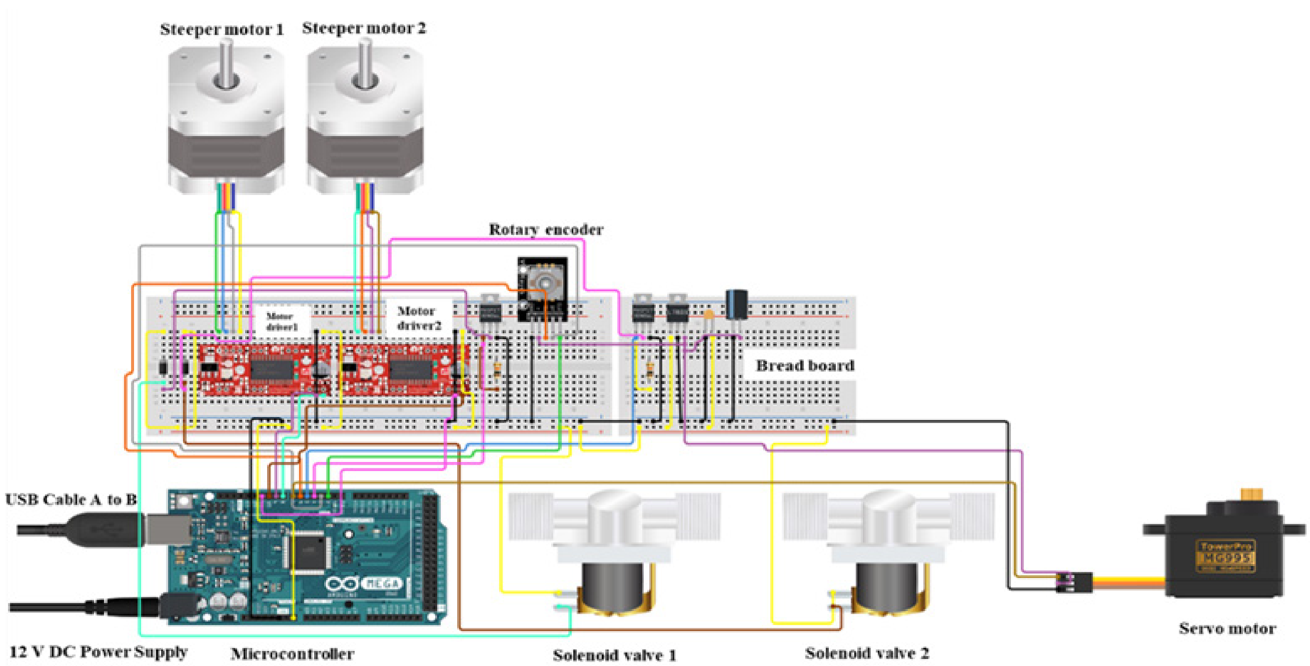
4.4.7 Design and Development of Sensor-Based Multiple Input Application System for Seeder

An integrated electronically controlled metering system of seed, granular fertilizer, water and pre-emergence herbicide application was designed for simultaneous and precise application of selected agricultural inputs. As the forward speed increased from 1.5 km/h to 2.5 km/h, the discharge rate of wheat seeds decreased from 207 to 61 kg/ha, missing index increased from 9.03 to 11.93%, multiple index decreased from 8.56 to 6.62%, quality feed index decreased from 82.56 to 81.14% and hill spacing increased from 9.38 to 11.9 cm. A flow rate of 6-8 lpm was ascertained by the water metering device. A rotary encoder effectively regulated the opening and closing actions of the two solenoid valves, which controlled the application of pre-emergence herbicide. The discharge rate of the air-injector flat nozzle ranged from 1.03 lpm to 2.42 lpm, the air-injector flat compact nozzle from 0.8 lpm to 1.4 lpm and the pre-emergence flat spray nozzle ranged from 1.02 lpm to 1.73 lpm with an increase in pressure from 1.5-3.5 kg/cm^2.

4.5. MICROBIOLOGY

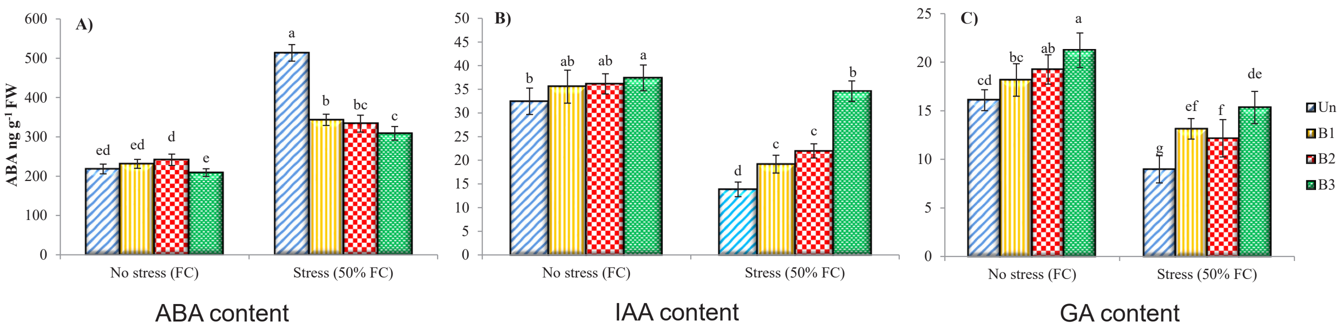
4.5.1 Development and Evaluation of Microbial Consortia/Formulations for Crops to Mitigate Stress

Field evaluation of the promising rhizobacterial bioformulations (B1, B2, B3) on mustard seedlings grown under osmotic stress (20% PEG 6000) showed



Sensor-Based Multiple Input Application System for Seeder

improved relative water content (RWC), plant photosynthetic pigments, reduced proline content and superoxide dismutase (SOD) activity. An increase in abscisic acid (ABA) content was also noticed under osmotic stress with a lowering of indole acetic acid (IAA) and gibberellic acid (GA).



Effect of rhizobacterial bioformulation on plant phytohormone status of mustard seedlings. Un-Uninoculated, B1- Bioformulation 1, B2- Bioformulation 2, B3 – Bioformulation 3

Under osmotic stress, inoculated treatments led to a significant lowering of ABA with the lowest observed for B3 (309 ng g^{-1} FW) compared to uninoculated (514 ng g^{-1} FW); while higher IAA and GA contents were noted in the bioformulation treatments compared with the uninoculated control. Seed endophytic bacteria from pearl millet exhibited a significant effect on plant growth, root traits and antioxidant status under osmotic stress conditions. Cyanobacterial inoculation (*Nostoc* sp. SGR3 and *Neowestiellopsis* sp. SGR8) demonstrated a significant ($p<0.05$) reduction in drought-induced effects like growth, water status, photosynthetic activity and antioxidant enzyme activities of wheat cultivar HD-2967 under irrigated (75% FC) and drought stress (25% FC) conditions

4.5.2 Microbial Inoculation Influencing Seed Germination and Seedling Growth under Water Deficit Stress Conditions

Sixty-three root-associated (rhizobial, non-rhizobial) bacterial isolates obtained from low and high-nodulating chickpea genotypes were screened for their various functional attributes. Indole acetic acid production by the non-rhizobial isolates ranged from 1.22 to 5.82 µg mL^{-1} of culture filtrate. Out of 36 non-rhizobial isolates, 15 isolates showed positive reactions in the qualitative assay for nitrogen fixation and 11 isolates showed pellicle formation, while 18 isolates showed positive reactions to full form ACC deaminase activity. The endobacteriome associated with spores of *Rhizophagus irregularis* were screened for functional traits and around 47% showed PGP activities.

A notable variation was observed among methylotrophic communities colonizing the phyllosphere of the studied crop species in terms of CO_2 release. The observed order was rice BPT >rice PB 1824 >rice Pusa Samba 1850 >rice Pusa 2070 >rice PB 6; among maize varieties maize CAH >maize AH 4675>maize Bio >9544 and among pearl millet varieties pearl millet HHB->pearl Millet Pusa 2303 >pearl millet Pusa 2202.

4.5.3 Harnessing the Potential of Microorganisms for Value-added Products and Conversion of Farm Waste to Wealth

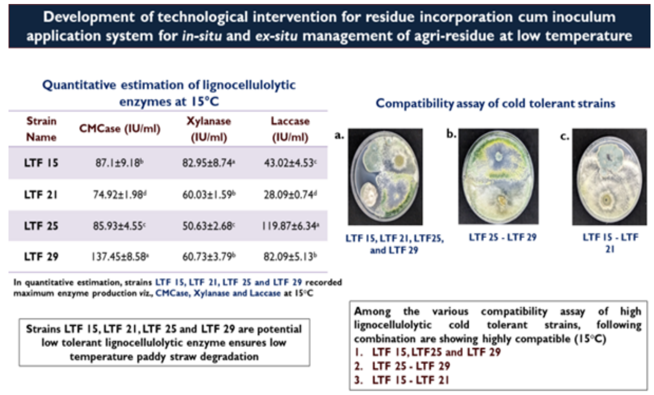
4.5.3.1 Gluconic acid, ethanol and pigments from microbes for value addition

A fungal consortium of *Talaromyces pinophilus, Penicillium oxalicum* and *Penicillium rubens* was used for gluconic acid production using potato waste. Fermentation parameters optimized for the production of gluconic acid were substrate (potato waste) 30g/L, pH 6.0, inoculum size 4%, temperature 30°C and 11 days fermentation period, which yielded 58.0 g/L of gluconic acid.

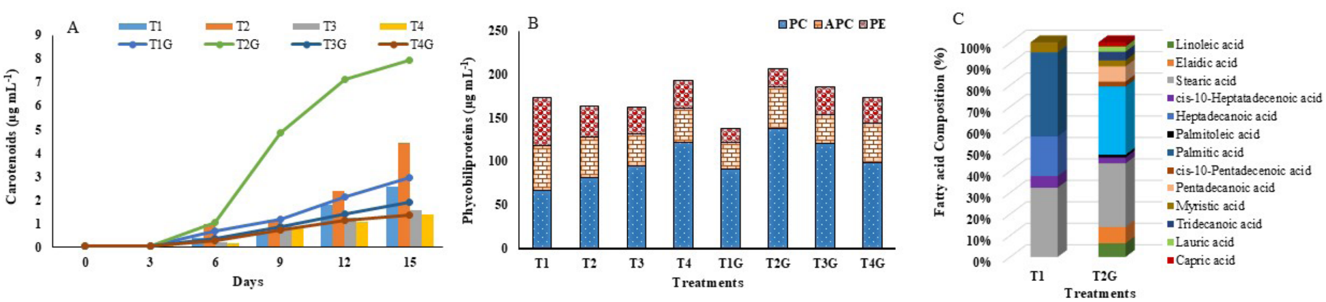
Initial alkali pretreatment of corn stover led to 53 and 47% enrichment in glucan content in variety PJHM 1 and PJHM2 of corn stover, respectively. The sugar concentration in the acid hydrolysates derived from PJHM 1 and PJHM 2 varieties were 0.9 and 1%, respectively. Saccharification efficiency of 85 to 90% was achieved at 5% substrate loading. Fermentation of the enzymatic hydrolysates with *Candida tropicalis* Y6 and *Saccharomyces cerevisiae* LN yielded maximum ethanol concentrations of 2.60 and 2.66%, respectively, within 48 h.

4.5.3.2 Technology for *in-situ* and *ex-situ* Management of Agri-Residue at Low Temperature

Based on various qualitative and quantitative assay, psychrotolerant microbes (LTF 8, LTF 15, LTF 16, LTF 19, *Penicillium chrysogenum*, LTF 25 and LTF 29) were observed to potentially degrade paddy straw at low temperatures. *Penicillium chrysogenum* showed consistent colony forming units (cfu/100 μL) after 24, 48, 72 and 96 h incubation at 15ºC as evident from freeze-drying experiments. FTIR analyses revealed that the psychrotolerant consortium of *Penicillium aethiopicum*, *Penicillium echinulatum* and *Penicillium chrysogenum* enhanced the cellulose and lignin degradation in paddy straw at low temperature.



The interactive effect of salinity (0, 5, 15 & 30 g/L) and trophic mode of growth (0 and 1g/L galactose) on the growth and biochemical composition of *Spirulina* species was assessed. The addition of NaCl significantly reduced the growth but led to a 3.08-fold increase in carotenoid production as phycobiliproteins and lipids. The unsaturated fatty acids, such as linoleic acid, elaidic acid and palmitoleic acid also increased.

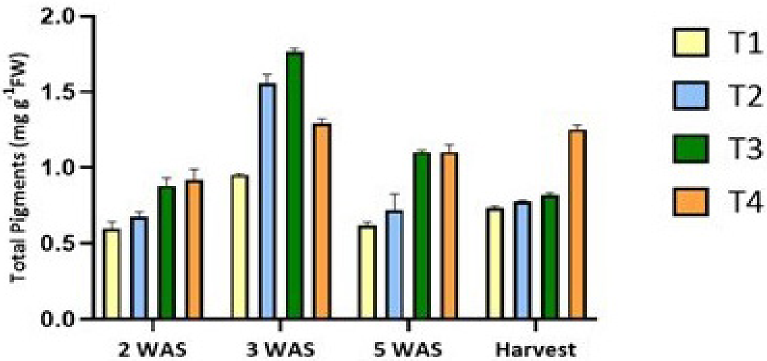


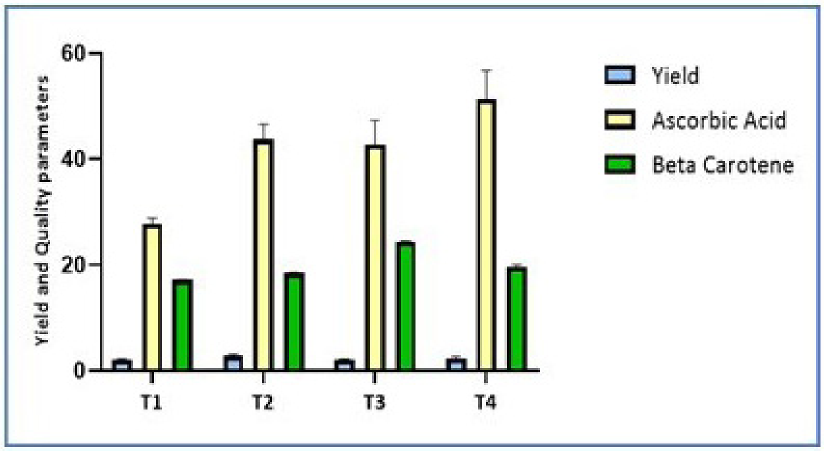
Optimization of carotenoids (A) and phycobiliproteins (B) production in *Spirulina platensis* CCC540 at different salinity levels under autotrophic and mixotrophic mode of nutrition at varying time intervals. Fatty acid profile (C) of *Spirulina platensis* CCC540 grown under Control (T1) vis-à-vis Optimal condition (T2G).
Control (T1); Control + 1 g L^{-1} Galactose (T1G); 5g L^{-1} NaCl (T2); 5 g L^{-1} NaCl + 1 g L^{-1} Galactose (T2G); 15 g L^{-1} NaCl (T3); 15 g L^{-1} NaCl + 1 g L^{-1} Galactose (T3G); 30 g L^{-1} NaCl (T4); 30 g L^{-1} NaCl + 1 g L^{-1} Galactose (T4G)

Carotenoid (A), Phycobiliproteins (B) content of *Spirulina platensis* CCC540 at different salinity levels under autotrophic and mixotrophic modes of nutrition at varying time intervals

4.5.4 Novel Bacteria-based Bioinoculants and Delivery System for Crop Nutrient Management and Climate Resilience

Cyanobacterium-based formulations (*Anabaena laxa* C11, *Nostoc carneum* BF2 and *Anabaena* laxa RPAN8) for seed coating followed by soil drenching at selected growth stages was evaluated in the spinach variety, Pusa All green, in the nursery, followed by a field experiment under shade net conditions. RPAN8 treatment increased yield while BF2 treatment stimulated ascorbic acid (0.37-fold), antioxidants (0.36-fold) and β carotene (0.41-fold) in leaves over control. C11 treatment was the top performer as it brought about overall enhancement in terms of growth, yield and quality attributes.



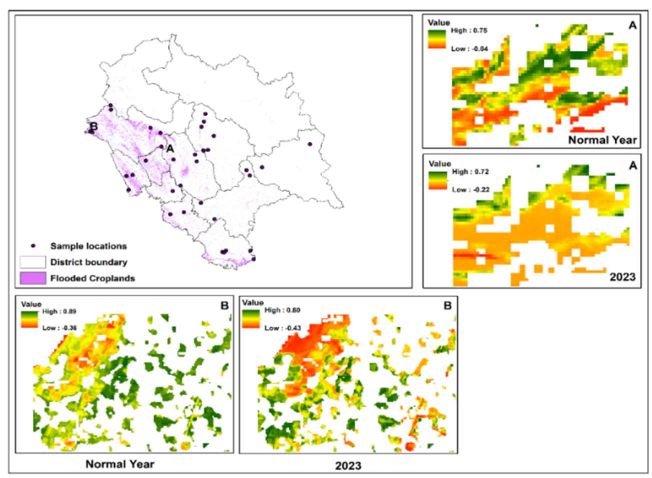


Dual inoculation of arbuscular mycorrhizal fungi (AMF) with P solubilizing mycorrhiza helper bacteria was compared with AMF alone in maize and wheat under field conditions. There was a significant increase in maize cob length (18%) and weight (12%) with enhanced P content under dual inoculation. Phosphatase enzyme activities and available phosphorus were considerably enhanced up to 36.67% in rhizospheric soil and further 26.94% increased uptake in the shoot, root and grains of wheat.

4.6. ENVIRONMENTAL SCIENCE

4.6.1 Machine Learning–Remote Sensing Data-based Method for Flood-related Crop Loss Estimation

A method for estimation of yield loss due to extreme flood events using remote sensing microwave data and machine learning algorithms is developed and applied for crop yield loss estimation in Himachal Pradesh. The



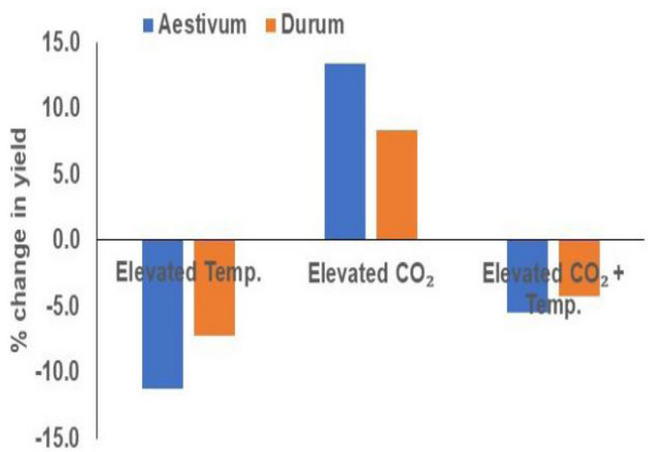
efficiency of this method in estimating the croplands affected by the flash flood that occurred in July 2023 in Himachal Pradesh was found to be very good with Una, Hamirpur, Kangra and Sirmaur districts identified as the most affected areas, with about 9.0, 6.0, 5.74 and 3.61% of the respective districts' total geographical area under flood. Further, four machine learning algorithms (random forest, support vector regression, k-nearest neighbour, and extreme gradient boosting) were evaluated to forecast maize and rice crop production and potential loss during the Kharif season in 2023. Amongst the four algorithms, random forest showed outstanding performance compared to others. The maximum production loss of maize is estimated for Solan (54.13%), followed by Una (11.06%) and of rice in Kangra (19.1%), Una (18.8%) and Kinnaur (18.5%) districts. This indicated the utility of the proposed methodology for a quick in-season forecast on crop production loss due to climatic hazards.

4.6.2 Global Climate Model (GCM) Ensemble Data Generated for Analysing Agricultural Seasonal Climate Scenarios

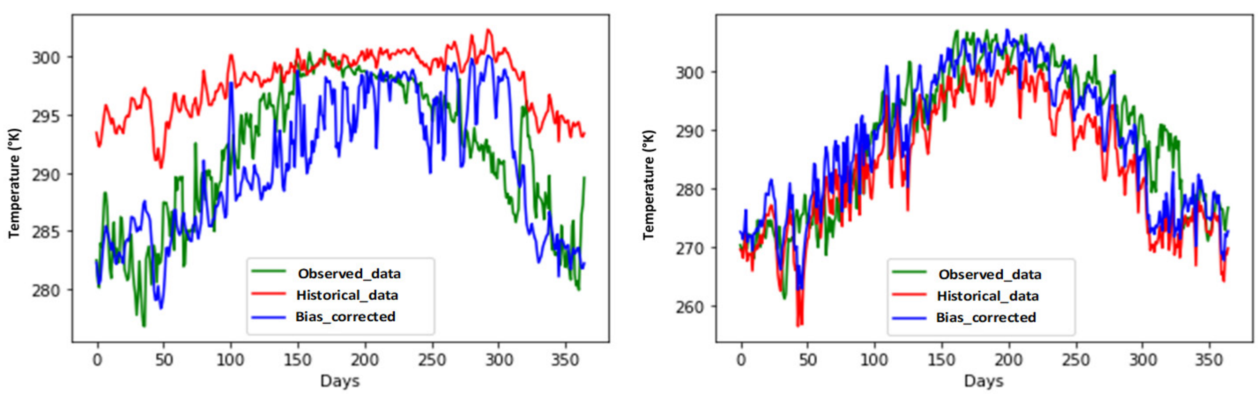
The 21 GCM historical simulated data on daily data on maximum and minimum temperatures and rainfall were analyzed for bias identification with respect to the Indian Meteorological Department gridded data for the 1980-2014 period. The models were found to have a cold bias in the Northern latitudes and higher altitudes of India while a hot bias in the southern latitudes of India. The models' data were bias corrected using the quantile mapping method for the historical period (1951-2014) and then proceeded for the bias correcting the future climate scenarios for the 2015-2100 period under shared socioeconomic pathway (SSP)-representative concentration pathway (RCP) combination of 2-2.4; 3-7.0 and 5-8.5. This is being done to develop the climate scenarios for agricultural seasons in India.

4.6.3 Response of *aestivum* and *durum* Wheat to Elevated CO_2 and Temperature

A field study was undertaken to evaluate the interactive effect of elevated CO_2 and temperature on *aestivum* and *durum* wheat. Both *aestivum* (HD 3226)



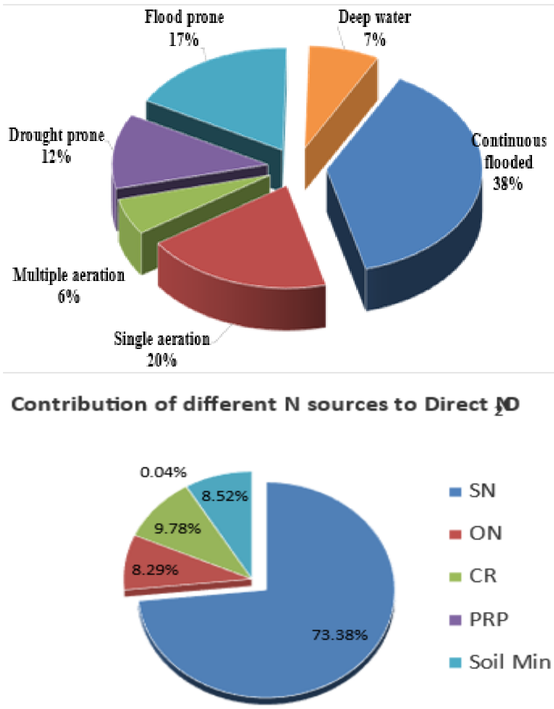
and *durum* (HI 8627) varieties were grown inside the open-top chambers (OTC) under two levels of CO_2 concentration (ambient and elevated 550 ± 25 ppm and two temperature levels *i.e.* ambient and elevated (+2.5^{0}C above ambient). The seasonal mean temperature within the controlled chamber was 17.7-17.9°C. Yield reduction due to temperature rise was less in *durum* varieties as compared to *aestivum* varieties. In combined elevated CO_2 and temperature treatment, yield reduction was 5.5% in *aestivum* wheat and 4.2% in *durum* wheat compared to ambient treatment. Elevated CO_2 concentration compensated reduction in yield by 5.7% in *aestivum* and by 3.0% in *durum* varieties, under elevated temperature conditions.



Global climate model data bias for historical temperatures and bias corrected ones

4.6.4 Methane and Nitrous Oxide Emissions from Agricultural Soils

The inventory of methane and nitrous oxide emissions from agricultural soils was prepared using the IPCC inventory preparation guidelines for the base year 2021-22.



(a) Methane emission from different rice grown under different water regimes, (b) Contribution of different N inputs to nitrous oxide emissions

The methane emissions from rice cultivation amounted to 3.57 Gg from 46.28 Mha of cultivated area under different rice ecosystems. The total direct emissions of nitrous oxide were 231.96 Gg, out of which 168 Gg were from consumption of 19.438 MT of synthetic N fertilizer. The indirect N_2O emissions for 2021-22 were estimated to be 58.36 Gg from all sources of N input to agricultural soils.

4.6.5 Phosphogypsum-coated Urea for Methane Mitigation and Reducing Greenhouse Gas Intensity in Rice

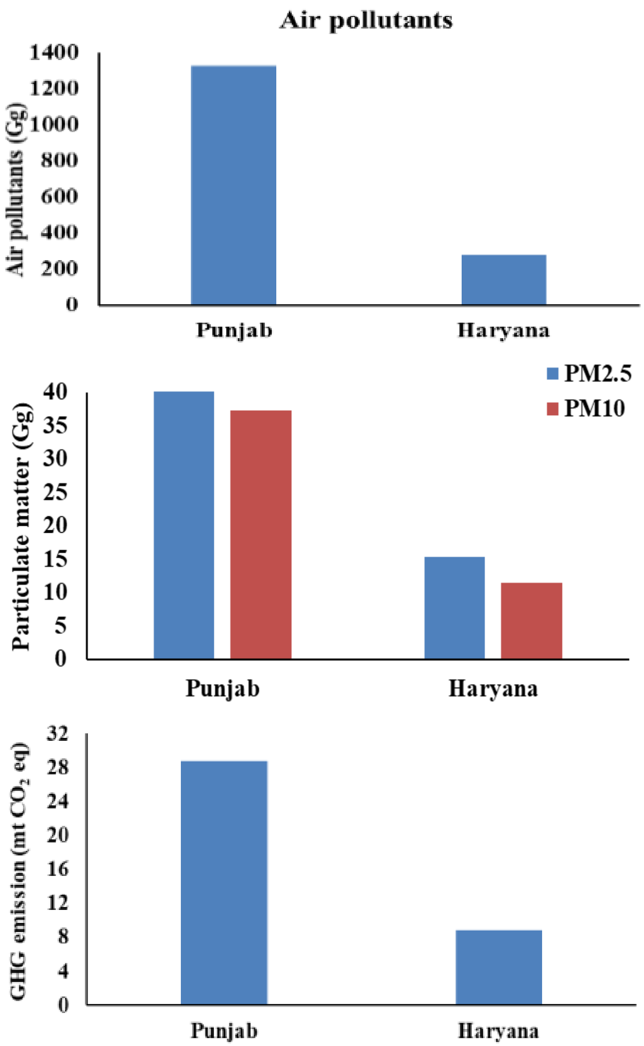
A 5% coating of phosphogypsum was coated onto prilled urea with guar gum to make it a slow-release fertilizer and was evaluated for reducing greenhouse gas (GHG) emissions from rice under alternate wetting and drying irrigation. Phosphogypsum-coated urea significantly improved yield parameters, agronomic efficiency and reduced cumulative CH_4 and N_2O emissions and global warming potential by 12.5% compared to prilled urea and by 6.2% compared to neem-coated urea.

4.6.6 Plant-based Coated Fertilizer for N_2O Mitigation from Vegetable Crops

Three plant-based coated fertilizers namely resin-coated urea (PCU), tagetus extract-coated urea (CU1) and biochar-coated urea (CU3) were prepared and tested under lab conditions for their N release pattern. These fertilizers were then tested under field conditions growing onion (var. AFLR) and were compared with urea and neem-coated urea (NCU). The N was applied @ 150 kg N/ha in three equal splits. The N_2O emission varied between 0.44 and 2.28 kg/ha and the N loss ranged from 0.53-0.78% in different N sources. The mitigation potential of different coated fertilizers ranged from 10-25.8% and biochar-coated urea showed maximum mitigation potential (25.8%) compared to urea and 17.32% compared to NCU. The bulb yield was at par with urea in all the treatments except the CU3 treatment, where it was significantly higher than urea but similar to NCU.

4.6.7 Greenhouse Gases (GHG) Emission from Rice Residue Burning in Punjab and Haryana

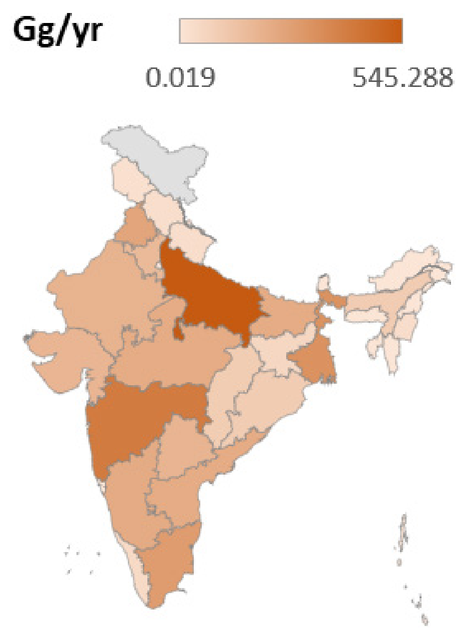
The amount of rice straw burnt and the emission of GHG and air pollutants due to the burning of rice residues in the districts of Punjab and Haryana was quantified based on real-time monitoring of rice area burning. In 2023, ~78% of rice residue was burned in the districts of Punjab compared to ~ 70% in 2022, whereas in Haryana, rice straw burned was ~66% compared to ~25% in 2022. The rice stubble burning in the districts of Punjab and Haryana (~27 million tons) resulted in the emission of 37.6 million tonnes of GHG (CO2 eq) and 65.10 Gg of PM2.5. 48.82 Gg of PM10 and 2.69 million tonnes of gaseous air pollutants. The area under rice cultivation is almost the same in the two states, but the percent of rice area burned has shown an increasing trend from 2019 in Punjab and 2021 in Haryana.



Emission of air pollutants and GHG from rice residue burning in the states of Punjab and Haryana

4.6.8 Emission of Reactive Nitrogen from Crop and Livestock in India and Mitigation Strategies

Agricultural activities like crop and livestock production are the major source of reactive nitrogen (Nr) emission accounting for 80-90% of NH_3, 10% NO and 60-70% of N_2O to the global anthropogenic emission of these gases. The present study estimated the emission of the two Nr gases (NH_3, NOx) from Indian agriculture for the base year 2015 using IPCC 2006/EMEP guidelines and India-specific management practices and emission factors. The NH_3 and NOx emissions were estimated to be 2864 Gg/yr and 191.86 Gg/yr from agricultural soil and 105.8 Gg/yr and 256.4 Gg/yr from crop residue burning, respectively. Uttar Pradesh had the highest emission of Nr among the states of India. Our estimates were lower compared with estimates of the Emissions Database for Global Atmospheric Research (EDGAR) and Hemispheric Transport of Air Pollution (HTAP) for India.



Spatial distribution of reactive nitrogen (Nr) emission from agriculture

4.6.9 Conservation Agriculture Impacts on Soil Organic Carbon Sequestration in a Rice-wheat Cropping System

After nine years of conservation agriculture (CA)-based rice-wheat cropping system, a CA practice that involved mung bean residue (MBR)+ zero-till DSR-rice residue (RR)+zero-till wheat (ZTW)-wheat residue (WR)+zero till mungbean resulted in ~29.9% higher total soil organic carbon (SOC) in the topsoil (0-5 cm) (7.77 g kg^{-1}) and ~23.0% higher total SOC stock and ~27.9% higher labile C in bulk soil than in puddled transplanted rice (PTR)–conventional till wheat (CTW) plots. These also led to ~31% higher macroaggregate-associated carbon and ~46.3% higher labile C within macroaggregates. This can be a viable practice for rice-wheat cultivation through enhancing carbon sequestration and soil stabilization and mitigating climate change.

5. PLANT PROTECTION

The school of Plant Protection develops innovative technologies for the management of pests and diseases in crops. During the year under report, studies were taken up on the diversity of pathogens and insects, new records of invasive pests/pathogen strains, utility of genomic tools to unravel host pathogen/nematode interaction, mining of novel genes, identifying resistant sources of crop cultivars against pests and pathogens, epidemiology, new disease reports, genome editing techniques to suppress the nematode infection and utilization of genomic and AI tools for development of rapid diagnostic kits against pests and pathogens were undertaken. Besides biological control agents, novel chemical molecules were identified to form a part of integrated management.

5.1 PLANT PATHOLOGY

5.1.1 Disease Diagnosis and Pathogen Characterization

Maintenance of fungal cultures and disease specimens: About 50,650 fungal specimens at HCIO; 4190 fungal cultures at the Indian Type Culture Collection (ITCC) were maintained under different preservative methods at the Division of Plant Pathology. A total of 446 authentic fungal cultures to various scientific and industrial institutions were supplied on request. Forty cultures were accessioned out of 143 cultures identified.

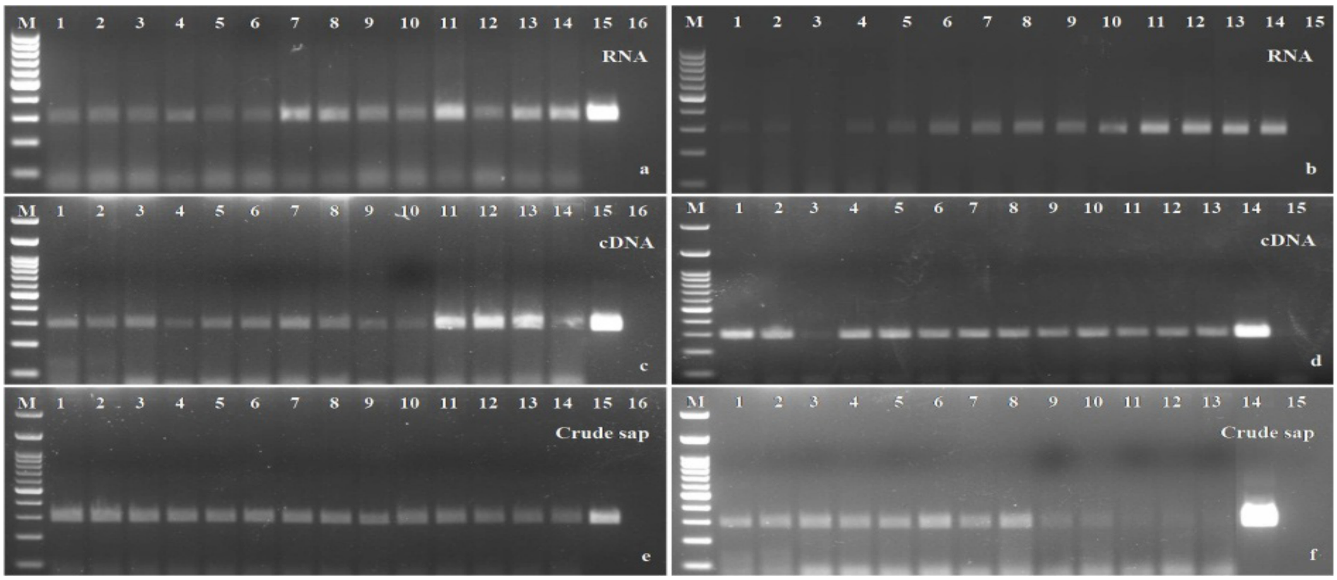
Diversity of fungal pathogens: Cryptic diversity *Fusarium oxysporum* species complex (FOSC) was explored using 100 isolates collected from diverse ecosystems across India. Morphological characterization and molecular analysis identified eight cryptic species *viz*., *Fusarium foetens, F. inflexum, F. vanleeuwenii, F. hoodiae, F. nirenbergiae, F. gossypinum, F. vaughaniae* and *F. landiae*. Macro fungi diversity in Kashmir Valley identified a total of 45 distinct mushroom species belonging to *Ganoderma, Trametes, Schizophyllum, Pleurotus, Coprinellus, Coprinopsis* and *Pholiota* genera. Forty *Aspergillus* isolates were obtained from infected maize cobs across 14 states in India. *Aflatoxin B1* (*AFB1*) levels ranged from 0 to 9.65 ppm. Isolate AF-11 (New Delhi) was the most aflatoxigenic (9.65 ppm AFB1), ITS sequencing confirmed 39 isolates as *A. flavus*, while one isolate (AF-35) was identified as *A. nomiae*. A total of 67 fungal isolates, comprising 25 *Macrophomina phaseolina* isolates, 35 *Fusarium* spp., four *Lasiodiplodia* spp. and 3 unidentified isolates were established from maize stalk samples infected with Post Flowering Stalk Rot (PFSR) of maize.

Detection, identification and molecular characterization of phytoplasma: Nested PCR assays identified the phytoplasma, *Candidatus Phytoplasma asteris* (a6SrI-B group) associated with sesame phyllody. Surveys of symptomatic and asymptomatic *Aegle marmelos* detected the presence of *murraya little leaf* phytoplasma, *Ca. P. australasiaticum* (16SrII-D subgroup). Analysis of black cumin (***Nigella sativa***) plants exhibiting leaf yellowing and witches' broom symptoms identified the phytoplasma, *Ca. P. trifolii* (16SrVI-D subgroup). A survey in *Withania somnifera* fields in Uttar Pradesh recorded the presence of phytoplasm *Ca. P. trifolii* (16SrVI-D subgroup).

Diagnostic kits

- A rapid and reliable duplex RT-PCR assay was developed and standardized for the simultaneous detection of Citrus yellow vein clearing virus (CYVCV) and Citrus yellow mottle associated virus (CiYMaV) in infected Kinnow mandarin.
- The LAMP-based detection method (*MagnaTracker*) was refined for the rapid and accurate diagnosis

of rice blast disease in field conditions and early pathogen detection in seed lots. An RPA-based assay was optimized for the detection of grapevine virus B (GVB) using RNA, cDNA and crude sap templates. This assay is an efficient and reliable alternative to conventional RNA and cDNA-based assays.



RPA validation in grapevine rootstocks Dogridge (a, c & e), Paulsen and Ramsey (b, d & f) for the detection of GVB using three templates a-b: RNA. c-d: cDNA and e-f: crude sap

- Developed a one-step RT-RPA assay for the detection of potato Leaf roll viral disease (PLRV). The assay can detect up to 10^{-2} RNA copies with high specificity with no cross-reactivity to other potato viruses; the assay efficiently detects PLRV from simple extracts of fresh or preserved leaf and tuber samples. This is the first report of a simplified RT-RPA method for PLRV detection.
- A one-step RT-RPA assay was developed for *Potato Virus A* (PVA) detection in leaves and tubers. This assay is ideal for indexing tissue-cultured plants, seed certification and germplasm screening for PVA resistance.
- Standardized a CRISPR-Cas12a-based Lateral Flow Assay (LFA) for on-site detection of Chilli leaf curl virus using FAM-biotin-tagged oligo reporter. This LFA system has high specificity to detect only ChiLCV.

5.1.2 Host-pathogen Interaction and Genomics

Virulence analysis of powdery mildew (*Bgt* isolates): By applying avirulence/virulence formulae of Bgt cultures, the effective and ineffective powdery mildew (PM) gene(s) were detected from PM-infected wheat samples collected from different wheat-growing areas of the country. Virulence was detected on the *Pm3a*, *Pm3b*, *Pm3c*, *Pm5*, *Pm7* and *Pm8* genes, while no virulence (avirulence) was detected on the *Pm1*, *Pm2*, *Pm4a* and *Pm6* genes, indicating the effectiveness of these genes in the country.

Histopathology and transcriptomic analysis of wheat-rust interaction: Rust resistant wheat genotypes, Avocet (with *Yr*15 and without *Yr*15) and C 306 (with *Lr*28 and without *Lr*28) were selected for this study based on the preliminary findings of relative expression analysis of PR genes (PR 1, PR 2, PR 3, PR 5 and PR 10) in these wheat genotypes challenged with virulent pathotypes of *P. striiformis tritici* and *P. triticina*.

Efficacy of antagonists and chemical inducers in inducing resistance, promoting growth and biocontrol against wheat biotrophs: Tested the potential of three bacterial (*Pseudomonas fluorescens* strain DTPF-3, *Bacillus amyloliquefaciens* strain DTBA-11 and *Bacillus* *subtilis* strain DTBS-5), two fungal (*Trichoderma harzianum* strain Pusa-5SD and *Aspergillus niger* strain An-27) antagonists and two chemical inducers (BABA, Salicylic Acid) at different doses against wheat rusts and for its impact on induced resistance and plant growth promotion under greenhouse conditions. All tested microbial antagonists at 10 g/kg significantly reduced disease severity, with *B. subtilis* strain DTBS-5 outperforming others in reducing disease severity and achieving the highest biocontrol efficacy. Wheat crop treated with *B. subtilis* strain DTBS-5 exhibited substantial increases in defense-related enzyme activities and biochemicals, suggesting an induced resistance mechanism.

IARI-PDSN entries (460) evaluated at multi-hot-spot locations across the country for rusts, leaf blight and PM resistance. Evaluation of wheat genotypes, IPPSN (1214), PPSN (324), EMDSN (59) and FFSN (134), revealed that 578, 134, 28 and 78 entries, respectively, were found to be resistant to moderately resistant at adult plant stage against both stripe and leaf rust.

Micro RNA sequencing of *Tilletia indica* using the Illumina NovaSeq 6000 platform identified a total of 172 miRNAs in *T. indica*. Transcriptome analysis of *Bipolaris sorokiniana*- barley revealed 6,283 genes of *Hordeum vulgare* were differentially expressed in resistant genotype, whereas, 1,158 genes were differentially expressed in the susceptible genotype. Further, pathways involved in MAPK signaling, plant-pathogen interaction and plant hormone signal transduction were highly enriched in resistant genotypes. Genome analysis of *Bipolaris maydis* inciting leaf blight of maize computed its genome size (36.05 Mb) having 56 contigs and predicted a total of 8,866 genes (SRA: SRR19262264, SRR19262263). Seed treatment with *B. bassiana* and *T. asperellum* enhanced biochemical defenses in chickpea against *Sclerotinia sclerotiorum*. The *T. asperellum* isolate (ITCC 8687) showed the highest seedling vigor index. Morphological and phylogenetic analyses identified *Fusarium falciforme*, *F. incarnatum* and *F. proliferatum* in Indian eggplants for the first time. Pathogenicity tests confirmed all isolates as pathogenic, with varying virulence. *SIX* effectors were expressed in some non-*F. oxysporum* isolates for the first time. A highly aggressive *Rhizoctonia solani* isolate infecting rice produced a phytotoxin inducing necrotic symptoms. Bioassay-guided fractionation identified 3-butylpyridine (3-BP) as the primary bioactive compound. Two *Trichoderma* spp. isolates effectively neutralized 3-BP and reduced toxin-induced symptoms.

Characterization of bakanae resistance: Transcriptome analysis of bakanae-inoculated resistant and susceptible genotypes of rice analyzed a total of 32 genes *in-silico* and predicted their functions. Expression of RGA 2, RGA 5(b) and RGA 5(c) correlated with the varietal resistance at the early germination stage.

Identification of viruses and viroids: Transcriptome analysis of eight peach samples from four varieties (*Nemagaurd, Meripendent, B6* and *Uzbek White Nucipersica*) identified infections by eight viruses: *Prune dwarf virus* (PDV), *Prunus necrotic ringspot virus* (PNRSV), *Nectarine stem pitting-associated virus* (NSPaV), *Peach-associated luteovirus* (PaLV), *Grapevine red globe virus* (GRGV), *Citrus sudden death-associated virus* (CSDaV), *Grapevine asteroid mosaic-associated virus* (GAMaV) and *Peach virus D* (PVD), along with a novel *Prunus persica marafi virus* (PPMV). Near complete genome sequences of citrus concave gum-associated virus (CCGaV), apple rubbery wood virus 1 (ARWV-1), ARWV-2, apple necrotic mosaic virus (ApNMV), apple mosaic virus, apple stem pitting virus, apple stem grooving virus, apple chlorotic leaf spot virus, apple hammerhead viroid and apple scar skin viroid were reconstructed. Among them, CCGaV, ARWV-1 and ARWV-2 have been recorded in apples in India for the first time. A novel grapevine viroid was discovered in an asymptomatic grapevine of Indian rootstocks. The whole genome sequence of the viroid (370 nt) by high-throughput sequencing determined the demarcation criteria for viroids and the novel viroid identified was named as “grapevine yellow speckle viroid 3” and is a putative new member of the genus Apscaviroid.

Molecular mechanism of resistance against begomoviruses: In tomato resistance against begomoviruses are governed by Ty-3 loci. RNA dependant RNA Polymerase 5 (RDR5) gene. Four host proteins, *i.e*. AGO-1, Hsp70, SGS3 and EiF4E were found to interact with RDR5 protein through yeast 2 hybrid analysis. In soybean, the RNA silencing pathway genes *RDR1* and *SGS3* were upregulated in resistant genotypes following *Mungbean yellow mosaic India virus* (MYMIV) inoculation. The transcriptomics and metabolomics analyses revealed the involvement of secondary metabolites in the resistance mechanism. High-throughput sequencing (HTS) identified the viruses associated with the Kinnow mandarin (*Citrus reticulata*). RNA sequencing using NovaSeq 6000 revealed near-complete genomes of two mandariviruses, *i.e.* citrus yellow vein clearing virus (CYVCV) and citrus yellow mottle-associated virus (CiYMaV).

Virus vector interactions: The silencing of *BtPGRP* using double-stranded (ds) RNA led to the loss of innate immunity to ChiLCV, resulting in increased virus titer within *B. tabaci*. The test plants inoculated with ChiLCV by *dsBtPGRP*-exposed *B. tabaci* expressed severe curling symptoms with a higher virus load and transmission ratio than the control. The silencing of BtPGRP also induced up to 56.67% mortality in treated *B. tabaci*. The silencing of *V-ATPase-B* of *T. palmi* resulted in increased mortality (57.03%) of the thrips and reduced reproductive fitness (67.73%). Two consecutive sprays naked ds*V-ATPase-B* at a concentration of 5.0 μg/mL provided substantial protection against the fresh release of *T. palmi* for up to 10 days.

5.1.3 Host Plant Resistance

Fusarium Head Blight (FHB) and Karnal Bunt (KB): Four genotypes *viz*. IC082302, IC573145, IC5099326, IC73595 showed moderate resistance to FHB during 2022-23 and 2023-24. Sumai 3, resistant genotype showed the presence of a band with FHB1 marker. All other genotypes did not show a band with the FHB1 marker. Out of 238 wheat germplasm evaluated, 15 genotypes were found resistant *viz*. IC111822, PRB5, IC296437, IC311079, IC347884, IC416026, IC416065, IC469485, IC531233, IC531275, IC532086, IC582705, IC398298, IC273946 and IC362041.

Rice Blast: Out of 500 rice genotypes, 13 entries showed complete resistance. In AICRP Rice Trials, 31 entries were found promising, giving resistant-type reactions (score ≤3). The entries included IET Nos. 28645, 28451, 28421, 28178, 28171, 27358, 28664, 27823, 28489, 27686, 27641, 28507, 27037, 27851, 28732, 27637, 28654, 28664, 27829, 28491, 28452, 27077, 27438, 28818, 28160, 28683, 27907, 28750, 28136, 27809 and 28641 were promising.

Bakanae: Out of 500 germplasm evaluated against bakanae disease of rice, nine accessions IC 115788, IC 388273, IC 135584, IC597677, IC 619255, IC 121871, IC 458745, IC 463089, IC 454659 were identified resistant against bakanae disease of rice.

Sheath Blight: Out of 500 germplasm evaluated against sheath blight of rice 14 accessions IC455563X, IC86190, IC207598, IC460318, IC132874, IC259026, IC518955, IC449663, IC464447, IC283602, IC386259, IC461682, IC386345, IC517880 were observed moderately resistant.

Pearl Millet: Out of 77 pearl millet genotypes evaluated for blast resistance different trials *viz.,* 19 entries (PMBVN-20-1, PMBVN-20-2, PMBVN-20-3, PMBVN-20-7, PMBVN-20-8, PMBVN-20-10, PMBVN-20-13, PMBVN-20-15, PMBVN-20-17, PMBVN-20-18, PMBVN-20-36, PMBVN-20-38, PMBVN-20-42, PMBVN-20-43, PMBVN-20-48, PMBVN-20-50, PMBVN-20-51) were identified as resistant.

Maize leaf blight and banded leaf sheath blight: Screening of 365 maize genotypes for resistance sources for maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*) diseases found that only one genotype (AHD-2077) was resistant against MLB and none to BLSB disease. Some promising MR genotypes identified for MLB were BAUMH 22-1-1, SRHM 99M66, HM22201, BS 600, DH 361, INDAM 1252, HM 21204, IQPMH 2012. Against BLSB some promising genotypes identified were AHD 8751, BRMQ-20-1, JKHSB 20K-10, IW 8477, CP 509, R 8050, PM 211112.

Identification of resistance sources against Fusarium wilt of chickpea caused by *Fusarium oxysporum* f.sp. *ciceris*: Out of 268 Chickpea entries comprising IVT, AVT1 and AVT 2 (Desi, Kabuli, Rainfed Late Sown, MH, DTIL, WRIL etc.), 34 entries were recorded resistant to Fusarium wilt. 123 entries exhibited moderate resistance, 59 entries were moderately susceptible, 38 were susceptible and 14 entries were highly susceptible.

Identification of resistance sources against stem rot of chickpea caused by *Sclerotinia sclerotiorum:* Out of 99 chickpea entries, two entries, namely IGK 2021-54 and GJG 2206 exhibited resistance against stem rot disease of chickpea caused by *S. sclerotiorum*. Five entries namely IG-21-68, GLK 21080, GLK 21098, Phule G 1302-03-05, GJG 1809 and ICCV 13616 had expressed moderately resistance reaction to stem rot disease.

Production and distribution of decline free/resistant citrus planting materials for NE India: For production of virus and virus like pathogens free (CTV, CG, CYVCV and ICRSV) Khasi mandarin (*C. reticulata*), 11 Khasi mandarin plant Mohan MP 1, Mohan MP 3, Boko KM- 9, G-Das-7, Karuna KM-3, Karuna KM-6, Karuna KM-11, Karuna KM-13, Karuna KM-30, Karuna KM-31, Karuna KM-34 were identified free from these infection by ELISA and PCR test.

5.1.4 Disease Management

Plant endophytic *Bacillus* for management of rice blast and bacterial wilt: The endophytic *Bacillus* isolated from rice leaves and triangular spurge showed potent inhibitory activity against the rice blast pathogen through antagonism and plant defense activation. Additionally, two strains of *Bacillus amyloliquefaciens* showed antibacterial activity against *Ralstonia pseudosolanacearum*. Five antimicrobial peptide genes were identified in the isolates. *B. amyloliquefaciens* application reduced wilt and exhibited antifungal activity against *Sclerotium rolfsii* and *Alternaria alternata.*

Analysis of mycobiome for induced disease resistance: Mycobiome isolates from disease-free maize tissues showed *in vitro* inhibition (5.5 to 52%) of *Rhizoctonia solani*. *In vivo* trials with *Penicillium oxalicum* and *Aspergillus niger* significantly reduced disease severity. qRT-PCR analysis confirmed the upregulation of PTI-related defense genes, including SOD, PPO, POA, CAT and β-1,3-glucanase, following mycobiome application with SA and JA.

Phyllosphere endophytic bacteria mediated MLB disease suppression in maize: The *Pseudomonas putida* inhibited *Bipolaris maydis* mycelial growth by 54.99% through secretory metabolites and 61.39% through volatile metabolites. *In planta* pathogen challenge trials further demonstrated its efficacy on MLB suppression on maize leaves.

Evaluation of bioagents, organic materials and fungicides for management of charcoal rot of maize: A field experiment conducted during *kharif* 2024 revealed that a single spray of Azoxystrobin 18.2% w/w + Difenoconazole 11.4% (@0.1%) at 30 DAS was the most effective, reducing charcoal rot incidence by 68.7% and increasing yield by 48.5% compared to the control.

Foliar application of fungicides for bakanae disease management: Out of seven fungicides evaluated as foliar spray method at tillering and booting stage against bakanae disease revealed that Carbendazim 50% WP followed by Tebuconazole 50% + Trifloxystrobin 25% WG application reduced disease incidence by 50.00%.

Exploring core microbiome for the management of emerging bakanae disease of rice in direct seeded rice (DSR) ecosystem: Core microbiome of the two different locations of Panipat (Haryana) region identified the microbial diversity. Further, molecular characterization of culturable microbes identified a few PGPR bacteria and fungi offering scope for control of bakane disease.

Evaluation of biocontrol agents against *Tilletia indica*: *In vitro* analysis showed that *Trichoderma asperellum* 6413 inhibited Ti12 and Ti18 isolates of *T. indica* by 42.07 and 63.97%, respectively. This was followed by *T. asperellum* 8619, which inhibited Ti12 and Ti18 isolates by 37.93 and 61.07%, respectively. The pre- and post-inoculation application of *T. asperellum* 6413 showed significantly good results in inhibiting the Karnal bunt of wheat.

Studies of the comparative efficacy of *Beauveria bassiana* and *Trichoderma asperellum* effective against *Sclerotinia sclerotiorum* causing stem rot of chickpea: Comparatively, *Trichoderma asperellum* isolates (ITCC 8687 and ITCC 8619) were more effective than *Beauveria bassiana* isolates (BbR2 and BbR3) in inhibiting the mycelial growth of *Sclerotinia sclerotiorum.*

Screening of All India coordinated wheat and barley pathological nurseries for rust resistance: Out of a total of 1722 entries included in PPSN (434), IPPSN (1214) and EMDSN (74) evaluated for field resistance to stem and leaf rusts under artificial inoculations, 1402 entries showed resistance to both stem and leaf rusts at Indore. In addition, 37% of the AVT entries (134) showed resistance to stem rust pathotypes 40A and 11.

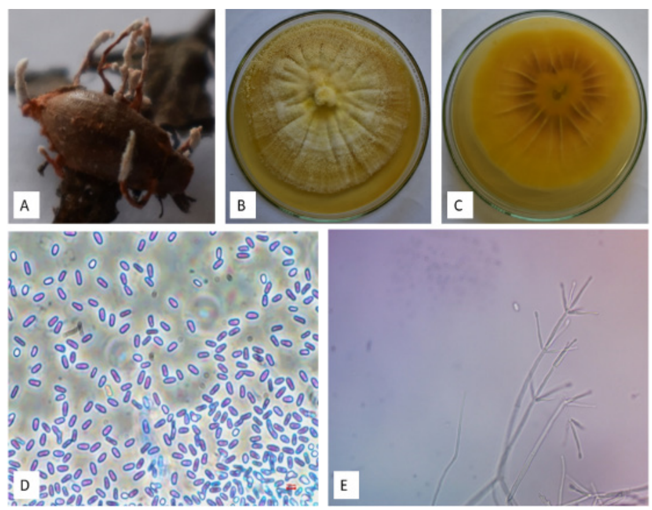
Chemical evaluation for leaf rust control: Azoxystrobin 11% + Tebuconazole 18.3% w/w SC @ 0.1% showed the highest and best level of protection than the standard recommended fungicide (Propiconazole @ 0.1%) and Tebuconazole 25.9% EC (0.1%). The foliar application of fungicides at disease initiation was followed by a second spray at 14-day intervals.

Chemical evaluation for stem rust control: The foliar spray of Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.06 % followed by Tebuconazole 25.9 % EC @0.1% was found significantly best among all the treatments when applied at disease initiation and repeated after 14 days.

Screening of IARI advanced generation lines for stem and leaf rust resistance: Out of the total of 460 genotypes from the Preliminary Disease Screening Nursery (PDSN), evaluated for field resistance, 361 were showing resistance to stem and leaf rusts under artificial inoculation at Indore. In the IARI Common Varietal Trials (CVT), 62 (40%) were resistant, while 12 showed segregation. Additionally, in station trials at IARI-RS Indore, 528 entries exhibiting resistance to both rust diseases were found.

First report on pathogenicity and management of damping-off disease caused by *Fusarium equiseti* in apple (*Malus* × *domestica* Borkh.): *Fusarium equiseti* was identified as the causal agent of damping-off in apple seedlings. This is the first report of *F. equiseti*-induced damping-off in India. *In vitro* evaluation of eight fungicides and nine botanicals using the poison food technique showed that drenching with Propiconazole (1 ml L^{-1}) and Fluopyram + Tebuconazole (0.62 ml L^{-1}) ensured 90% seedling survival, making them effective treatments recommended for nursery growers.

Eco-friendly management of woolly aphid in apple: Isolated and characterized *Clonostachys rogersoniana*, as an entomopathogenic fungus from a beetle. This is the first report of the occurrence of this fungus from India and the isolate "*C. rogersoniana* isolate PUSACR01" showed 85% mortality in adult females of woolly apple aphid on day 11 at a concentration of 1×10^7 conidia ml^{-1}.



***Clonostachys rogersoniana* (A) Insect cadaver infected with entomopathogenic fungi (B&C) Pure colony observed on PDA (D) Conidia (E) Verticillium-like primary conidiophore**

Diseases identification system based on image analysis: Images of leaves (12,364 in number) related to seven diseases of tomato from the Plant Village data were utilized for CNN-based image analysis models. The training set contains 11,218 images while 1,146 images constitute the validation set. CNN model takes these images to extract features that classify among seven classes of tomato leaf disease. This dataset contains seven types of leaf diseases of the tomato crop, models were trained for classes such as Class 1: "Bacterial spot", Class 2: "Late blight", Class 3: "Septoria Leaf Spot", Class 4: Two Spot Spider Mite:, Class 5: "Target Spot", Class 6: "Yellow-Leaf Curl Virus", Class 7: Mosaic Virus". The architecture of CNNs consists of two main parts viz. (i) feature extractors (ii) a classifier. In the feature extraction layers, each layer of the network receives the output from its immediate previous layer as its input and passes its output as the input to the next layer. In the classification layer, the extracted features are taken as inputs with respect to the dimension of the weight matrix of the final neural network. A deep learning model for disease identification of tomato leaf disease was developed using VGG architecture with different activation functions ("softmax", "tanh", 'relu", "Sigmoid"), optimizer (SGD, Adam, Adadelta and RMSProp) and loss function combination with a batch size of 128. The model provides the probability of a detected disease in addition to the disease's name.

5.1.5 Genomics and Transcriptomics

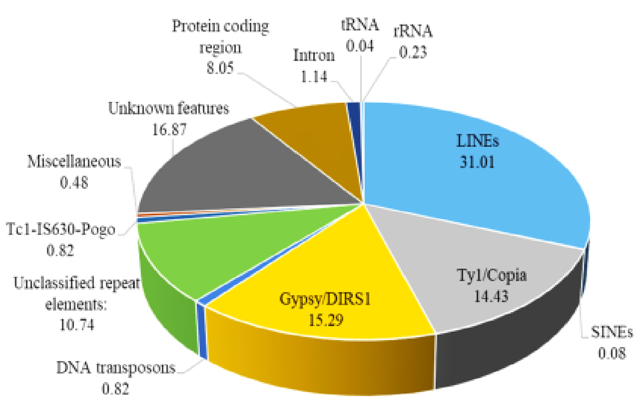
The whole genome sequencing of wheat powdery mildew pathogen (*Blumeria graminis* f. sp. *tritici*): ICAR-IARI has successfully decoded the complete genome of the wheat powdery mildew pathogen, *Blumeria graminis* f. sp. *tritici* Wtn1, a native virulent strain isolated from Wellington, with a genome size of 140.61 Mb containing 8480 genes and identified 583 tRNA anticodon sequences, 7707 protein-encoding genes and 805 effectors linked to virulence. This genomic resource will aid in developing strategies for effective management of wheat powdery mildew in Indian wheat cultivars.

Mycoparasites in the management of rust diseases: The mycoparasite, *Acremonium sclerotigenum* (SHZA1), isolated from Wellington, effectively reduced uredospore germination and germ tube elongation of cereal rust pathogens and suppressed pustule development of stem and leaf rusts in wheat and oats under glasshouse conditions.

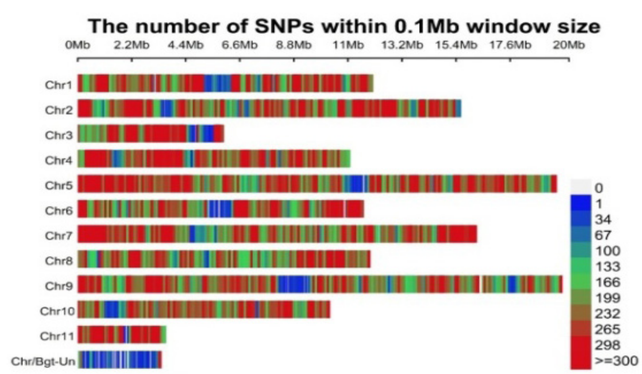
5.2 ENTOMOLOGY

5.2.1 Insect Physiology

Lipid composition and hormonal regulation in diapause and nondiapause stages of *Chilo partellus*: During diapause in *Chilo partellus*, linoleic acid, methyl 3-methoxytetradecanoate and l-(+)-ascorbic acid 2,6-dihexadecanoate decreased, while oleic and palmitoleic acids increased. Cholesterol was higher in pre-diapause hibernation and diapause/post-diapause aestivation stages. Hormonal analysis revealed elevated 20-hydroxyecdysone (20E) in pre-diapause, with a decline during diapause hibernation and a rise in aestivation. Juvenile hormone III (JH III) remained high during diapause and peaked in non-diapause larvae. These biochemical and hormonal shifts provide key insights for targeted pest management strategies.



Overview of different components of *B. graminis*f. sp. *tritici* Wtn1 genome



Chromosome-wise SNP density plot representing the number of SNPs within 0.1 Mb window size, in *B. graminis* f. sp. *tritici* Wtn1 genome

Biochemical and enzymatic adaptations in *Chilo partellus* during hibernation: During hibernation in *Chilo partellus*, lipid content increased, with oleic, palmitic and linoleic acids predominant. Myristic, palmitoleic and stearic acids rose in fat bodies and integuments, while oleic acid declined in the integument. Protein levels peaked pre-hibernation but declined during hibernation. Histidine, arginine and proline increased, whereas aspartic acid decreased. Amylase and lipid peroxidation were elevated, while protease activity dropped. Enhanced antioxidant enzymes (catalase, peroxidase, SOD) indicated strong oxidative stress defenses. These metabolic shifts aid survival and development, offering potential targets for pest management.

Induced phytochemical variations in maize parental lines affect the life table and age-specific reproductive potential of *Spodoptera frugiperda* and *Chilo partellus:* This study identified maize parental lines with strong resistance to *S. frugiperda*, revealing that both A-lines (CML 565, AI 544, PDIM 639) and R-lines (AI 125, AI 155, AI 1100) significantly reduced reproductive success and increased its generation time, with greater increases in insect-induced phytochemicals like tannins, CAT, PAL, TAL and APX. These phytochemicals were linked to an antibiosis effect, accounting for 25.0 to 72.8% of the variation in life table parameters. This study found that maize A-lines (CML 565, AI 501, AI 544) and R-lines (AI 125, AI 542, AI 1100), including the resistant check CML 442, exhibited a significant increase in secondary metabolites and antioxidant enzyme activities in response to *C. partellus* infestation. These biochemical changes led to reduced population growth and reproduction of *C. partellus*, with tannins, TAL, PAL, AO, APX and CAT playing key roles in the induced-biochemical defense mechanisms.

Phenology and morphological traits of wild crucifers impacting host selection and population build up by mustard aphid: The study found significant variation in phenology, morphological traits and resistance to mustard aphid (*Lipaphis erysimi*) across wild crucifer genotypes, with traits such as siliqua number, seed count, plant height and petal color influencing aphid preference and multiplication rate, while species like *Lepidium sativum*, *Sisimbrium* spp., *Eruca sativa* and *Crambe abyssinica* exhibited the least aphid preference and population build-up.

Constitutive and induced biochemical defense in wild crucifers against mustard aphid, *L. erysimi*: The wild species exhibited prolonged aphid developmental periods, lower survival and fecundity compared to *B. juncea*, with significant variations in constitutive and aphid-induced biochemical traits that explained up to 92.2% of aphid biological parameter variations, with species like *Brassica fruticulosa, Diplotaxis* spp., *Eruca sativa, Crambe abyssinica* and *Lepidium sativum* showing strong aphid-induced biochemical responses that hindered aphid development.

Functional characterization of gut microbes in insects: Whole genome shotgun sequencing and Metagenomics have been done from honeybee samples from locations across different agro-climatic regions of India. Comparative bioinformatics analysis is done using genomic data of honey bee species for identifying the core gut microbiome of honey bee species, *Apis mellifera*, *A. cerana indica* and *A. cerana.* Identified and characterized cellulose-degrading gut bacterial genera like *Cedecea, Clostridium, Enterobacter, Klebsiella* Serratia having high cellulolytic and hemicellulolytic activities which could be exploited for crop residue degradation

Molecular characterization of phosphine resistance in insect pests: The role of antioxidant enzymes, CYP 450 enzymes and polymorphism in dihydro lipoamide dehydrogenase gene associated with phosphine resistance was estimated in *Tribolium castaneum* and *Rhyzopertha dominica*

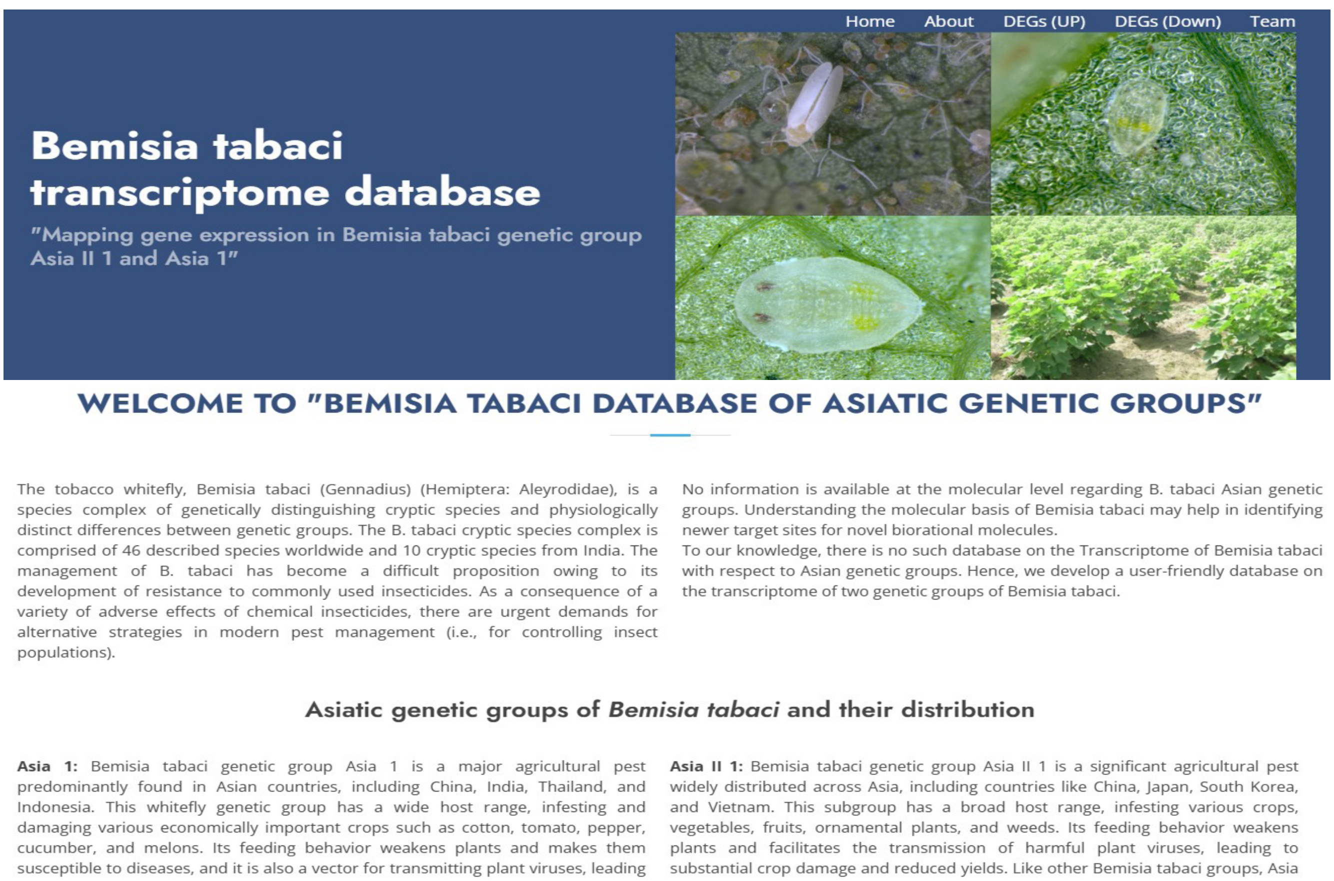
Genome wide analysis in whitefly *Bemisia tabaci*: Computational analysis identified and characterised 14 Odorant binding proteins (OBPs) in *B. tabaci* Asia II-1, including six novel OBPs. Functional characterization revealed that the *OBP3* and *OBP10* are associated with plant host recognition and behavioural assays identified potential attractants, repellents and oviposition deterrents.

Detection and diagnostics of phosphine resistance in *Tribolium castaneum*: An antioxidant enzyme-based assay was developed for rapid detection of strong phosphine resistance in *Tribolium castaneum*, a major stored grain pest. This assay leverages the strong association of antioxidant enzymes-superoxide dismutase (SOD), catalase (CAT) and peroxidase (POX)—with phosphine resistance. Additionally, Cleaved Amplified Polymorphic Sequence (CAPS) markers targeting a SNP mutation in the rph2 gene (coding for dihydrolipoamide dehydrogenase, DLD) were validated as a diagnostic tool for identifying phosphine-resistant *T. castaneum* populations in grain storage structures.

Development of *Bemisia tabaci* Transcriptome Database: The tobacco whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is a species complex of genetically distinguishing cryptic species and physiologically distinct differences between genetic groups. The *B. tabaci* cryptic species complex is comprised of 46 described species worldwide and 10 cryptic species from India. The management of *B. tabaci* has become a difficult proposition owing to its development of resistance to commonly used insecticides. As a consequence of a variety of adverse effects of chemical insecticides, there are urgent demands for alternative strategies in modern pest management (*i.e.*, for controlling insect populations). Understanding the molecular basis of *Bemisia tabaci* may help in identifying newer target sites for novel biorational molecules. To our knowledge, there was no such database available over the transcriptome of *Bemisia tabaci* with respect to Asian genetic groups. Hence, we developed a user-friendly database on the transcriptome of two genetic groups of *Bemisia tabaci*. The database is online and available at http://bemisia.iari.res.in/about.html.

5.2.2 Insect Toxicology

Termite scenario in maize residue-based conservation agriculture system in North India: This study revealed that tillage had a significant impact on termite and



pink stem borer infestation, with the lowest termite damage in the zero-till system and the highest pink stem borer damage in permanent bed practices, while nitrogen treatments influenced coccinellid populations. Additionally, *Spodoptera* infestation in mung bean was highest in permanent bed practices and lowest in conventional tillage. The study suggests that reduced tillage practices, particularly zero-till may help minimize termite damage in wheat and reduce *Spodoptera* infestations in mung bean. Coccinellid populations, did not significantly interact with tillage practices to influence pest damage. These findings indicate that adopting zero-till and optimizing nitrogen application can be part of an integrated pest management strategy to balance pest control and natural enemy support in cropping systems.

Evaluation of fumigants and novel molecules against storage pests: The combination of carbon dioxide and phosphine showed a synergistic effect against *Stegobium paniceum*, enhancing toxicity by 6.25-fold at 24 hrs, 3-fold at 48 hrs and 2-fold at 72 hrs compared to phosphine alone. Detoxification enzyme activity was higher in phosphine-treated insects than in combination treatments. Additionally, Carvacrol exhibited strong bioactivity against *Callosobruchus maculatus*, with fumigation LC_{50} of 1.08–2.32 μl/L air, contact toxicity LC_{50} of 0.8%, oviposition inhibition ED_{50} of 0.02–0.03 μl/L air, ovicidal LC_{50} of 1.64–3.2 μl/L air and significant repellence against adults.

Control failure likelihood (CFL) of chlorantraniliprole 18.5 SC (Coragen) against rice leaf folder and stem borer of rice during *Kharif* 2023: The registered and recommended label rate of chlorantraniliprole 18.5% SC against rice stem borer and leaf folder in rice is 30 g *a.i.*/ha (60 ml per acre). CFL was calculated using the equation '100−[achieved mortality (%) × 100]/ expected mortality'. The risk of CFL scales was set as follows: CFL <0% (negligible risk), 0–10% (low risk), 10–20% (moderate risk), 20–30% (high risk) and >30% (extremely high risk). The CFL values of chlorantraniliprole against leaf folder and stem borer were 21.42 and 37.14 indicating high risk and extremely high-risk category. The study recommended the withdrawal of the insecticide for managing the mentioned pests in rice fields of IARI.

5.2.3 Biological Control

Life table studies of *Geocoris ochropterus* fed on *Corcyra cephalonica* eggs: The life history of *Geocoris ochropterus* fed on *Corcyra cephalonica* eggs were examined at 27, 30, 33 and 36°C. Highest survival and reproductive rates occurred at 27°C, while mortality rates were lowest. At 36°C, both survival and reproductive rates were minimal, with the highest mortality rates observed. The gross reproductive rate was highest at 27°C (83.792) and lowest at 36°C (5.095), indicating optimal population growth at 27°C and significant temperature influence on life table parameters.

Feeding potential of *Apertochrysa astur:* The study highlights the prey-dependent performance of *Apertochrysa astur*, with cotton aphids (*Aphis gossypii*) emerging as the most suitable prey. Cotton aphids supported the shortest pre-adult development (29.95 days), longest adult longevity (51.26 days), highest fecundity (313.81 eggs/female) and greatest predation potential (475.51 prey consumed). Third instar larvae were the most voracious feeders, further emphasizing the suitability of cotton aphids. These findings suggest that *A. gossypii* associated with cotton is an optimal prey species for the development, reproduction and feeding efficiency of *A. astur*.

5.2.4 Integrated Pest Management

Evaluation of different breeding materials and advanced lines of mustard for aphid resistance: A total of 713 *Brassica juncea* advanced lines and breeding materials comprising of six trials *viz.*, MSTH-1 (50), MSTH-2 (94), MSTHQ (8), MST-TS (26), MST-RF (17) and Pedigrees of Mustard Crosses (518) were evaluated for resistance to mustard aphid in replicated trials.

Assessment of avoidable yield losses by mustard aphid in rapeseed-mustard: There was a significant reduction in number of aphids/plant on the test varieties *viz*., Radhika, Brijraj and PM 30 after both 1st and 2nd insecticide applications. Yield loss assessment in Radhika, Brijraj and PM 30 revealed significantly higher seed yield and lower aphid population under-protected as compared to unprotected conditions. The seed yields under protected conditions were 1361.3, 1018.9 and 1100.0 kg/ha, while under unprotected conditions 1092.8, 704.8 and 799.4 kg/ha in Radhika, Brijraj and PM 30, respectively. Need-based insecticide application resulted in 19.7, 30.8 and 27.3% increase in seed yields of Radhika, Brijraj and PM 30, respectively.

Evaluation of AICRP-rapeseed-mustard trials for aphid resistance: A total of 193 *Brassica* genotypes comprising of 140 IVT and 53 AVT-1 & 2 entries were evaluated for resistance to mustard aphid. Average aphid resistance index among the test genotypes varied from 1.9 to 3.6. The average aphid resistance index in test entries *viz*. SBG 23-78, SBG 23-80, SBG 23-71 and SBG 23-123 was significantly lower (≤ 2.0) as compared to other test IVT entries. Average aphid resistance index among the test AVT entries varied from 1.5 to 3.7. Average aphid resistance index was significantly lower in AVT entries *viz*., SAG 23-12, SAG 23-46, SAG 23-26 to 23-28, SAG 23-06, SAG 23-40, SAG 23-03, SAG 23-16, SAG 23-18, SAG 23-14, SAG 23-38, SAG 23-24, SAG 23-47 and SAG 23-33 (AARI ≤ 2.4) as compared to other genotypes.

Evaluation of AICRP Rice trials for brown planthopper (BPH) resistance: In the plant hopper screening trial (PHS) involving 167 germplasm lines, 11 lines were identified as superior performers against the BPH, with a score value of less than 3.00. In the plant hopper special screening trial (PHSS) conducted with 22 germplasm lines, PTB 33, RP 2068-18-3-5 and Swarnalatha (a landrace) demonstrated the best performance in terms of BPH resistance. In the planthopper monitoring trial (PHPM), RP 2068-18-3-5 and Salkati were the top performers against BPH. In National Screening Nursery Trials (NSN) for Basmati, CSR BT-252-146, Pusa 3057-9-69-37-160-9-185-1, CSR BT-252-19 and HKR-17-422 were performing well against stem borer, leaf folder and BPH.

Development of attractant lure and repellents for whitefly *Bemisia tabaci*: The potential attractant compound was evaluated in the cotton crop at farmers' fields in Delhi, Rajasthan, Punjab and Haryana. The lure from the newly identified compound along with the yellow sticky trap showed 76 to 339% increase in attraction compared to the conventional yellow sticky trap. Besides, two repellents at a concentration of 0.1% were identified as potential repellents with 74.59 and 69.13% repellence. These two synthetic compounds were also found effective as ovipositional deterrents as they were showing 67.17 and 64.4% reduction in oviposition and 76.60 and 74.13% reduction in egg hatching.

Estimation of rice grain yield through INFOCROP v2.1 simulation model considering brown planthopper damage in New Delhi conditions: Validation of the Infocrop pest model for the brown planthopper (BPH), *Nilaparvata lugens*, over a five-year period from 2017 to 2021 was conducted. This validation encompassed three different transplanting dates, spaced at 15-day intervals: early, normal and late transplanting. The Infocrop model successfully forecasted rice yields over a consecutive five-year period, factoring in the incidence of BPH with an agreement of ≥95%, underscoring the credibility of the model in predicting yield loss in rice due to BPH damage.

5.3 NEMATOLOGY

5.3.1 Nematode Management Using Conventional and Molecular Methods

Nano-emulsions of different essential oils (Garlic, Annona and Citronella) were prepared and particle size was determined. *In-vitro* mortality of rice root-knot nematode, *Meloidogyne graminicola* was maximum in garlic oil @ 1000 ppm compared to other 2 botanicals and showed 100% juvenile mortality after 96 hrs.

Using overexpression and promoter: GUS reporter analysis, a putative susceptibility (*S*) gene amino acid permease (*AAP6*) was characterized from the model plant *Arabidopsis thaliana* that proliferated *M. incognita* infection. A homozygous edited line (AtAAP-cr-5) obtained in T_0 generation that harboured

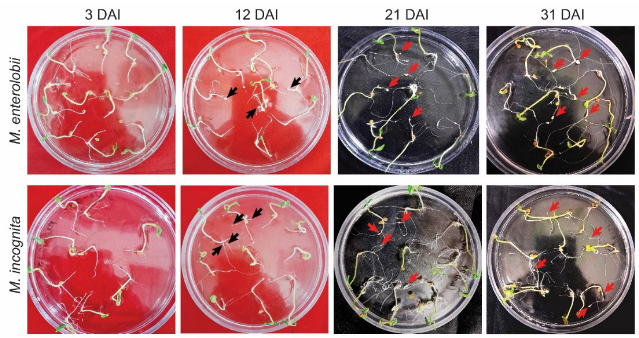
6 and 4 bp deletions (in two target regions of *AAP6* genomic DNA) resulting in the premature translation termination of AAP6 protein. Phenotypic analysis of T_2 plants revealed reduced nematode infection in edited lines compared to wild-type plants. Additionally, no growth penalty was incurred in edited plants.

WRKY45 has been found to play a role in promoting root-knot nematode, *M. incognita*, susceptibility to infection. Knocking down the expression of WRKY45 in the host plant using RNA interference (RNAi) results in reduced nematode infection and reproduction. Similar results are reported with respect to the soybean cyst nematode, *Heterodera glycines* infection. The Arabidopsis wild-type plants transformed using the CRISPR/Cas9 system to target the WRKY45 and KRP6 genes were subjected to *M. incognita* infection analysis. Mutated/gene-edited lines (KRP6-1, KRP6-2, WRKY45-1 and WRKY45-2) showed a significant reduction in root galling. The decrease in the adult female development was 60.39% in the KRP6 and 53.33% in the WRKY45 transformed events. The shape of the females in the edited lines appeared distorted, indicating disrupted development due to the gene mutations.

Selection of edited events KRP6 and WRKY45 on hygromycin

5.3.2 Basic and Fundamental Research in Plant Nematology

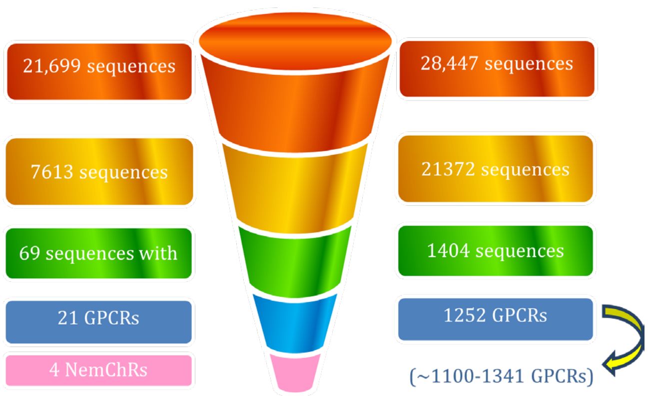
Seven chemosensory genes (*Mg-odr-1, Mg-odr-3, Mg-odr-7, Mg-tax-4, Mg-tax-4.1, Mg-osm-9* and *Mg-ocr-2*) were characterized from *Meloidogyne graminicola*, revealing their role in host-finding. These genes were highly expressed in early life stages and RNAi knockdown disrupted juvenile tracking, root attraction and development, impairing chemotaxis to volatile and non-volatile compounds. The first *Anguina tritici* transcriptome (133.2 Mb) was assembled, identifying 105,606 ORFs. BUSCO analysis showed 80.3% completeness, providing insights into nematode survival and plant parasitism. Comparative analysis of *M. enterolobii* and *M. incognita* showed *M. enterolobii*'s higher invasiveness, larger galls and a genome enriched with effectors aiding immune evasion, explaining its aggressive pathogenesis. *M. incognita* survival in polyhouses post-harvest depended on soil conditions and juvenile lipid reserves. Bioagents (*Trichoderma asperellum* and *Bacillus subtilis*) improved tomato photosynthetic rate and reduced fruit quality loss. *T. asperellum* formulation shelf life was extended to six months at 15°C and 4 months at 30°C.



Comparative life cycle and biology of *Meloidogyne enterolobii* vs. *Meloidogyne incognita* in pluronic gel. *M. enterolobii* produced more number of large-sized galls on roots

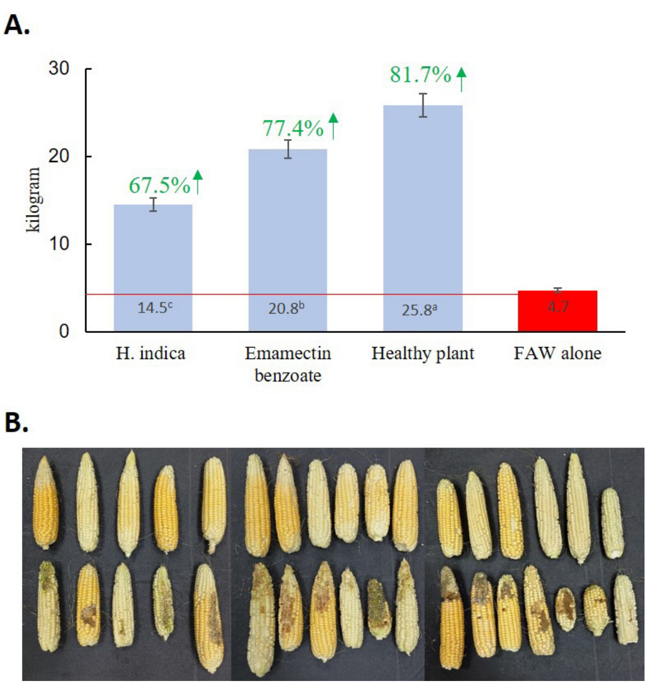
Entomopathogenic nematodes and their symbiont bacteria: To search for the chemosensory GPCRs in entomopathogenic nematode (EPN), *Heterorhabditis bacteriophora*, a stringent bioinformatic pipeline was developed and 21 GPCRs were identified. Among these, four (Hba_18427, Hba_18743, Hba_17528, Hba_07805) were identified as NemChRs based on a Pfam search. These genes were further characterised functionally.

Pathogenicity of insect-specific native EPN isolates against important insect pests was tested. Unlike *S. abbassi*, *H. indica* caused significant mortality in mango mealy bugs within 24 hrs. The symbiotic bacteria,



Bioinformatic pipeline identified four chemosensory G-protein coupled receptors in entomopathogenic nematode *Heterorhabditis bacteriophora*

P. luminescens was isolated from the cadavers after 72 hrs but *H. indica* could not develop beyond immature hermaphrodites. The interactive allelopathy between EPN and plant-parasitic nematodes was evaluated. Five months post-application, survival of *H. indica* in open maize fields and polyhouses was 12.5 and 67.5%, respectively. In microplot trials, the average damage score (scale 0-10) of sweet corn plants infected with the fall army worm (FAW) for 3 consecutive months was 4.55 for *H. indica* treated plants as compared to 1.59 in plants treated with Emamectin benzoate and 8.77 in untreated plants. In microplot trials, the average recovery of FAW pre-pupae cadavers infected with *H. indica* was 13.7 in plots with dual application of *H. indica* (foliar + soil); 26.3 in plots with only soil application of *H. indica*; 1.1 in Emamectin benzoate treated plots and 9.3 in untreated plots.



Effect of *H. indica* treatment on Fall armyworm management in sweet corn

Gut-active *Photorhabdus* toxins conferred insecticidal activity against *Spodoptera frugiperda* and *S. litura*. In order to identify putative gut receptors in *S. frugiperda* and *S. litura* a gut-active chimeric toxin Cry1AcF was used. Histopathology of the midgut transverse sections, exhibited Cry1AcF-induced extensive gut damage followed by cytotoxicity in terms of reduced hemocyte numbers and viability. Using RNAi-based functional validation, two transmembrane (CAD, ABCC2) and two GPI-anchored (ALP1, APN) proteins were identified as the putative receptors for Cry1AcF protein in the gut epithelial cells. The mechanism of action unravelled can be used as a reference to understand the *in vivo* pathogenesis of *Photorhabdus* gut-active toxins in the test insect.

5.4 AGRICULTURAL CHEMICALS

5.4.1 Synthetic Crop Protection Agents

A series of bioactive compounds were synthesized and evaluated for their pesticidal and antifungal properties. *Mentha spicata* extracts (hexane and methanol) yielded 16.0 and 12.97%, respectively, with carvone as the major hexane component. Six compounds, including stigmasterol and flavones, were identified in the methanolic extract, with 3β,13β-dihydroxy-urs-11-en-28-oic acid being reported for the first time in *Mentha*. The essential oil (1.03% yield) exhibited nematicidal activity (91.67% mortality) against *Meloidogyne incognita*. Carvone nano emulsions were highly effective against aphids (*Rhopalosiphum maidis* and *Sitobion avenae*), showing strong mortality and acetylcholinesterase inhibition.

Datura methanolic extract, rich in alkaloids (apoatropine, scopolamine, methyl-hyoscyamine), exhibited potent molecular docking interactions with ryanodine receptors. A soluble concentrate formulation (SL) containing 10% extract was optimized. *Litsea cubeba* essential oil (rich in d-limonene) and its chitosan-based nano-emulsion showed strong antifungal efficacy against *Aspergillus flavus*. The essential oils of *Alpinia officinarum* and *A. zerumbet* displayed antifungal activity against *Fusarium verticillioides* (EC_{50} 22.98 and 46.55 ppm).

Two series of 32 prenylated chalcones were synthesized and tested against *M. incognita*, with 2′-hydroxy-3-bromo-5′-O-prenylchalcone being the most potent (LC_{50} 4.69 ppm at 72 h). Pot trials confirmed enhanced plant growth and nematode suppression. A series of 27 imines exhibited antifungal activity, with chlorine and bromo substitutions enhancing efficacy. Additionally, 20 tetrazolyl-chromenone derivatives were synthesized, with compounds 6r and 6t showing strong antifungal activity against *Sclerotium rolfsii* and *Fusarium oxysporum* (EC_{50} 17.75 and 20.50 ppm).

5.4.2 Plant-based Crop Protection Agents

Hexane and methanol extracts of *Mentha spicata* leaves yielded 16.0 and 12.97%, respectively. Carvone was the major compound in the hexane extract, while six compounds, including 3β,13β-dihydroxy-urs-11-en-28-oic acid (first-time reported in *Mentha*) were identified in the methanolic extract. Essential oil (1.03% yield) contained carvone, d-limonene, 1,8-cineole and β-caryophyllene. The oil and extracts showed strong nematicidal activity (91.67% mortality of *Meloidogyne incognita* J2 after 96 h), supported by molecular docking. Aphidicidal and repellent activities against *Rhopalosiphum maidis* and *Sitobion avenae* resulted in 100% mortality within 48 h. Nanoemulsions of the oil and carvone showed potent aphidicidal effects (LC50 0.87–1.94 mg/mL) and acetylcholinesterase inhibition (IC50 0.07–3.83 mg/mL).

Bioassay-guided fractionation of *Datura* methanolic extract, characterized by LC-TOF-MS, identified 18 alkaloids, with apoatropine, scopolamine and methyl-hyoscyamine as major compounds. Molecular docking showed the ryanodine receptor as the most suitable target (ΔG: -75.89 to -135.69 kcal/mol). A soluble concentrate (SL) formulation (10% extract, 5% Triton-X 100, 3% glycerol, 1.25% propylene glycol) was developed.

Litsea cubeba essential oil (GC-MS: 70.31% monoterpene hydrocarbons) had dl-limonene (58.40%) as the predominant compound. Chitosan-based nanoemulsion was highly effective against *Aspergillus flavus* (EC_{50} 87.9 ppm). Essential oils from *Alpinia officinarum* (0.12% yield, caryophyllene oxide 7.42%) and *A. zerumbet* (0.07% yield, fenchyl acetate 12.09%) showed antifungal activity against *Fusarium verticillioides* (EC_{50} 22.98 and 46.55 ppm, respectively).

5.4.3 Pesticide Formulations for the Management of Fall Armyworm and Brown Planthopper

Two drone-compatible formulations, OD (chlorantraniliprole + emamectin benzoate) and EC (natural insecticides), were developed for fall armyworm management in maize. Active ingredients were finalized through in-silico docking and formulations met CIPAC stability standards. Field trials (IARI, Punjab, Maharashtra) showed OD was significantly more effective than Chlorantraniliprole 18.5 SC, reducing damage by 42–58% compared to 18–23% in commercial formulations. Additionally, three multicomponent formulations (EC, OD, floating tablet) were developed for brown planthopper (BPH) control in rice. Against 3rd instar nymphs, EC (92.41% mortality) was most effective, followed by OD (90.56%) and floating tablet (81.67%), outperforming the positive control (82.59%).

5.4.4 Method Development and Decontamination of Contaminants in Food and Environment

The persistence and degradation of tembotrione, a triketone herbicide, were studied in loamy soil from maize fields. Using a modified QuEChERS method with LC-MS/MS analysis, >95% recoveries of tembotrione and its metabolites (TCMBA, M5) were obtained. Dissipation (85.55–98.53%) was observed over 90 days, increasing with temperature and moisture. Vermicompost-amended soil showed the highest degradation, with half-lives ranging from 15.7 days (35°C) to 33 days (air-dry). TCMBA increased up to 45 days before declining, while M5 was undetected. A significant negative correlation was found between tembotrione persistence and organic carbon, moisture and temperature. Microbial biomass carbon showed a strong correlation with degradation ($p < 0.05$).

A robust QuEChERS-LC-ESI-MS/MS method was developed for detecting 103 pesticides in cookies. With minor modifications, acceptable recoveries were obtained for 98 pesticides. Validation followed SANTE guidelines, with recoveries satisfactory for 95, 80 and 60 pesticides at 0.1, 0.05 and 0.01 µg/g, respectively. The method had an eco-score of 77, indicating environmental friendliness.

Sulfamethoxazole (SMXZ) adsorption on mesoporous silica-graphene oxide (MPS-GO) was influenced by dissolved humic acids (HAs), with adsorption increasing above 1 mg/mL HAs. Adsorption was significantly affected by the sequence of additions, with the (MPSGO-HAs)-SMXZ system showing the highest removal.

Feeding honeybees with oxytetracycline (OTC) resulted in residues (0.128 µg/g) exceeding regulatory limits. Dissipation studies in five honey types revealed mustard honey retained OTC longest (DT50: 28 days), while acacia degraded fastest (DT50: ~4 days). Higher temperatures accelerated degradation.

A β-cyclodextrin-based molecularly imprinted polymer (MIP) was developed for tricyclazole detection, showing high specificity, stability and reusability. Adsorption followed the pseudo-second-order kinetic model and Freundlich isotherm, with a maximum capacity of 4656.7 µg/g. MIPs effectively recovered tricyclazole from rice (90.81-93.62 %) and water (87.75 -92.01%).

A validated LC-MS/MS method for pesticide residue analysis in apple juices showed suitable recoveries (70–120%) using citrate-buffered QuEChERS. Tricyclazole and ethiprole were detected in some samples, with ethiprole exceeding 0.01 µg/mL in two.

6. BASIC AND STRATEGIC RESEARCH

At ICAR-IARI, groundbreaking research focuses on unlocking the genetic and molecular cues that underpin stress tolerance and enhanced crop yields. It involves exploring novel genes, QTLs, proteins, and metabolites to revolutionize breeding and accelerate the crop improvement program. With cutting-edge techniques like High-Throughput Plant Phenotyping (HTPP), genome editing, and climate-smart solutions for agriculturally important crops, the future of agriculture is being redefined. This section briefly presents the significant achievements under the above-mentioned areas.

6.1 BIOCHEMISTRY

6.1.1 To Analyse Seed-priming Induced Physio-biochemical Imprints in Rice Across the Generation under Drought Stress

Seed priming with a cocktail of Methyl jasmonate, $FeSO_4$ and $ZnSO_4$ bioformulation improved tiller number and panicle formation in drought-sensitive rice genotype Pusa Sugandh 5 (PS5). It also increased seed number in the drought-tolerant Nagina 22 (N22), indicating memory imprinting to mitigate the effects of drought stress.

6.1.2 Epigenomic Insights into Adaptive Plasticity of Rice

Comparative methylome and transcriptome analyses identified 4078 genes regulated through DNA (de)methylation in N-22 under direct-sown conditions. Gene-body methylation exhibited significant variations in gene expression in the leaves of N-22 and IR-64.

6.1.3 Physico-enzymatic Treatments to Enhance the Retrograding in Resistant Starch (RS III) of Rice

Physico-enzymatic treatments (Microwave-Autoclave-Pullulanase) increased resistant starch (RS) content by 300% in Swarna and 275% in BPT 5204 compared to untreated flour of both cultivars. Mw-Ac treatment enhanced RS by 259% in Swarna and 257% in BPT5204.

6.1.4 Formulation and Validation of Algal and RBO Blend for Enhanced Nutritional Quality and Stability

Among all formulated oil blends, (Rice bran oil + Schizochytrium algal oil (RBO+SCO, 80:20) was found superior in physicochemical as well as omega-3 fatty acid content (20.71%).

6.1.5 Formulation of Fortified Pearl Millet Flour 'Divine Dough' with Low Glycemic Index

"Divine Dough" was formulated under the base of pearl millet flour (developed by chemical free conversion of starch into resistant starch-IV) and fortified with the richness of buckwheat, resistant starch of sweet-potato, protein of chick pea and fibre, iron/ zinc of barnyard millet. The low glycemic index (~47.1) of the flour makes it a suitable diet for the diabetic population and can be introduced to manage malnutrition due to its high protein and micronutrient content.

6.1.6 Improved protein quality of pigeonpea dal & whole grains by thermal processing methods

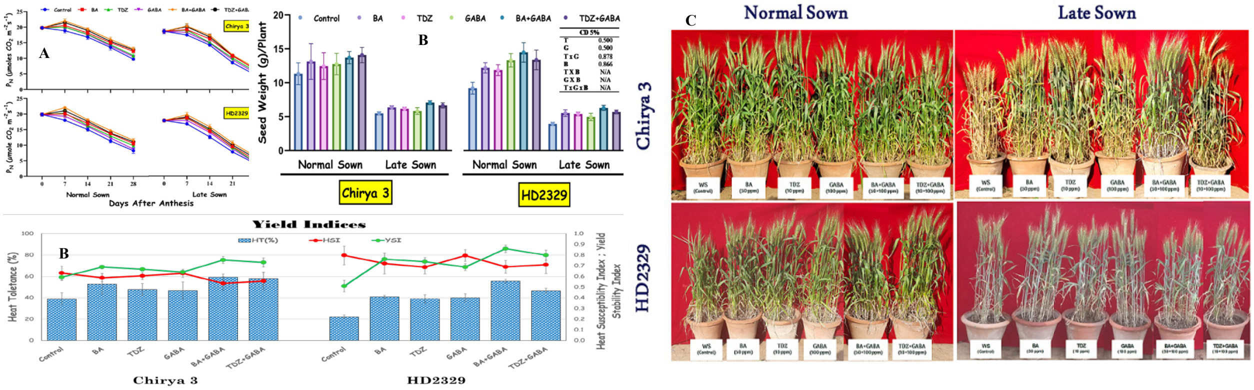
Thermal treatments, particularly autoclaving, significantly increased protein digestibility (PD) in pigeon pea, with ICP-1452 showing 90.4% PD and Pusa-Arhar 2018-4 84.32%.

6.2 PLANT PHYSIOLOGY

6.2.1 High Temperature Stress

6.2.1.1 Phenotyping of wheat genotypes for stay-green traits in relation to heat tolerance

Hierarchical clustering showed Chirya 3 and HD2851 as stay-green genotypes, characterized by delayed senescence, higher chlorophyll content and stable yields. Additional heat-tolerant genotypes, including Bacamove, C 306, Dharwad Dry, HI 1544, PBW 555, Triticale and Tammin, offer valuable potential for developing heat-resilient wheat cultivars.



Effect of cytokinins and GABA on photosynthesis (A), yield (B) and heat tolerance indices (C) and plants performance (D) under normal and late sown heat stress conditions

6.2.1.2 Dissecting cytokinin and γ-Aminobutyric acid (GABA) modulated stay green trait for heat tolerance and yield in wheat

Cytokinins (BA, TDZ) and GABA treatments, especially BA+GABA, enhanced stay-green, photosynthetic efficiency, antioxidant activity, osmolyte accumulation, thermotolerance and yield under terminal heat stress with HD 2329 showing greater susceptibility.

6.2.1.3 Aspartate-derived amino acids accumulate in wheat grains during high night temperature (HNT) stress

HNT (+3°C>ambient) from anthesis to physiological maturity resulted in a significant ($p < .0001$) increase in free amino acid pool in grains of early-maturing wheat genotypes which were associated with aspartate-derived amino acids and methionine. These genotypes rely on the rapid turnover of the derived amino acids as alternative respiratory substrates for nighttime respiration.

6.2.1.4 Analyzing the physiological basis of heat tolerance in mungbean

Tolerant genotypes (MH-421, SML-668) exhibited superior growth, photosynthetic efficiency, antioxidant activity and osmolyte accumulation, ensuring higher yield and resilience compared to sensitive genotypes.

6.2.2 Drought Stress

6.2.2.1 Identification of drought tolerance traits and associated QTLs in lentil at the seedling stage

Six drought-tolerant genotypes e.g., IC560032, FLIP-96-5, IC560246, P3227, IC560051, IG134349 were identified with 62 SNPs under control and 72 under stress linked to drought tolerance genes.

6.2.2.2 Genomic identification of early vigour and drought tolerance in wheat RILs

Genomic regions linked to early vigour and drought tolerance were identified in 198 wheat recombinant inbred lines (RILs) from HD 3086 and HI 1500. QTL mapping revealed significant regions for drought tolerance and agronomic traits.

6.2.2.3 Identification of drought-tolerant sesame accessions

A study of 69 sesame accessions identified three groups based on physiological traits: drought-tolerant, moderate and sensitive. Tolerant accessions (EC370700, PB Til-2) showed minimal trait reductions. Gene expression analysis revealed 10 *Sesamum indicum* peroxidase (SiPRX) genes upregulated in tolerant accessions, highlighting their potential for improving drought tolerance in the sesame breeding program.

6.2.3 Nutritional Stress

6.2.3.1 Seedling stage N deficiency tolerance GWAS in emmer wheat (*T. dicoccum L.*)

A GWAS on 170 *Triticum dicoccum* lines and 2 bread wheat varieties identified genetic factors for nitrogen deficiency tolerance (NDT) and nitrogen use efficiency (NUE). The study revealed 40 significant marker-trait associations (MTAs) across six traits.

6.2.3.2 Haplo-pheno association for *OsNRT1.1* paralog in rice for higher nitrate uptake

The study identified superior haplotypes of the NRT1.1 nitrate transporter to enhance nitrate uptake in rice. Haplotype analysis of 272 accessions revealed two haplogroups for *OsNRT1.1A*, three for *OsNRT1.1B* and five for *OsNRT1.1C*.

6.2.4 Phenomics

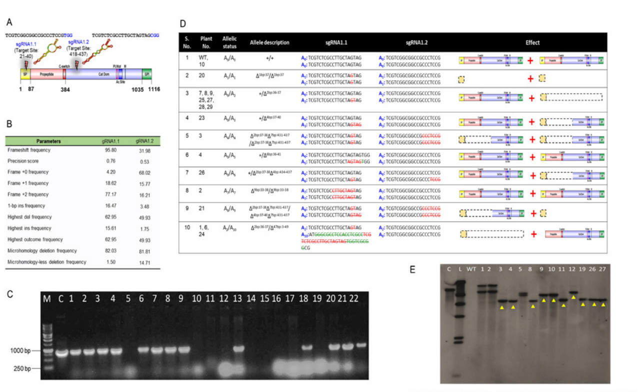
6.2.4.1 i-Traits for wheat early vigour using computer vision techniques

An image dataset comprising 130 wheat genotypes of the N population from the rabi 2024 experiment was prepared to depict early vigour using machine vision. Projected shoot area (PSA), automated YOLOV5-based leaf count, derived i-traits were extracted derived from digital image processing and DL models. The selection of early vigour wheat genotypes was finally conducted done through multivariate analysis and multi-trait genotype-ideotype distance index (MGIDI).

6.2.5 Genome Editing

6.2.5.1 Functional characterization of matrix metalloproteinase 1 of rice (*OsMMP1*)

To understand the function of MMP gene, knockout and overexpression lines of rice *MMP1* were generated. Several classes of mutants among which deletions of two base pair (Δ^{2bp}) were obtained. The overexpression cassette was constructed by cloning the coding sequence of *OsMMP1* in overexpression vector and transforming rice genotype Kitaake overexpression cassette. The putative transgenic plants were further confirmed using Southern Blot Hybridization, based on which a total of 10 single copy events for *OsMMP1*were identified.



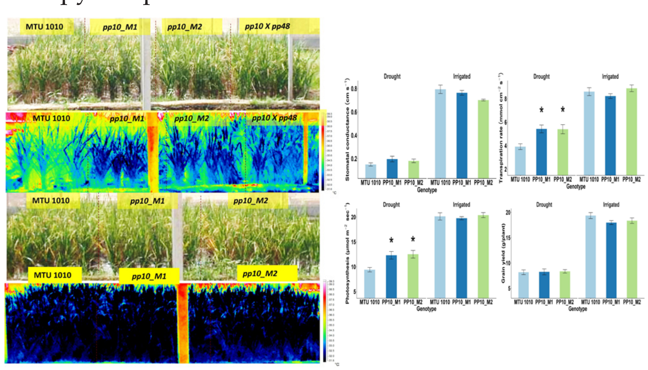
Development of knockout lines and overexpression lines of *OsMMP1* gene

6.2.5.2 Identification of genes and sgRNA designing for gene editing in mustard and pearl millet

Genes influencing key traits in mustard and pearl millet were identified and characterized. In mustard, the *IND*, *ALC* and *JAGGED* genes affecting pod shattering and flowering were found using the BRAD database. In pearl millet, the *ARE1* gene was identified *via* BLAST. sgRNAs were designed manually for both species.

6.2.5.3 CRISPR-Cas9-mediated disruption of *OsPP10* gene for enhanced abiotic stress tolerance

The *OsPP10* gene, part of the *OsPP2C* family, negatively regulates stress tolerance in rice *via* the ABA signaling pathway. Using CRISPR-Cas9, *OsPP10* mutant lines were developed that showed enhanced tolerance to osmotic and salinity stress during the seedling stage, with improved survival, membrane stability, chlorophyll content and reduced oxidative damage. Under field conditions, the mutants exhibited better drought stress tolerance, as evidenced by lower canopy temperatures.



6.3. GENETICS

6.3.1 Wheat

6.3.1.1 Genomic selection for seedling parameters and grain yield

This study evaluated genomic selection (GS) for wheat seedling traits and grain yield using a 700-genotype breeding population and 230-genotype training set, genotyped with a 35K SNP chip. Genomic Best Linear Unbiased Prediction (GBLUP) showed the highest predictive ability for seedling traits (0.36) and grain yield (0.4), outperforming other methods like Least Absolute Shrinkage and Selection Operator (LASSO) and Bayes A.

6.3.1.2 Molecular mapping of yellow rust resistance in *T. spelta* derivative TSD858

For mapping of the gene 20 HR and 20 HS plants were identified and Bulk segregant analysis (BSA) was carried out using 35K SNP chip. In a 26 MB region, 14 SNP markers on chromosome 1B were found to be linked with the yellow rust resistance gene.

6.3.1.3 Molecular mapping of yellow rust resistance in *T. turgidum* derivative TTD533

The bread wheat introgression line TTD533, derived from *T. turgidum* acc. IARI183, showed resistance to yellow rust in both seedling and adult stages. BSA with a 35K SNP chip identified potential resistance loci on chromosomes 1D (12 SNPs in 10 MB region) and 5A (14 SNPs in 26 MB region).

6.3.2 Rice

6.3.2.1 Identification of Shah Pasand as a donor for low phytic acid and GWAS to identify significant MTAs

Screening of rice genotypes led to the identification of Shah Pasand, an aromatic landrace, with significantly lower phytic acid (LPA) (0.032 g/100g) compared to Pusa Basmati 1121 (2.193 g/100g) and higher inorganic P (1.133 g/100g). A genome-wide association study using the Affymetrix 50K SNP chip identified 11 significant marker-trait associations (MTAs) for phytic acid, inorganic P and total P, with key loci on chromosomes 2, 3, 6, 8, and 9. Shah Pasand is an ideal donor for the LPA trait.

6.3.3 Maize

6.3.3.1 Development of gene-based marker for *A1* gene governing anthocyanin biosynthesis in maize

The entire 4467 bp of *Anthocyanin1* (*A1*) gene was sequenced among five wild-type (*A1*) and five mutant (*a1*) maize inbreds. Two breeder-friendly PCR-based codominant markers *viz*., a gene-based SNP-specific CAPS marker (MGU-A1-1053) and a functional InDel marker (MGU-A1-2840) specific to *A1* were developed and validated among 48 inbreds and four F_2 populations.

6.3.3.2 Development of marker for *silkless1* (*sk1*) gene

A *sk1* gene-based marker (MGU_sk1-1) was developed and validated in backcross and F_2 segregating generations, revealing a polymorphic marker corresponding to a silkless phenotype.

6.3.3.3 Understanding the role of the *fea*3 gene in determining kernel row number (KRN)

A set of 10 selected genotypes were analysed for sequence variation in the *fea3* gene. The presence of potential haplotypes viz TTTG (low KRN) and TTTC, CCTC & CCCC (High KRN) could be used in breeding programs.

6.3.3.4 Validation of marker for TLB resistance

Three SSRs namely, *dupssr24, bnlg1316* and *umc1864* showed an association with TLB resistance in F_2 population. Of these, *dupssr24* explained 16.12% variation in TLB resistance implying its possible utility in marker-assisted selection of TLB resistance.

6.3.3.5 Transformation for CRISPR/Cas9 gRNA constructs for MTL and DMP genes

Three gRNAs were designed and inserted into different vectors (PFH51, PAk002 and PAk003) using Golden Gate cloning. These gRNAs were multiplexed into a CRISPR/Cas9 binary vector (pRGEB32) and mobilized into the Agrobacterium strain EHA105 for transformation. The immature embryos of four maize inbreds (PMI-PV-3, PMI-PV-5, PMI-PV-6, PMI-PV-7) were transformed, with PMI-PV-3 showing the highest transformation frequency (20%).

6.3.3.6 Androgenic response of maize genotypes

The evaluation of androgenic response in 12 maize genotypes demonstrated that 'Pusa HM8 Improved', 'Pusa HQPM1 Improved' and 'Pusa Popcorn Hybrid-1' has an induction frequency of calli within 4-8% on the YP media.

6.3.4 Pearl millet

6.3.4.1 Genetic variability for biochemical parameters influencing rancidity of pearl millet

High heritability for comprehensive peroxide value (CPV) and lipoxygenase (LOX) indicated additive genetic effects. Pearl millet lines IP 5695 and IP 19334 were identified as low rancid lines.

6.3.5 Lentil

6.3.5.1 Delineation of loci governing extra-earliness in lentil using QTL-Seq

Whole-genome resequencing (WGRS) and QTL-seq analysis identified three QTLs (*LcqDTF3.1, LcqDTF3.2, LcqDTF3.3)* on chromosome 3 associated with earliness. An InDel marker (I-SP-383.9) linked to the LcqDTF3.2 region explained 82.35% of the phenotypic variation in earliness.

6.3.5.2 Identification of loci governing plant architecture in lentil using QTL Seq

Genomic regions governing plant architecture traits in lentil were identified using QTL-Seq analysis with an RIL mapping population (L4775 × Globe Mutant). A QTL associated with these traits was identified on chromosome 6, within the 6-9 Mb region.

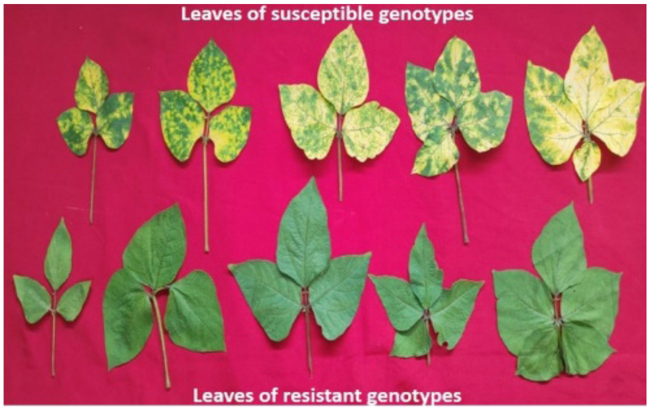
6.3.5.3 Genome-wide identification and expression profiling of ATP-binding cassette (ABC) transporter gene family in lentil under aluminium stress conditions

ABC transporter genes (138) in lentil were classified into eight subfamilies, with some linked to aluminium detoxification. Gene expansion was driven by tandem duplication and lentil's ABC genes showed collinearity with soybean. Promoter analysis revealed stress-responsive elements and qRT-PCR showed variable expression under aluminium stress.

6.3.6 Mungbean

6.3.6.1 GWAS for earliness, MYMIV resistance and other associated traits in mungbean (*Vigna radiata* L. Wilczek) using GBS approach

A GWAS of 132 genotypes identified 31,953 SNPs with 44 linked to key traits like YMD resistance, flowering time, SPAD value, leaf area and trichome density. Notable genes include *TIR-NBS-LRR* (YMD resistance) and *FPA* (for earliness in flowering time).



Responses of resistant and susceptible mungbean genotypes to MYMIV infestation

6.3.7 Mustard

6.3.7.1 Identification of heterotic genomic segment(s) in *Brassica carinata* derived *Brassica juncea* introgression lines

Genetic variability in *B. juncea* was achieved through introgression from *B. carinata* and 153 hybrids were generated. Of these, 61 showed significant heterobeltiosis and standard heterosis. It also led to the discovery of candidate genes like *PUB10*, *FLA3*, *GSTT2*, *TT4*, *SGT*, *AP2/ERF*, *SANT4*, *MYB* and *UGT73B3* regulating yield-related traits.

6.3.7.2 Identification of candidate genes associated with the SNPs for yield and quality traits

Stable SNPs associated with days to flowering were identified: Bn-A03-p19798208 (Heading date 3b), Bc-B3-p317964 (Heading date 1) and Bn-A07-p21096706 (FRIGIDA LIKE PROTEIN 5). SNPs Bj-B4-p10707039 and Bj-B3-p17726495 were linked to SAMBA and NAC transcription factor 25 for seed weight. Bn-A02-p636428 was associated with oil content, linked to WRI1 and Oleosin genes.

6.3.8 Soybean

6.3.8.1 Expression of proteins and genes for waterlogging tolerance

Biochemical analysis showed increased antioxidant enzyme activity (catalase, peroxidase, TSP) and reduced malondialdehyde (MDA) in tolerant genotypes (EC472119, EC471972, EC471920) under waterlogging stress. Transcriptome analysis revealed upregulation of xyloglucan endo trans-glucosylase and 1-aminocyclopropane-1-carboxylate synthase, with zinc finger proteins and MYB transcription factors enhancing waterlogging tolerance.

6.3.8.2 Indirect embryogenesis from anther-culture of soybean

In vitro protocol for haploid production in soybean genotypes (SKAF148, Pusa12-13, DS9712, SL958) through anther-culture was developed and SKAF148 showed the highest callus induction (84.6%) on BNN medium.

6.3.9 Drosophila

6.3.9.1 Transcript localization of *DWnt4* and *Hh* genes by RNA *in situ* hybridization

The expression of *DWnt4* was checked in segment polarity gene mutations to understand cell signalling during Drosophila embryo patterning. A probe for Hedgehog was developed using its entire CDS, cloned in TOPO TA vector and confirmed by PCR and restriction digestion.

6.4 REMOTE SENSING, GIS AND AGRICULTURAL PHYSICS

6.4.1 Evaluation of Fabricated Impedance Biosensor using Contact Angle Method

The zeta potential of -28.4±4.5 mV for carbon nanotubes revealed high stability of the dispersions. The contact angle values were found to be decreasing as surface roughness increased and the immobilized biosensor was found to be lower than the material electrodes.

6.4.2 Fabrication and Development of Screen-Printed Electrode-based Optical Biosensor

An optical biosensor was developed using CNT-α-Fe_2O_3 nanocomposite for the detection of nitrate. The biosensor exhibited a high sensitivity of 0.117 Abs [log (conc.)]$^{-1}$ and a low detection limit of 0.13 mg/L. The optical biosensor demonstrated good specificity and reproducibility (RSD = 1.2%).

6.4.3 Evaluation of the Effect of Foliar Nitrogen Fertilization through Drone and Knapsack Sprayer on the Growth and Yield of Wheat

Results showed that the nitrogen fertilization through drone sprayer outperformed in uniformity of application, except coverage. No significant differences were found among nitrogen sources (Nano Urea, Prilled Urea and Nano-DAP). The optimal treatment, T7, combining 75% RDN with two foliar sprays of Nano-DAP applied by drone, yielded the highest growth parameters and yield attributes.

6.4.4 Drone-based Thermal Remote Sensing for Assessing Water Stress in Wheat

Strong correlations were observed between crop water stress index ($CWSI_{si}$) and factors like relative water content (RWC), stomatal conductance (Gs), transpiration rate (Tr) and soil moisture support drone-based thermal sensing for real-time monitoring of water stress, enhancing water and nitrogen management for higher wheat yields.

6.4.5 Hyperspectral Remote Sensing of Wheat Yellow Rust (*Puccinia striiformis* f.sp.*tritici*)

Spectral observations at canopy level using a spectroradiometer (350-2500 nm) led to the formulation of two indices, NYRI1 and NYRI2, for disease prediction. The Enhanced Vegetation Index (EVI) showed an R^2 of 0.89, while partial least square regression (PLSR) yielded the highest prediction accuracy (R^2 = 0.977).

6.4.6 Near Real-Time Monitoring of Crop Fields through Satellite Remote Sensing

An optimized methodology using Sentinel-2 multispectral data (10 m resolution) and the PROSAIL model, along with Gaussian Process Regression (GPR), was developed to monitor crop phenology (LAI) over large areas. The approach, validated with in-situ data of mustard, chickpea and wheat from IARI, enables near real-time crop monitoring at multiple scales using Google Earth Engine.

6.4.7 Exploring 5G Captive Network for Precision Agriculture through the Internet of Drones

A 5G use laboratory under the Department of Telecommunications (DoT) was set up at IARI, in collaboration with IIT Delhi, to implement a 5G network for precision agriculture. Using drones and IoT sensors, soil moisture and irrigation were monitored in real-time. A network-in-a-box (NIB) for a captive 5G network environment developed by IIT Delhi was integrated with the drone and flown over the farm to collect data from IoT sensors in the field.

6.4.8 Development of a Multistage Crop Yield Estimation Model using Machine Learning and Deep Learning Techniques

Wheat yield estimation was performed in five Punjab districts at different growth stages (tillering, flowering and grain-filling stages) using weather variables. The Random Forest (RF) model outperformed others, making it an ideal choice for district-level wheat yield estimation at various stages.

6.4.9 Dissemination of Biweekly Weather-based Agromet Advisory Bulletin

Agromet advisory bulletins, based on weather data, were issued twice a week in Hindi and English to guide farmers on field operations. Feedback showed that the advisories helped reduce cultivation costs, save resources and increase profits.

6.4.10 Effect of Magnetic Field on Seedling Growth of Wheat

Magnetic field treatments (100 mT for 30 min and 150 mT for 30 min) significantly enhanced germination, seedling growth and vigor in wheat.

6.4.11 Effect of Flyash Application on Soil Health and Plant Growth under Maize-Wheat Cropping System

The highest soil organic carbon (SOC) was recorded with FYM + NPK. Water-holding capacity improved by 28.2%. Combining flyash with FYM enhances maize-wheat cropping system in Inceptisol without harming soil health.

6.4.12 Machine Learning for Forecasting Agricultural Drought using Remote Sensing and Weather Forecast

Machine learning algorithms, including random forest (RF), were used to forecast CADI, achieving 70% accuracy in generating drought outlooks, as compared to artificial neural network (ANN) and Classification and Regression Tree (CART).

6.5 NATIONAL PHYTOTRON FACILITY (NPF)

The National Phytotron Facility (NPF) provides controlled environmental facilities to researchers from ICAR-National Institute of Plant Biotechnology, ICAR-National Bureau of Plant Genetic Resources, Delhi University and ICAR-Indian Agricultural Research Institutes for conducting 195 experiments on various aspects.

6.6 VEGETABLE SCIENCE

6.6.1 Musk Melon

6.6.1.1 Evaluation of new RILs for fruit quality traits and yield

Eighty-three RILs from a cross between C. melo var. reticulatus (Pusa Madhuras) and DHM 159 (C. melo var. inodorus) were evaluated for yield, quality and climacteric ripening traits. DMM-205, DMM 207, DMM 211, DMM 216 , DMM 228 and DMM 241 were found very promising for higher yield and shelf-life.

6.6.1.2 Identification of candidate gene (s) conferring resistance against ToLCNDV in melon

QTL-seq identified a 0.9 Mb region on chromosome 6 of melon closely linked to ToLCNDV resistance in DSM-132. Six candidate genes, including Serine/threonine protein kinase, LRR receptor-like kinase and Glutathione S-transferase were identified.

6.6.2 Bitter Gourd

6.6.2.1 Expression of charantin biosynthetic genes in bitter gourd

PVGy-201 consistently exhibited the highest expression of multiple genes associated with charantin production. Similarly, the DBGS-2 (Sel-2) genotype demonstrated high multi fold changes, particularly in the *McHMGR* and *McPMK* genes, suggesting it as another promising genotype for high charantin content.

6.6.2.2 High-quality *Momordica balsamina* genome for improving stress resilience and therapeutic properties of bitter gourd

Genome sequencing of *M. balsamina* identified 632098 transposons, 215379 SSRs, 567483 transcription factor binding sites and 41652 protein-coding genes.

6.6.2.3 Screening and genetic inheritance for leaf curl disease in bitter gourd

Genotypes DBGS-2 and EC795800 were resistant, with DBGS-2 showing superior yield (24.8 t/ha) and resistance to ToLCNDV. Genetic analysis indicated a single recessive gene controlling resistance, with a 1:3 segregation ratio in DBGS-2 × Pusa Vishesh.

6.6.2.4 First report of squash leal curl China virus (SLCCV) in bitter gourd

PCR assays of 30 bitter gourd samples (25 symptomatic, 5 asymptomatic) revealed the presence of begomovirus in 27 samples (25 symptomatic, 2 asymptomatic). Specific primers identified 20 samples with ToLCNDV (~202 bp) and 7 with SLCCV (~513 bp).

6.6.2.5 Genetic inheritance of white flower colour in bitter gourd

The segregating F_2 population of DBGS-54-18 (white flower) and DBGS-2 (yellow flower) in 1: 3 ratio confirmed that white flower colour in bitter gourd is governed by a single recessive gene.

6.6.2.6 Screening for SLCCNV resistance in pumpkin

Upon challenge inoculation by whitefly, out of fifty genotypes/ advanced breeding lines, DPU-41, DPU-43 and DPU-133 were found to be highly resistant to Squash Leaf Curl China Virus (SLCCNV).

6.6.2.7 Screening for downy mildew disease resistance in sponge gourd

A total of 68 accessions of sponge gourd germplasm were evaluated for downy mildew disease in field conditions in *Kharif* 2024 and out of these three genotypes, VRSL-1-1, VRSL-6 and VRSL-10 showed resistant reaction.

6.6.2.8 Screening for leaf curl disease resistance in ridge gourd

A total of 26 accessions of ridge gourd germplasm were evaluated for Tomato leaf curl New Delhi virus (ToLCNDV) in field conditions in *kharif* 2024 and two genotypes VRRGL-1-13-3 and VRRGL-1-14-3 were found to be resistant.

6.6.2.9 Evaluation of brinjal genotypes for different biochemical traits

G-57 has higher ascorbic acid (5.18 mg/100 g), while Pusa Hara Baigan-2 recorded the highest dry matter (10.52%). NDB-25 showed the highest soluble sugar content and Pusa Shyamla had the highest anthocyanin content.

6.6.2.10 Genetic diversity in bitter gourd

Among 46 genotypes characterized, the highest total carotenoids at the edible stage was recorded in Pusa Do Mousami (19.76 μg), vitamin-C in DBG-33-2 (95.49 mg), saponins in Sel-32 (67.52 μg) and charantin in PVGy-201 (39.64 μg) per 100g fruit weight.

6.6.3 Okra

6.6.3.1 *In vitro* studies of epicotyl and embryo culture in cultivated, wild and inter-specific hybrids of okra (*Abelmoschus* spp.)

In vitro regeneration protocols were developed for five okra genotypes using 64 MS medium combinations. The best regeneration efficiency was achieved with NAA, IBA (0.5-1 mg/L) and kinetin (1-1.5 mg/L).

6.6.3.2 Hybridity confirmation for interspecific hybrids

PCR analysis with OSSR 23 and AVRDC–Okra 21 primers confirmed hybridity in interspecific crosses of *Abelmoschus esculentus* cv. Pusa Sawani with *Abelmoschus manihot* var. tetraphyllus and *A. moschatus*.

6.6.3.3 Plant regeneration by embryo culture in wild species and interspecific crosses

IC-141055 exhibited 65% regeneration efficiency, while IC-90476-1 had 45% in MSOM media.

6.6.4 Cole Crops

6.6.4.1 QTL-seq analysis for Alternaria leaf spot resistance in cauliflower

The parents and bulks were sequenced and four QTL regions were identified namely 45 to 50 Mb region in Chr 1 (CM068072.1), 55 to 60 Mb region of Chr 2 (CM068073.1), 5 to 10 Mb region in Chr 7 (CCM068078.1) and 45 to 50 Mb region of Chr 9 (CM068080.1).

6.6.4.2 Candidate gene marker analysis for glucosinolates in cauliflower

A total of 13 candidate gene markers were screened in 21 commercial public sector varieties/hybrids of cauliflower and ESP, TGG, ATSOT, MYB28, CYP83A1, GSL-PRO, CYP79C2 and BoGSL-ALK were identified as polymorphic in these varieties/hybrids.

6.6.5 Cucumber

6.6.5.1 Haploids induction in cucumber through parthenogenic embryo development

Genotypes, doses of irradiation and embryo developmental stage influenced the successful generation of *in-vitro* haploid plants. Haploid embryos were effectively induced using irradiated pollen at 400 to 500 Gy doses.

6.6.5.2 Identification of heat tolerant lines from diverse cucumber germplasm

The lines WBC-13, DGC-103 and DARL-106 of cucumber showed enhanced heat tolerance based upon tolerance index.

6.6.5.3 Tissue-specific expression of genes in cucumber under drought stress

In tolerant genotype WBC-23-2 possessing long roots with high volume under drought stress. Transcription factors (Csa1G589140, Csa1G008430, etc.) and GA2ox1 were highly expressed in roots.

6.6.5.4 Identification of genomic regions linked with resistance to ToLCNDV in cucumber and melon

QTL-seq analysis in cucumber identified a ToLCNDV resistance QTL on Chromosome 2 (2.1-2.8 Mb) with 1759 variants. Also, two novel QTLs on Chromosomes 1 (23.3-25.0 Mb) and 2 (14.7-18.8 Mb) were found.

6.6.5.5 Transcriptome analysis for the identification of DEGs and susceptibility factors associated with ToLCNDV resistance in cucumber

Expression analysis of 80 genes across chromosomes 1, 2 and 6 identified key susceptible and resistant genes related to ToLCNDV resistance in cucumber. qRT-PCR validation of 27 genes confirmed the abundance of transcripts, with exceptions like CsGy2G016180, CsGy2G016190, and CsGy6G026150.

6.6.6 Nutritional Qualities of Vegetable-based Microgreens under Different Light Conditions

LED light treatments (white-blue and white-red) enhanced the levels of antioxidants, vitamins, and minerals in microgreens, while white light maximized both fresh and dry weights in Brassica microgreens, thereby optimizing the health benefits.

7. SOCIAL SCIENCES AND TRANSFER OF TECHNOLOGY

The Division of Social Sciences plays a pivotal role in assessing and disseminating agricultural technologies to enhance productivity and profitability. The studies highlight the economic benefits of improved crop varieties, alongside policy evaluation of fertilizer subsidies and market reforms. Institutional interventions such as FPOs, KCC and MGNREGA have positively impacted farmer incomes and food security. Extensive on-farm trials, technology demonstrations and outreach programs like SCSP, TSP, NEH and MGMG have facilitated large-scale adoption of high-yielding, climate-resilient crops. Initiatives like Pusa Krishi Vigyan Mela, Pusa Samachar and KVK training programs continue to empower farmers through knowledge dissemination and entrepreneurship support. Strengthening institutional linkages and scaling up successful extension models remain crucial for enhancing agricultural sustainability and profitability.

7.1. AGRICULTURAL ECONOMICS

7.1.1 Technology, Resources and Environment

The Division conducts a comprehensive impact assessment of technologies developed by ICAR and IARI, evaluates key agricultural policies and assesses agroecosystem services. The ex-ante impact analysis of basmati varieties PB 1979, PB 1985, PB 1885 and PB 1882 projected a combined economic surplus of ₹ 806 crores by 2030 at 2022-23 prices. The wheat varieties HD 3385 and HD 3406 are expected to improve yields under climate stress, with a total economic surplus of ₹ 1110 crores by 2030. While the mustard variety PDZM 33 is expected to generate a surplus of ₹ 93 crores, the chickpea variety Pusa Manav would generate ₹ 840 crores at 2022-23 prices. Studies in Maharashtra and Kerala highlight the importance of preserving ecosystem services and sustainable practices. In Maharashtra, land-use changes led to cropland losses and reduced carbon sequestration, highlighting the need for conservation agriculture, with 98% of farmers willing to adopt it, if incentivised at ₹ 5,645/ha. Kerala's Kole Wetlands generated a net benefit of ₹ 1,738.20 crores per year, out of which 85% accounts for non-marketed ecosystem services. A study on fertilizer subsidies using the IFPRI Computable General Equilibrium (CGE) model revealed trade-offs in subsidy reductions. While redirecting savings to rural households improved their incomes, cuts negatively affected Gross Domestic Product (GDP) and non-agricultural sectors, thus hinting the need of sustainable policy solutions.

7.1.2 Agricultural Markets and Value Chain

India's agricultural sector continues to face significant marketing and economic challenges, even with advancements in production techniques. The Electronic National Agricultural Market (e-NAM), introduced to enhance market efficiency, has had mixed results. Between 2021 and 2024, e-NAM facilitated over 2.1 million transactions but showed a concentration of trade in specific commodities, such as flowers and oilseeds. Although it expanded market access, price realization for farmers often fell short of AGMARKNET prices and the Minimum Support Price (MSP). To achieve more equitable market outcomes, it is crucial to address gaps in infrastructure, technology and farmer education. Market access and price realization vary considerably based on the perishability of crops. Data from the 77th NSSO survey indicated that non-perishable crops tend to utilize formal channels more effectively, while perishable crops face limited options and greater price instability. Enhancing market linkages for perishable crops through farmer-producer organizations (FPOs), contract farming and cooperatives could help stabilize prices and improve farmers' incomes. India's agri-startup sector, with over 27,500 ventures, is rapidly growing and funding in this area has increased at a 49% compound annual growth rate (CAGR) from 2014 to 2021. Food technology leads this sector, bolstered by venture capital and is projected to create a $21.2 billion market opportunity by 2025. A study using the IFPRI CGE model based on India's 2019-20 Social Accounting Matrix (SAM) found that recent rice export bans aimed at stabilizing domestic prices negatively impacted rural farming households by reducing incomes and consumption while offering only minor gains to the milling and food industries.

7.1.3 Institutional Innovations and Rural Livelihood

This theme encompasses impact studies of major institutional initiatives such as Farmer Producer Organizations (FPOs), Kisan Credit Card (KCC) and the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), along with a focus on malnutrition. The impact of FPOs on the commercialization of mango farming was studied in the Rehmankhera block of Lucknow, Uttar Pradesh. Utilizing multistage sampling, endogenous switching regression and Instrumental Variable (IV) methods, the study found that participation in FPOs significantly enhances the commercialization of smallholder farming, resulting in an average income increase of 28.5%. For each additional member of an FPO, commercialization increases by 2.1%, while household market surplus rises by ₹ 6,22,274 and market prices improve by ₹ 49,650. Another study investigated the regional outreach of the KCC scheme in India and the factors influencing its access among agricultural households, based on data from the NSSO 77th round survey. The coverage of the KCC scheme varied significantly across India, with the central and southern regions holding the largest shares of operative KCCs, each at 26%. Despite fair access to institutional credit via bank accounts, only 19.12% of agricultural households could access KCCs. The findings suggest that the outreach of the KCC scheme must be strengthened to serve disadvantaged groups and regions better. Insights from the Latur District in Maharashtra revealed that KCC beneficiaries in soybean farming achieve higher yields and net returns—even with higher input costs—resulting in an increase of ₹ 10,035.64 per hectare compared to non-beneficiaries. In livestock farming, KCC adoption led to a net income increase of ₹ 12,219.11 per animal annually, attributed to lower variable costs and improved management practices. KCC adoption enhanced farm income, financial stability and productivity in the study area.

Utilizing data from the 77th round of the NSSO's Situation Assessment of Agricultural Households, a study evaluated the role of Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) in promoting consumption diversification. Findings reveal that 56% of farmers held job cards, with 57% of these households participating in MGNREGA. The Simpson Index (SI) for consumption diversification was higher for participants (0.34) than for non-participants (0.32), indicating greater diversification among those involved in the scheme. Regression analysis confirmed that MGNREGA positively impacts consumption patterns, with significant influences from factors such as age, gender, education, landholding size and social group. Participation in MGNREGA enables rural households to diversify their consumption beyond basic necessities, highlighting its importance in enhancing economic resilience and living standards. A comprehensive analysis of the prevalence of double and triple malnutrition in India was conducted using data from the 2019-2021 National Family Health Survey, focusing on 132,710 mother-child pairs. Between 2019 and 2021, 10.85% of mother-child pairs experienced the double burden of malnutrition, while 4.61% faced the triple burden, particularly in wealthier and urban areas of southern India. Key factors influencing these trends include maternal education, wealth and place of residence. The study calls for targeted interventions in southern India and emphasizes the importance of public health initiatives, nutrition education and women's empowerment in addressing malnutrition.

7.2 AGRICULTURAL EXTENSION

7.2.1 Evaluation of Farmer-centric Government Schemes and Programmes for Agricultural Extension Policy Advocacy

The effectiveness of the *PM-KISAN Samman Nidhi Yojana* was assessed in Gujarat (Junagadh, Porbandar, Gir Somnath and Jamnagar districts), Tamil Nadu (Madurai and Theni districts) and Kerala (Thrissur District). In Gujarat and Tamil Nadu, the majority (94%) of the farmer respondents reported the smooth functioning of Aadhar-enabled DBT accounts. Further, 61% of farmers reported that the financial assistance should be increased to meet the growing input costs. The major constraints reported in accessing the scheme benefits were Aadhar linking, distance of bank from village, biasedness in the selection of beneficiaries, non-availability of inputs on time and inaccessibility of PM-KISAN portal. In Kerala, the majority of the farmers (90%) reported that this scheme encourages them to continue farming. All the farmers suggested periodic revision of the funds and the provision of funds in proportion to the size of the landholding of the farmer. The socio-economic impact of the *Pradhan Mantri Fasal Bima Yojana* (PMFBY) was assessed in Uttarakhand, Gujarat and Tamil Nadu. The analysis of household income showed a positive correlation with PMFBY participation after controlling demographic characteristics and access to agricultural inputs. The majority (82%) of farmers who have received claims for losses are found to be satisfied with the scheme. In Gujarat, farmers perceived constraints such as delay in payments and farming system-related crop-specific damage assessment issues. The effectiveness of *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) was assessed in Andhra Pradesh (Anantapur and Cuddapah districts). It was found that poor quality of irrigation pipes, lack of support service, high cost of installation, lack of training of farmers in irrigation management and undulating topography were the major constraints faced by the beneficiary farmers.

A study on 'Operation Greens' was conducted in the production cluster of Tomato, Onion, and Potato crops in Gujarat, Maharashtra and Uttar Pradesh. The findings revealed that post-harvest loss was high in tomatoes (21.51%), followed by onions (12.59%) and potatoes (13.67%). Tomato, onion, and potato producers have contributed 23.17, 20.58 and 26.50% to value-addition, respectively. The processors of each crop have contributed significantly higher value-addition as compared to producers, *i.e.*, 38.46, 35.33 and 49.52%, respectively. An effectiveness score of 0.695 revealed that Operation Greens is 69.5% effective in the value realization of the selected crops in production clusters. In-depth analysis and validation of Pusa Samachar was done based on primary data from the viewers. Analysing the sources of information, YouTube was found to be the major source of information (71%), followed by WhatsApp (18%), verbal communication with fellow colleagues (6%) and Facebook (5%). Three-fourths of the farmers believed that the time duration of each crop section within an episode is optimum. However, the full-time duration of each episode should be reduced.

In North Bengal, a study conducted under the IARI regional station, Kalimpong reported that PMKSY significantly expanded sprinkler irrigation in Jalpaiguri from 857.76 acres to 1,035 ha (2022), while drip irrigation reached 2.4 ha (2021). In Darjeeling, sprinkler irrigation declined from 2,109.69 ha (2020) to 1,145 ha (2022) and drip irrigation ceased by 2022. Primary data revealed that 84 percent of respondents reported an increase in vegetable and fruit cultivation, while 83 percent observed a shift in irrigation sources and 79 percent in irrigation methods. The scheme led to increased yield (88 percent), productivity (81 percent) and income (83 percent), along with 100 percent reporting reduced water scarcity and community asset generation. Additionally, 91 percent noted the formation of water user groups and 67 percent observed increased protected cultivation. Farmers' perception analysis indicated that 53 percent strongly agreed that micro-irrigation saved water, while 51 percent affirmed its role in increasing yield.

7.2.2 Converging Agripreneurship, Farmers' Innovations and Modern Technologies

The scope and status of agribusiness opportunities and agripreneurship development were assessed.

Farmers of Parkhpur village were mobilized for collective action and encouraged to form a Farmer's Club. Additionally, linkages were established with the State Agriculture and Horticulture Departments of Rajasthan and Uttar Pradesh, along with KVK Mathura. A scale was developed for measuring individuals' readiness for entrepreneurship by assessing personal traits and features. This tool comprises five subscales: Risk-taking ability, Proactive approach, Competitive aggressiveness, Innovativeness and Autonomy. The validity and reliability of the scale were confirmed, ensuring the scale accurately measures entrepreneurial readiness. Bibliometric analysis was carried out using the Scopus database to understand the current status of Agri-entrepreneurship research globally. A total of 2199 research articles on Agri-entrepreneurship were selected during the period 2000-2024. The number of published articles showed an increasing trend from four in 2000 to two hundred and forty one in 2023. India stands 7th among the most cited countries with a number of citations as 868. The research articles were mainly focused on the sustainability aspects, rural development and gender aspects. There is less evidence on the entrepreneurial ecosystem, institutional support mechanisms and impact assessment of different government policies or schemes. From the list of 2199 research articles, 226 were case studies on different agripreneurship models or ventures. Out of these, only 11 case studies were reported from India, which shows a wide research gap in documenting successful business models.

7.2.3 Agricultural Extension for Nutrition and Health (AE4NH)-Strategies and Models

In the Kumaon division of Uttarakhand, the determinants of small holder farmers' adoption of improved nutritional technologies were assessed. The data was collected from 150 children and 600 adults in this region. Findings revealed widespread inadequate Body Mass Index (BMI), with Nainital showing its highest prevalence among women (55%) and children (44%). Almora recorded inadequate BMI among 37% of men, 49% of women and 32% of children, while Bageshwar reported 29, 42 and 36%, respectively. Overall, underweight prevalence was 19% for men, 37% for women and 41% for children. Assessment of the status of technology adoption revealed that male farmers adopt agricultural innovations more frequently than female farmers due to unequal access to resources like land, credit and agricultural inputs. The dietary habits and the associated psychological factors were assessed among 3150 students from different state agricultural universities who visited IARI, New Delhi, under the 'Student READY Program'. The results revealed that obesity and underweight issues were more prevalent in females (19.8 and 12.7%) as compared to males (10.1 and 11.5%), respectively.

The effects of crop diversification and nutrition-sensitive interventions were assessed. The farmers in Gujarat (Junagadh and Porbander Districts) reported challenges regarding the adoption of nutri-sensitive crops, such as lack of awareness (38%), limited resource access (56%), climate variability (72%), input unavailability (41%) and marketing difficulties (34%). Nonetheless, the interventions showed positive outcomes, improving income and livelihoods (64%), health and nutrition (48%), household food security (53%) and environmental sustainability (38%). A study evaluated the physical drudgery among farm workers in the East and West Godavari districts of Andhra Pradesh using the Human Physical Drudgery Index (HPDI). It revealed a high physical strain in load-carrying tasks, with 70% of males categorised at "very high risk." Female-dominated tasks such as transplanting, weeding, harvesting, and winnowing were assessed using Rapid Upper Limb Assessment (RULA), demonstrating ergonomic risks due to repetitive motions and awkward postures. The study underscores the need for ergonomic interventions, such as mechanised tools and supportive devices, to reduce physical strain.

A dietary study of 100 respondents in Darjeeling and Kalimpong revealed daily per capita consumption of 183.5 g cereals, 25 g pulses, 117 g vegetables, 82.5 g leafy greens, 136 g roots/tubers, 85 g fruits, and 257 g dairy products. Fermented foods such as mohi (74.2 ml/day), dahi (34.1 ml/day), and Kodo ko jaanr/chyang were common among rural households. A case study on Nirmal Farm documented the transformation of fruit processing and value addition for mandarin oranges. Fruit juice production increased from 500 liters (2005) to 500,000 liters (2024), generating a gross income of ₹ 25 lakh. Additionally, orange-based value-added products contributed ₹ 12.50 lakh from orange powder and ₹ 10 lakh from orange jelly, showcasing the potential of agripreneurship and value chain development.

7.3. TECHNOLOGY ASSESSMENT AND TRANSFER

7.3.1 Assessment and Outscaling of IARI Technologies for Enhancing Farm Income

During *rabi* 2023-24, the project was in operation at three villages, namely Nidana (Rohtak, Haryana), Maholi (Palwal, Haryana) and Kanvi (Hapur, U.P). The performance of location-specific improved varieties of wheat, mustard, carrot, onion and spinach was assessed through 342 trials over an area of 129.48 ha. At Nidana (Rohtak, Haryana), IARI wheat varieties outperformed the local check, with HI 1620 yielding the highest (6.23 t/ha) and achieving the highest net profitability (₹ 1,13,346/ha). HD 2967 and HD 3086 exhibited superior tillering and chapati-making qualities. In Maholi, Palwal (Haryana), wheat variety HI 1620 (6.32 t/ha) had the highest yield (7-19% higher than WH 711). Mustard varieties Pusa Vijay (2.09 t/ha), PM 30 (1.95 t/ha), and PM 33 (1.90 t/ha) outperformed the local check (1.85 t/ha). Onion (Pusa Red, 26.25 t/ha; Pusa Madhavi, 25.25 t/ha), Carrot (Pusa Rudhira) and Spinach (Pusa Bharti) were also preferred for yield and income. At Kanvi (U.P.), HI 1620 (6.25 t/ha) was the highest-yielding wheat variety. Mustard varieties Pusa Vijay (2.16 t/ha), PM 30 (1.87 t/ha) and PM 33 (1.95 t/ha) performed better than the local check (1.85 t/ha, Coral 432). During *Kharif* 2023, 163 assessment trials were conducted on paddy (PB 1692, PB 1509, PB 1847, PB 1885, PB 1886, PB 1718) and vegetables (okra, cowpea, brinjal) over 68.01 ha across Nidana, Maholi and Kanvi. The highest paddy yield was observed for PB 1692 (5.33 t/ha) at Nidana, PB 1847 (5.25 t/ha) at Maholi and PB 1847 (5.25 t/ha) at Kanvi, showing a 16-27% yield increase over local checks. In vegetables, Okra (Pusa Bhindi-5) at Kanvi (14.02 t/ha, ₹ 1,97,000 net return) and Maholi (11.55 t/ha, ₹ 1,61,000 net return) outperformed local varieties. Cowpea (Pusa Sukomal, 13.5 t/ha, 17% higher yield) and Brinjal (Pusa Vaibhav, 22.55 t/ha, 9.73% higher yield) were also preferred by farmers. Nutri-gardens were promoted for crop diversification and 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/AUs/VOs in different parts of the country. Partner organizations helped in the assessment and promotion of the technologies through demonstrations, training, field days, etc. During *rabi* 2023-24, 389 demonstrations covering 21 varieties of eight crops were conducted over 100.02 ha area. Wheat demonstrations (176) on IARI varieties (HD 2967, HD 3086, HD 3226, HD 3249, HI 1634, HI 1605, HI 1620, HS 562) were carried out over 25.3 ha area while mustard varieties (Pusa Vijay, PM 30, PM 32, PM 33) were demonstrated in 82 trials over 12 ha area. Additionally, 131 demonstrations on Gram (P 547, P 3062), Onion (Pusa Red, Pusa Madhavi), Spinach (Pusa Bharti), Marigold (Pusa Bahar, Pusa Naragi), Carrot (Pusa Rudhira) and Lentil (L 4717) were conducted in an area of 10.55 ha. The on-farm demonstrations of improved crop varieties across multiple states highlighted significant yield advantages, better adaptability and higher economic returns compared to local checks. These demonstrations focused on major crops like wheat, mustard, onion, carrot, chickpea, spinach, lentil, and marigold, ensuring wider dissemination among farmers. Wheat varieties such as HI 1634, HD 3226 and HD 3086 demonstrated 6.19-46.88% higher yields due to their adaptability across diverse agro-climatic conditions, rust resistance and superior grain quality. Mustard varieties Pusa Vijay and PM 32 showed a 9.30–10.34% yield advantage, with improved oil content and better disease resistance, making them preferable for sustainable mustard production. Similarly, lentil varieties exhibited better disease resistance and higher yield potential, encouraging their adoption in pulse-growing regions. High-value vegetable crops such as onion (Pusa Red), carrot (Pusa Rudhira) and marigold (Pusa Narangi) recorded 16.93–25% higher yields, reflecting their strong market demand and profitability. These crops, particularly marigold, proved beneficial for floriculture-based income diversification. Overall, the demonstrations reaffirmed the advantages of improved varieties in terms of yield, quality, and profitability.

During *kharif* 2024, a total of 581 demonstrations were conducted on five major crops, covering 105.75 hectares across 12 ICAR Institutes/SAUs and 16 Voluntary Organizations. A total of 271 demonstrations were conducted on seven high-yielding paddy varieties (PB 1850, PB 1692, PB 1509, PB 1718, PB 1847, PB 1885 and PB 1886) across multiple locations. The varieties demonstrated significant yield improvements, ranging from 8.13-59.3% over local checks. Notably, PB-1850 yielded 55.40 q/ha in Varanasi, with a 13.52% increase over the local check, and PB 1886 in Jammu recorded the highest yield of 47.5 q/ha with a B: C ratio of 3.63. Farmers preferred IARI-developed varieties due to their higher productivity, superior grain quality, aroma and better market acceptability. Seed production has also been initiated through FPOs engaged in basmati export zones.

A total of 310 demonstrations were conducted on okra, cowpea, bottle gourd, and brinjal, covering 6.87 ha. Okra variety Pusa Bhindi-5 exhibited a yield increase of 33.4% in Odisha and was found to be highly resistant to YVMV. Cowpea Pusa Dharni recorded an increase of 39.74% in Rajasthan, while bottle gourd Pusa Naveen was appreciated for its sweetness and low disease incidence. Farmers favored cylindrical-shaped bottle gourd varieties over pear-shaped ones for better market acceptability. Brinjal Pusa Vaibhav, with a green calyx trait, recorded a 23.59% yield increase and was well-received by growers. The improved varieties demonstrated significant economic benefits, with B: C ratios ranging from 1.82-3.63, making them profitable and scalable.

7.3.3. Farmers' Outreach/Mobilization

A field visit was arranged for the 1500 farmers (special invitees for Republic Day) to ICAR-IARI, New Delhi campus, to showcase the improved agricultural technologies. The farmers explored 18 research clusters at IARI, covering advanced farming technologies, like protected cultivation (greenhouses and ornamental nurseries), vegetable nurseries, vertical farming and hydroponics, mushroom units, integrated farming (irrigated) models, integrated farming (rainfed) models, advanced water management technologies at the Water Technology Centre, Pusa Farm Sun fridge, millet fields, nutrition management fields, sub-surface irrigation and fertigation fields, conservation farming, paddy fields, composting units, Pusa Amrit Sarovar, farm machinery workshops, floricultural technologies, mango and kinnow orchards and Pusa Agri-Krishi Haat.

7.4 AGRICULTURAL TECHNOLOGY INFORMATION CENTRE (ATIC)

ATIC was established in 1999 at ICAR-IARI to serve as a 'Single Window Delivery System' to provide the Institutes' products, services, and technologies to the farmers/entrepreneurs, etc. The various services provided by ATIC are as follows:

Pusa helpline: A total number of 5,895 farmers' calls from 12 states were received, and queries were answered through Pusa Agricom (Toll-free 1800-11-8989); Pusa Helpline (011-25841670, 25841039, 25846233, 25803600) and *Kisan Call Centre* 1800-180-1551 (IInd level) on various aspects of agriculture.

Pusa seed and publication sale: Sales amounted to ₹ 5,80,570 for Pusa seeds and ₹ 13,045 for farm publications.

Crop *cafeteria*: Visitors were treated to live demonstrations of improved IARI varieties, a Nutri-garden and an herbal garden.

Publication of ***Prasar Doot:*** Four issues of Hindi farm magazine *Prasar Doot* were published and approximately 250 farmers' queries were answered *via.* e-mails.

Feedback and linkages: The centre has developed links with KVKs, State Line departments, SAUs, ICAR Institutes, and Farmer's Producer Organizations.

Pusa Agri ***Krishi Haat:*** A direct marketing platform with 60 shops is functional offering farmers a way to sell agri-products directly to consumers. Promotional activities like the Yoga program, Vegetable Gardeners' Exhibition, *Diwali Mela*, etc. were organized to raise awareness about the *Haat*.

7.5 KRISHI VIGYAN KENDRA

7.5.1 Training Programmes for Farmers/Rural Youth/Women

Training Program	Date	Location	Participants	Key Focus Areas
IDM in Tomato and Cucurbits	February 6-9 and March 12-15, 2024	KVK Shikohpur and Village Tajnagar	64	Disease identification & management
IPM in Gram Pod Borer, Cucurbits, Pearl Millet, Cotton, Pigeonpea, Mustard and Horticultural Crops	Feb 26-29, Mar 5-8, Aug 16, Jul 3 & Oct 1, Aug 21, Nov 11 & Nov 28-29, Nov 12, 2024	KVK Shikohpur	303	Pest management strategies
Judicial Use of Glyphosate	February 15, 2024	Gurugram District	25	Safe application of herbicide
Natural Farming Training and awareness programs	February 20-March 1, 2024	KVK Shikohpur	120+242	Preparation of *Jeevamrit, Ghanjeevamrit, Beejamrit, Neemastra, Brahmastra,* etc.
Integrated Nutrient Management in Pearl Millet	June 27-28 and July 26, 2024	KVK Campus & Village Udaipur (Langra)	47	Soil fertility & balanced nutrition
Solanaceous Crop Cultivation (ASCI Sponsored)	June 5-7, 2024	KVK Shikohpur	29	Enhancing solanaceous crop productivity
Vegetative Propagation & Nursery Management	July 22-26, 2024	Village Baaspadamka	25	Vegetative propoagation techniques like cutting, grafting, layering, budding, etc.
Water Harvesting & Alternate Crops in water-deficient areas	July 30-31, 2024	KVK Campus	25	Drip and sprinkler irrigation, water-saving crops, Roof-top harvesting
Safe Storage of Food Grains	July 02, 2024	Village Sarmathla, Sohna	15	Storage methods, storage pests & control measures
Leadership Development in Farmers' Groups	September 6, 2024	Village Lakhuwas	35	Farmers' groups & FPO formation
Group Dynamics of SHGs & Farmers' Organizations	October 22-23, 2024	KVK Campus	20	Strengthening SHGs & farmers' groups
Metabolic Disorders in Cattle & Management	October 21, 2024	Village Shikohpur	21	Prevention of cattle diseases, including ketosis, milk fever, fat cow syndrome, and hypomagnesemia

7.5.2 Vocational Trainings

Training Program	Date	Location	Participants	Key Focus Areas
Value Addition in Millets	July 23-27, 2024	KVK Campus, Gurugram	25	Millet-based products like biscuits, namkeen and flour
Vermicompost Production Technology	August 6-10, 2024	Village Dhani Chitrasen	25	Vermicompost, Vermi Wash, vermicompost unit construction & management
Production Technology of Mushroom	August 5-9, 2024	KVK Campus, Gurugram	25	Cultivation of different mushrooms, visit to button mushroom unit
Entrepreneurship Development through Dairy Farming	September 9-13, 2024	Village Kukrola	28	Breeds, housing, care, health management, production, marketing and value addition of dairy products
Entrepreneurship Development through Beekeeping	September 17-24, 2024	Village Baghanki	25	Types of bees, hive management, honey extraction and other bee products

7.5.3 Cluster Front Line Demonstrations/Front Line Demonstrations

Crop	Variety	Area (ha)	No. of farmers
***Rabi* 2023-24**			
Mustard	PM 31, Radhika	75	135
Nutri garden	Summer and winter vegetables	0.3	20
Wheat	HD 3298	4.0	10
Summer 2024			
Green Gram	Pusa Moong 1431	10.0	20
Pearl Millet	HHB 299	20.0	44
Pigeon Pea	Pant Arhar 6	10.0	25
***Rabi* 2024-25**			
Mustard	DRMR 215-17 (Radhika)	100.0	157
Vegetables	Palak	2.0	8
	Methi	2.0	8
	Dhaniya	2.0	10
Wheat	HD 2969	4.0	10
	HD 3296	6.0	15
	HD 3086	4.8	12
	HD 3406	5.20	13
	Total	**245.3**	**487**

7.5.4 Agricultural Extension Activities

Program	Date	Location	Details	Participants
Kisan Gosthi and awareness programme	Jan 9, Jan 28, Mar 13, Mar 22, Jun 18, Aug 5, Aug 15, Aug 29, Oct 28, 2024	KVK Gurugram	Organized on various themes such as New Agricultural Technologies, Kisan Samman Nidhi, Agricultural Drones, National Pest Surveillance System, World Water Day, Unnat Bharat Abhiyan and SCSP and Millenium Farmers Award	774 farmers, farm women, students, and extension functionaries
Viksit Bharat Sankalp Yatra	Jan 1-20, 2024	55 Gram Panchayats, Gurugram	Awareness program on natural farming, soil testing, and drone applications in agriculture	71,455 farmers and farm women
Rural Agricultural Work Experience (RAWE)	Apr 1-May 10, 2024 & Aug 1-31, 2024	KVK Gurugram	One-month training for B.Sc. (Agri) students, covering practical aspects of agriculture	16 students
Plantation Drive ("Ek Ped Maa Ke Naam")	Jun 28 & Aug 12, 2024	KVK Campus	Plantation of 150 trees (Arjun, Neem, Mango, etc.) along with a cleanliness drive	Staff of KVK
Field Day on Pigeonpea	Oct 10, 2024	Village Raiseena	Demonstration of new pigeonpea variety (Pant Arhar 421) with comparison to farmers' practice	20 farmers

7.5.5 Celebration of Important Days

S. No.	Particulars	Date	No. of Participants	Venue
1.	International Womens' Day	March 8, 2024	52	Krishi Vigyan Kendra, Shikohpur
2.	*Parthenium* Eradication Week	August 16-22, 2024	Staff	KVK Gurugram
3.	World Food Day 2024	October 16, 2024	69	Baghanki
4.	Krishi Shiksha Diwas	December 03, 2024	115	Government Middle School, Tripari
5.	World Soil Day	December 5, 2024	52	Lohsinghani, Sohna, Gurugram

7.6 TRANSFER OF TECHNOLOGY THROUGH OUTREACH PROGRAMMES

The institute implements various outreach programs, 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 programs are also regularly organized to build farmers' capacity.

7.6.1 Interventions Under Scheduled Caste Sub Plan (SCSP)

The main objective of the SCSP scheme is the economic development of SC individuals 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 of field and vegetable crops, *viz.* paddy, moong, pigeon pea, wheat, mustard, lentil, chickpea, onion, carrot, fenugreek and spinach for undertaking field demonstrations. Besides, vegetable seed kits were also distributed during the *rabi* and *kharif* seasons for household nutritional security. Several Farmer-Scientist interface meetings and training programs were organized across the districts. Twenty-two training programs 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 10996 farm implements like bill hooks, spades, rose cans, buckets, umbrellas, torches, secateurs, sprayers, and tarpaulins were distributed in Hapur, Ghaziabad, Aligarh, Hathras, Hamirpur, Champaran, Saharanpur, Palwal and Alwar. A total of 18 training programs on improved cultivation of paddy, *rabi* crops, horticultural crops and agricultural residue management were conducted, benefitting 5731 farmers.

Details of seeds distributed under SCSP during 2024

Crop	Varieties	Seed (q)	Location (District)
***Kharif* 2024**			
Paddy	Pusa Basmati-1121, 1509, 1692, 1718, 1847, Pusa Sugandh-5, Pusa Samba 1850 and 1853	2650	Bulandshahr, Hapur, Gautam Budh Nagar, Ghaziabad, Mathura, Aligarh, Agra, Muradnagar, Meerut, Saharanpur, Firozabad, Moradabad, Udham Singh Nagar, Palwal, Hathras, Firozabad, Kasganj, RS, Bihar
Arhar	Pusa 991, Pusa 992	10.88	
Moong	Pusa Vishal, Pusa 1431 and Pusa 9531	33.70	
Vegetable Kit	Different crop varieties	….	
***Rabi* 2024-25**			
Wheat	HD 3226, 3086, 3098, 3271, 3237, 3059, 2967, HS-562, HI-1653, 1654	3618.40	Bulandshahr, Hapur, Gautam Budh Nagar, Ghaziabad, Firozabad, Aligarh, Agra, Hathras, U.S. Nagar, Bhind and Meerut
Mustard	PM-30	10	
Palak	Pusa Bharti	5	
Barley	BHS-352	2.5	
Demonstrations at Regional Station Bihar			
Paddy	Pusa Sugandh-5	6900	Samastipur, Darbhaga Muzaffarpur, Siwan, Nalanda, Motihari, West Champaran, Patna
Moong	Pusa-44	1000	
	PNR-381	1800	
	Pusa Vishal	900	
	Pusa-1431	200	
Arhar Seed	Pusa-151	900	
Demonstrations at Regional Station, Kalimpong			
Rice	Rice (Pusa samba 1830)		400
Fruits	Grafted mandarin		300
	Dragon fruit (Siam red), UBKV		200
Arecanut	ICAR-Mohitnagar		1000
Vegetables	Drumstick		500
	Papaya		300


www.punjabkesari.in
हमीरपुर केसरी
रविवार SUNDAY, 5 जनवरी 2025

500 किसानों को मिलेट्स की खेती के लिए किया प्रेरित

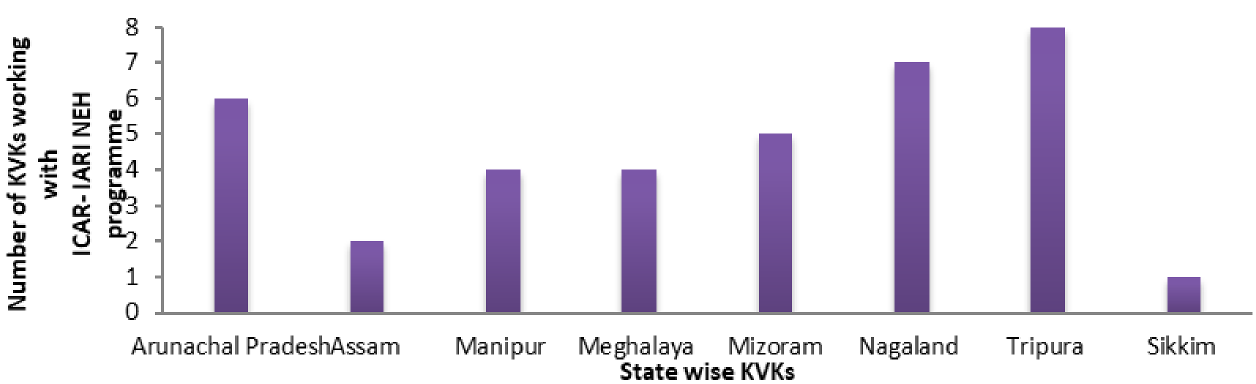
मिलेट्स की खेती से किसानों की आर्थिकी होगी मजबूत

Interventions under SCSP

7.6.2 Interventions under the NEH Programme

ICAR-IARI is implementing the NEH program across eight states—Arunachal Pradesh, Assam, Manipur, Meghalaya, Sikkim, Mizoram, Nagaland and Tripura. A total of 37 KVKs are directly connected with IARI, with six KVKs (KVK Phek, Nagaland; KVK Tirap, Arunachal Pradesh; KVK Kolasib, Mizoram; KVK West Garo Hills, Meghalaya; KVK Longding, Arunachal Pradesh; and KVK East Khasi Hills, Meghalaya) added to the NEH program in 2024. Additionally, the program covers five aspirational districts: Churachandpur (Manipur), West Khasi Hills (Meghalaya), Wokha (Nagaland), Mon (Nagaland) and Dhalai (Tripura).

During FY 2024-25, ₹ 189 lakh was utilized under the NEH program. Of this, ₹ 45 lakh was allocated for providing planting material to farmers in the NEH region through various KVKs for on-field demonstrations. Additionally, 236,700 kg of potato seed (varieties: Kufri Jyoti, Kufri Pukhraj and Kufri Himalini) was distributed to 4,000 farmers across 25 KVKs, covering approximately 170 hectares of land. Farmers also received 11,500 vegetable kits and 2,585 small hand tools to support agricultural activities in the region.



State-wise number of KVKs under the ICAR-IARI NEH Programme

7.6.3 Interventions under Tribal Sub-Plan

During the *rabi* season, 350 wheat demonstrations were conducted under the Tribal Sub Plan (TSP) in Rajasthan and Madhya Pradesh. The average yield recorded was 30 q/ha, compared to 15 q/ha for local varieties, resulting in a yield increase of 15 q/ha. Additionally, 500 mustard demonstrations were conducted in Dausa district, Rajasthan, featuring two new varieties, PM 28 and PM 30, with the recommended package of practices. These demonstrations achieved an 80% increase in yield over local varieties. Furthermore, 1,000 tribal families in Dausa district benefited from the promotion of vegetable kitchen gardens, aimed at enhancing household nutritional security.

7.6.4 *Mera Gaon Mera Gaurav* (MGMG)

The MGMG program enhances the farmer-scientist interface to ensure the timely delivery of agricultural information to farmers. The initiative provides regular advisories to farmers in 550 adopted villages, engaging 440 multidisciplinary scientists. Collaborations with organizations such as Gram Panchayats, NHB, NBPGR, CPRI, ACF, NABARD, HIMCOSTE, KVKs, IFFCO, YSPUHF, IIWBR and State Agricultural Departments have strengthened the program, benefiting 15,142 farmers.

Extension Activities conducted in MGMG villages (January- December, 2024)

S. No.	Name of Activity	No. of Activities Conducted	No. of Farmers Benefitted		
			General	SC/ST	Total
2	Demonstrations conducted	667	917	62	979
3	Interface meeting/ *Goshthis*	92	1191	160	1351
4	Literature support provided	1030	1052	104	1156
5	Trainings organized	10	181	36	217
6	Visit to village by teams	97	2593	260	2853
7	Mobile based advisories	283	3153	849	4002
8.	No. of villages covered	333	2593	260	2853
	Total	**2512**	**11680**	**1731**	**13411**

Distribution of seeds of Basmati rice and vegetables in different villages under the MGMG program

Kisan Goshthi on Nutri-Kitchen garden for enhanced household Nutrition Security and Climate Resilience

Distribution of seed to farmers of villages Bassi, Ratol, Sunheda Distt. Baghpat, U.P.

Under MGMG, a total of six training programs, 150 demonstrations and eight awareness programs covering 350 farmers were conducted at IARI Regional station, Kalimpong. Improved technologies of Darjeeling mandarin (nucellar seedling, grafted planting materials, rootstock, mulching technique to control fruit fly), healthy sucker of varlangey cultivar of large cardamom, seeds of vegetables (brinjal, cabbage, cauliflower, tomato, chili, green peas, bottle gourd, bitter gourd, etc.) were distributed under the program.

7.6.5 Pusa *Krishi Vigyan Mela* 2024

The annual Pusa *Krishi Vigyan Mela* 2024, themed '*Krishi Uddhyamita- Samriddh Kisan*,' was organized from March 10-12, 2024, at Albert Ekka Stadium, Simdega, Jharkhand. The *Mela* was inaugurated by Sh. Arjun Munda, Hon'ble Union Minister of Agriculture and Farmers' Welfare. On this occasion, two farmers, Sh. Meenu Mahto and Sh. Bina Oraon from Jharkhand was awarded the IARI–Innovative Farmers Award. Different public and private organizations exhibited their technologies and products through posters and live materials. The three-day event was visited by more than 4000 farmers, entrepreneurs, State agricultural officials, school children and other visitors. Vegetable seed kits and extension literature were also distributed to the participating farmers on this occasion. Technical sessions on improved technologies for cereals and horticultural crops and agri-enterprises were organized and the farmers' queries were also addressed by scientists of different disciplines from IARI. Scientists from IARI New Delhi, IARI Jharkhand, MGFRI Motihari, KVKs (Jharkhand), NHB, State Line Departments, etc. jointly participated in the event.

Inauguration of *Mela* by Sh. Arjun Munda, Hon'ble Union Minister of Agriculture and Farmers' Welfare

IARI Pusa Bihar also organized a three-day *Kisan Mela* (February 24-26, 2024) at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The mela showcased wheat, paddy, mungbean, and papaya varieties. Over 1,000 farmers and visitors benefited from IARI's agricultural advisory services.

7.6.6 Innovative Farmers Meet

An Innovative Farmers' meet was organized at the B. P. Pal Auditorium of ICAR-IARI, New Delhi on June 6, 2024, which was attended by selected progressive farmers from all over India. Thirty-one farmers were felicitated with the Innovative Farmer Award and seven farmers were conferred with the

Fellow Farmer Award. On this occasion, four farmers honored with the Padma Shri Award by the Govt. of India also participated as invited guests. Apart from the illustrious presence of awardee farmers and invited progressive farmers, policymakers of different levels, agricultural scientists and students also participated in the meet.

Innovative farmers meet at IARI, New Delhi

7.6.7 Pusa Samachar

A multimedia-based innovative extension model, Pusa Samachar, was launched on August 15, 2020 to educate farmers and other stakeholders about the latest technologies and seasonal cultural practices. Every Saturday at 7 PM, a new episode is uploaded on IARI's official YouTube channel. To date, 229 episodes in Hindi have been uploaded, along with 140 episodes in regional languages (Telugu, Kannada, Tamil, Bangla and Odiya), which are disseminated *via*. YouTube and WhatsApp groups. To enhance farmer-scientist interaction, a dedicated Pusa WhatsApp number (9560297502) was introduced, allowing farmers to send farm-related queries along with pictures for prompt responses from scientists. The IARI YouTube channel has amassed 53,000 subscribers and a total viewership of 2.3 million. Each episode includes season-specific crop management practices, success stories of farmers, Pusa WhatsApp Salah and weather advisories.

A total of 521 agricultural topics across 17 disciplines have been covered. The highest coverage was found in Vegetable Sciences (26%), followed by Agronomy (22%), Genetics (15%), Plant Pathology (11%), Horticulture (7%), Entomology (5%), and other disciplines, including Protected Cultivation, Agricultural Engineering, Microbiology, Soil Science, Economics, Floriculture, and success stories of farmers. Crop-wise, 153 topics were covered under cereals (rice, wheat, maize, millets), 103 topics on vegetables (leafy vegetables, pea, onion, garlic, carrot, tomato, potato, bathua, okra, bitter gourd, bottle gourd, cucumber, chili, general management), 43 topics on pulses (chickpea, lentil, mungbean), 41 topics on fruits (papaya, guava, mango, apple, citrus), 19 topics on oilseeds (mustard) and 4 topics on floriculture (rose, protected cultivation). Additionally, 75 general topics related to integrated farming systems, soil-less cultivation, Pusa decomposer, farm bills, careers in agriculture, Pusa STFR meter, biofertilizer applications, spirulina, and mushroom production were also covered, along with 51 special videos on different crops. In terms of audience engagement, 17.12% of total watch hours were contributed by females, while 82.88% were contributed by males. Sharing analysis revealed that WhatsApp was the dominant platform for content distribution with 90,015 shares, followed by Facebook (4,000 shares), Gmail (312 shares), Twitter (157 shares) and Facebook Messenger (91 shares). Analysis of traffic sources showed that viewers accessed the episodes primarily through browse features (870,000 views), external sources (450,000 views), suggested videos (200,000 views), YouTube search (120,000 views), channel pages (90,000 views), notifications (51,000 views), and other YouTube features (42,000 views).

A survey was conducted to assess stakeholders' perception and knowledge gain through Pusa Samachar. The results indicated that 86% of farmers regularly watch Pusa Samachar and 90% share the content with colleagues. Moreover, 84% of farmers believed that the content was timely, well-structured, systematically presented, comprehensible and highly relevant to their farming needs, especially during pest and disease outbreaks. To assess knowledge gain, a knowledge test was conducted, categorizing farmers into low, medium, and high knowledge levels based on mean and standard deviation scores. The findings showed that 41% of farmers belonged to the high knowledge category, 37% to the medium category and 22% to the low category.

Glimpses of Pusa Samachar

7.6.8 Training and Capacity Building

The Institute has organized several training courses to benefit farmers and extension workers.

Training programs organized by Divisions and Regional Stations

S. No.	Divisions	Number	No of trainees
1.	Division of Agricultural Economics	4	145
2.	Division of Environmental Science	4	143
3.	Division of Agricultural Engineering	1	20
4.	Division of Genetics	1	38

5.	Division of Floriculture and Landscaping	2	40
6.	Division of Plant Pathology	1	30
7.	Division of Agricultural Physics	2	125
8.	Division of Plant Physiology	5	123
9.	Division of Agricultural Extension	10	376
10.	Division of Water Technology Centre	3	72
11.	Division of Agronomy	6	100
12.	Division of Post-Harvest Technology	4	100
13.	Division of Fruits and Horticultural Technology	2	230
14.	Division of Vegetable Science	1	50
15.	Division of Food Science and Postharvest Technology	7	135
16.	Division of Soil Science and Agricultural Chemistry	5	100
17.	Division of Microbiology and CCUBGA	9	180
18.	Division of Seed Science and Technology	6	2332
19.	CATAT	6	110
20.	IARI- Regional Station, Katrain	2	70
21.	IARI-Regional Station, Kalimpong	3	150
22.	IARI- Regional Station, Indore	12	200
	Total	**96**	**4664**

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 objectives, KVK Gurugram organized the following activities in 2024, which benefitted 185 village women

Name of activity	Location	Date	No. of farm women
Training on Health benefits and value addition in millets	Hasanpur Village	January 22-25, 2024	19
Awareness on Value addition in millets	Nuh block, Nuh	March 16, 2024	70
Training on Value addition in millets	KVK Gurugram	July 23-27, 2024	25
Training on Vermicompost production technology	Dhani Chitrasen	August 6-10, 2024	25
Training on Entrepreneurship development through dairy farming	Kukrola	September 9-13, 2024	23
Training on Entrepreneurship development through beekeeping	Bagahanki	September 17-24, 2024	23

Rural women were made aware of the nutrients present in nutri-cereals like jowar, bajra, ragi, *etc.* and motivated to make them a part of their daily diet. They were urged to establish a nutri-garden in their backyard to include more fruits and vegetables in their household diet. They were educated about the recommended dietary practices to reduce the cases of anaemia. Also, hands-on training was given on processed products in millets. Training on vermicompost production was given to educate farmers on how to convert waste into wealth, enhance soil fertility and generate income. The farmers were made aware of different aspects of dairy farming like breeds, housing, care and management practices, disease management, production and post-production practices (marketing and value addition), *etc.* The bee-keeping training program discussed types of honey bees, bee hives, management of bees, extraction of honey and other products.

Promotion of biofortified varieties for nutritional security was also done, covering 79 male and 45 female farmers. The beneficiaries were informed about the health benefits of the bio-fortified varieties. Nutri-gardens were established at Tajnagar and Tirpadi, where summer and winter vegetables were cultivated using IARI vegetable seed kits.

Promotion of fortified varieties for nutritional security was also conducted in the district, covering 124 farmers, which covered nearly 45 women. The beneficiaries were informed about the health benefits of the bio-fortified varieties. detail is given below

Crop	Variety	Area (ha)	No. of Demonstrations		Remarks
			M	F	
Mustard	PM 31	25	40	10	Double zero mustard (Low erucic acid)
Wheat	HD 3298	4	-	10	Zinc and iron rich
Pearl millet	HHB 299	20	39	5	Zinc and iron rich
	Total	**49**	**79**	**45**	

8.2 EFFECTIVENESS OF SHGs FOR GENDER EMPOWERMENT

Twelve women SHGs trained under the ARYA project are running their value-addition enterprises sustainably, creating their own identities and gaining recognition in society.

- Khitiz SHG is associated with the Feeding India Program under *Anganwadi Poshan Abhiyan* and provides orders to Anganwadis of the Sohna block of the Gurugram district. A total of 3,85,000 laddoos were supplied, prepared from *Urad dal,* ragi and peanut.
- Arzoo SHG, which works on value addition in spices, has tapped the local market in villages and roadside hotels and employed three people.

The annual turnover for 12 SHGs in the year 2024 is given below:

Sl. No.	Name of SHG	No. of women	Village	Main products	Annual turnover (₹ lakhs)
1.	Kshitiz SHG	10	Chandu	Bakery products of millets	40 .00
2.	Arzoo SHG	10	Sakatpur	Spices	150.00
3.	Nai Pahal SHG	10	Shikohpur	Variety of pickles	2.80
4.	Naya Din SHG	10	Harinagar	*Ladoos* & savoury items	1.71
5	Nari Shakti SHG	12	Khwaspur	Pickles & *ladoos*	0.85
6.	Muqabala SHG	09	Garhi Harsaru	*Amla* products	1.55
7.	Prajapat SHG	10	Tajnagar	*Amla* products	1.25
8.	Ekta SHG	10	Tajnagar	*Ladoos*	1.35
9.	Pragati SHG	10	Kherki Majra	Pickles & *ladoos*	1.25
10.	Dev SHG	10	Dhani Chitrasen	Spices	2.80
11.	Saheli SHG	10	Uncha Mazra	Pickles, variety of *ladoos* and savoury items or snacks	1.15
12.	Sakhi SHG	10	Mushedpur	Pickles, variety of *ladoos* and savoury items or snacks	0.80

9. THE GRADUATE SCHOOL EDUCATION AND INFORMATION MANAGEMENT

The Indian Agricultural Research Institute (IARI) has a rich legacy of excellence of more than 118 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, 5047 M.Sc., 115 M. Tech. and 5666 Ph.D. students have been awarded degrees including 518 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 the National Agricultural Education Accreditation Board (NAEAB) of ICAR for a period of five years *i.e*. 2020-2025 with 'A' grade.

9.1 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 B.Sc./B.Tech./ M.Sc./M. Tech./Ph.D. degree programs 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 2024-25, admission under the open scheme is given below.

9.1.1. Admission during the Academic Session 2024-25

SI. 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**	80	82	124	124	204	220
1.	**Hyderabad hub**	20	20	19	20	19	20
2.	**Bengaluru hub**	0	0	34	34	36	38
3.	**Baramati hub**	26	26	04	05		
4.	**Nagpur hub**	0	0	10	10	8	8
5.	**Bhopal hub**	0	0	21	23	19	20
6.	**Ranchi hub**	23	25	20	20	9	13
7.	**Cuttack hub**	30	30	15	15	11	12
8.	**Kolkata hub**	23	25	9	11	4	5
9.	**Shillong hub**	26	25	0	0	0	0
10.	**Lucknow hub**	12	15	12	13	2	2
11.	**Jodhpur hub**	0	0	6	6	6	6
12.	**Karnal hub**	24	25	15	15	11	11
13.	**Raipur hub**	32	35	5	5	3	4
14.	**Patna hub**	19	20	0	0	2	5
15.	**Assam hub**	28	30	4	4	0	0
16.	**Jharkhand hub**	64	66	18	20	0	0
	Total	**407**	**424**	**316**	**325**	**334**	**364**

9.1.2. Convocation

The 62nd Convocation of the ICAR-IARI, New Delhi was organized on February 9, 2024, in the Bharat Ratna C. Subramanium Auditorium, NASC Complex, New Delhi. Hon'ble President of India, Smt. Droupadi Murmu graced the occasion as the Chief Guest of the function. Hon'ble Union Minister of Agriculture and Farmers Welfare, Shri Arjun Munda, presided over the function. Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR, also graced the occasion.

Hon'ble President of India, awarding IARI merit medals to students

During the Convocation, the Hon'ble President of India awarded IARI merit medals to six M.Sc./ M.Tech. students and five students receiving their doctoral degrees. He also awarded the IARI Best Student Award 2023 and NABARD-Professor VL Chopra Gold Medal-2023 to Ms. Sheel Yadav, a doctoral student from the Division of Molecular Biology & Biotechnology and Ms. Jagadam Sai Rupali, M.Sc. student of Division of Entomology. She also presented the 3rd Dr. H.K. Jain Memorial Young Scientist Award for the year 2023 to Dr. R.S. Bana, Senior Scientist, Division of Agronomy; 23rd Sukumar Basu Memorial Award for the biennium 2021-22 to Dr. Y.S. Shivay, Principal Scientist, Division of Agronomy; 2nd NABARD Researcher of the year 2022 to Dr. Vinayak R. Nikam, Senior Scientist, ICAR-NIAP, New Delhi and 3rd NABARD Researcher of the year 2023 to Dr. Anirban Mukherjee, Scientist, ICAR-RCER, Patna. In this Convocation, a total of 545 students (224 M.Sc., 15 M.Tech. and 306 Ph.D.), including five foreign students who studied at IARI under International programs, have received their Post Graduate and Doctoral degrees.

On this occasion, Shri Arjun Munda released the IARI publications and varieties and presented the first copy/booklet to the President of India.

Dr. A.K. Singh, Director, ICAR-IARI, presented the Director's Report and provided comprehensive insights into the institute's advancements. Dr. Anupama Singh, Joint Director (Edn.) & Dean, ICAR-IARI, New Delhi, presented the Dean's Report.

Speaking on the occasion, the President said that the Indian Agricultural Research Institute has made an unparalleled contribution to achieving food security in India. This institute has not only efficiently carried out research and development work related to agriculture but has also ensured that such research reaches the ground. She was happy to note that this institute has developed more than 200 new technologies. Between 2005 and 2020, IARI has developed more than 100 varieties and has more than 100 patents in its name.

9.1.3 Special Lectures

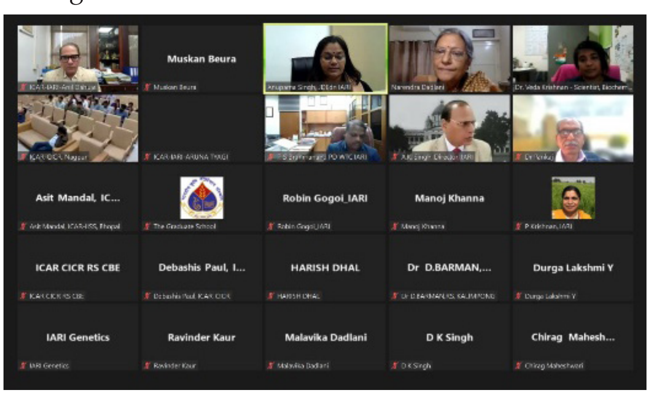
Lal Bahadur Shastri Memorial Lecture: As a part of the Convocation Week, the 54th Lal Bahadur Shastri Memorial lecture was delivered by Dr. Himanshu Pathak, Secretary, DARE & Director General, ICAR, New Delhi on February 8, 2024, on the topic "Transforming Agricultural Education for an Aspiring India" in Dr. B.P. Pal Auditorium, ICAR-IARI, New Delhi. The session was chaired by Dr. Panjab Singh, President, FAARD, Varanasi, & Former Secretary, DARE & DG, ICAR, New Delhi.

Dr. Himanshu Pathak, Secretary, DARE & Director General, ICAR delivering Shri Lal Bahadur Shastri lecture

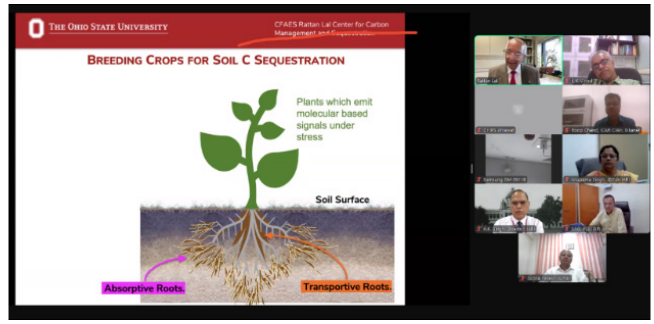
National Youth Day: ICAR-IARI, New Delhi, celebrated National Youth Day 2024 (NYD) on January 12, 2024. To mark the occasion, the NSS wing of The Graduate School, in association with the Indian Red Cross Society, organized a blood donation camp and walkathon in IARI, Pusa Campus premises. The main aim of the Walkathon and blood donation camp was "holistic development and social welfare."

Walkathon by NSS wing on NYD

Celebration of International Day for Women and Girls in Science: ICAR-IARI, New Delhi celebrated International Day for Women and Girls in Science on February 14, 2024. On this occasion, Dr. Malavika Dadlani, Former Joint Director (Research), ICAR-IARI, New Delhi, delivered a Lecture on 'Women in Science' through virtual mode.



31st Dr. B.P. Pal Memorial Lecture (through virtual mode): The 31st Dr. B.P. Pal Memorial Lecture was organized on May 29, 2024, by The Graduate School, ICAR-IARI, New Delhi, and the Genetics Club of IARI through virtual mode. On this occasion, globally revered IARI alumnus, Prof. Rattan Lal, Distinguished University Professor of Soil Science and Director,



Dr. B.P. Pal memorial lecture by Prof. Ratan Lal

CFAES Rattan Lal Center for Carbon Management and Sequestration, The Ohio State University, Columbus, USA and World Food Prize laureate, delivered a thoughtful lecture on "Soil Health in relation to Agrifood Systems Sustainability".

Adopt a plant initiative under the umbrella of World Environment Day-2024: Nature Club, an initiative of The Graduate School, ICAR-IARI, New Delhi, organized an "Adopt a Plant Initiative" drive on the occasion of June 5, 2024. The event was led by students in collaboration with the Nature Club, where 26 groups were made and responsibility was given to 69 students of B.Sc./B.Tech. 1st year students to take care of saplings of the Amaltas (*Cassia* fistula) and Gulmohar (*Delonix* regia) till the final year of their degree program.

Planting of Amaltas and Gulmohar saplings by students

The Pusa Graduate School Students' Union (PGSSU) at the ICAR-IARI, New Delhi, also organized an extempore and poster-making competition on June 05, 2024. The event, centered around the theme "Heal the Planet Against Rising Climate Crisis," aimed to engage students in environmental awareness and creative expression regarding climate change solutions.

Poster-making competition by PGSSU

Seminar-cum-awareness program on responsible use of the crop protection products: The Internal Quality Assurance Cell (IQAC), ICAR-IARI in collaboration with BASF, Agricultural Solutions, India organized a Seminar-cum-Awareness program on the topic, "Suraksha Hamesha-Responsible Use of the Crop Protection Products" for the benefit of students and faculty of ICAR-IARI, New Delhi on July 4, 2024 in Dr. B.P. Pal Auditorium. The program was chaired by Dr. Anupama Singh, Joint Director (Edn.) & Dean, ICAR-IARI, New Delhi.

Seminar-cum-Awareness program on Suraksha Hamesha-Responsible Use of the Crop Protection Products

Special lecture cum interactive session on scientific writing: Dr. Sergey Savary, renowned plant disease epidemiologist from France and an Adjunct Professor at Division of Plant Pathology, ICAR-IARI, conducted a series of lectures on "Scientific Writing" from July 9-11, 2024 at Virology Auditorium, Division of Plant Pathology, ICAR-IARI, New Delhi

Teachers' Day lecture: The Graduate School, ICAR-IARI, New Delhi, in collaboration with the Genetics Club of ICAR-IARI, organized the Teachers' Day Lecture on September 5, 2024. Prof. Appa Rao Podile, Senior Professor and JC Bose Fellow and Former Vice Chancellor, University of Hyderabad, Hyderabad, graced the event as a speaker who provided valuable insights to the audience. The session was presided over by Prof. S.L. Mehta, former Vice Chancellor, MPUAT, Udaipur & former Deputy Director General (Education), ICAR, New Delhi.

Teachers' Day Lecture by Prof. Appa Rao Podile

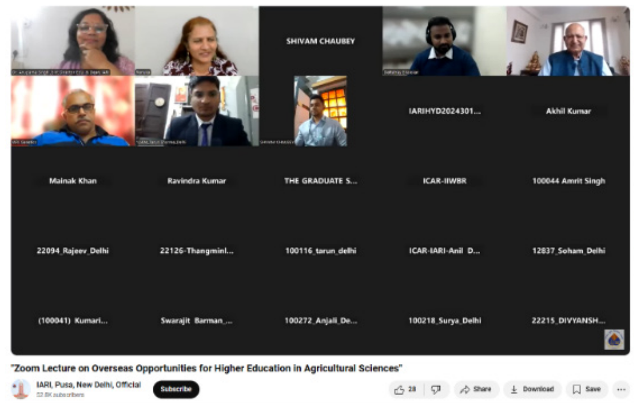
Special Lecture on Mental Health Wellness: To address the mental health wellness needs of the IARI students and stress management to cope with anger, loneliness, anxiety, or depression, a special lecture by Dr. Gayatri Bhatia, Assistant Professor (Psychiatry), AIIMS Rajkot, on the topic "Prevention of suicidal tendency and managing stress for the well-being of all" was organized on September 17, 2024, through online mode.

Online interactive Workshop on World Mental Health Day: On the occasion of World Mental Health Day on October 10, 2024, an online interactive workshop was organized, in line with the theme of 2024, "It is Time to Prioritize Mental Health in the Workplace," in collaboration with Brain Behaviour Research Foundation of India (BBFRI), for the faculty and staff at the ICAR-IARI, New Delhi. This session aimed to shed light on the importance of mental health and provide practical insights and strategies for enhancing well-being.

Deeksharambh: Student Induction Program 2024: The inauguration of "*Deeksharambh:* Student Induction Program 2024 " for newly admitted undergraduate students was organized at ICAR-IARI, New Delhi on October 15, 2024 in the Assembly Hall of the Division of Agricultural Engineering, ICAR-IARI. The occasion was graced by Dr. R.C. Agrawal, DDG (Education), ICAR, New Delhi; Dr. T.R. Sharma, DDG (Crop Science) and Director & VC (Addl. Charge), ICAR- IARI, New Delhi; Dr. Anupama Singh, Joint Director (Education) & Dean, ICAR-IARI and Dr. Harshawardhan Choudhary, Associate Dean (UG), ICAR-IARI and other esteemed dignitaries from ICAR-IARI, alongwith faculty and newly admitted UG students from the hub campuses in online mode. The objective of this two-week orientation program is to familiarize the students with the institute, its culture, rules, resources, and more, so that they can embark on their academic journey smoothly and successfully.

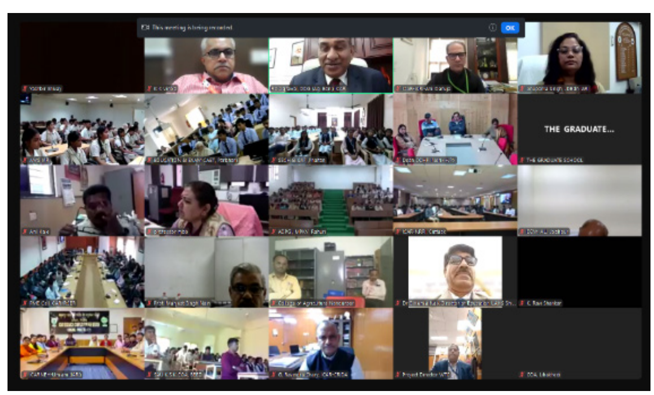
Inauguration of "*Deeksharambh:* Student Induction Program 2024

Brainstorming session on "Overseas opportunities for Higher Education in Agricultural Sciences: the PGSSU of ICAR-IARI, New Delhi organized a Brainstorming session on "Overseas opportunities for Higher Education in Agricultural Sciences through online mode on November 17, 2024. In this session, Ms. Renuka Vallarapu, Senior Management Analyst, Seattle University, USA, delivered a talk on "Beyond Borders Cultivating a Global Career: Navigating Study Abroad Options for Indian Graduates," and Mr. Dattatray G. Bhalekar, Ph.D. Scholar Washington State University, USA also delivered a talk on "Mastering the Path to Higher Education in the USA: Tips and Strategies." The session was chaired by Dr. R.S. Paroda, Chairman, TAAS, New Delhi; President of IARI Alumni Association and Former Secretary of DARE & DG ICAR. Dr. Anupama Singh, Joint Director (Edn.) & Dean, ICAR-IARI was the Guest of Honour.



A one-day workshop on "IARI SDG strategies: A strength-based approach": A workshop entitled 'IARI SDG Strategy—A strengths-based approach based on research, FWCI and cite scores' was organized on November 18, 2024, in hybrid mode in the Board Room, Directorate, ICAR-IARI, New Delhi, under the guidance of Dr. Jen Dollin, Director, Sustainability Education and Partnerships, Western Sydney University (WSU), Australia. After the opening meeting, Dr. Jen Dollin also organized a campus tour.

Agricultural Education Day: ICAR-IARI, New Delhi, organized Agricultural Education Day through virtual mode on December 3, 2024, to commemorate the birthday of the first President of India, Shri Rajendra Prasad and also the first Union Minister of Food & Agriculture.



Agricultural Education Day lecture by Dr. R.C. Agrawal, DDG (Education)

Dr. R.C. Agrawal, Deputy Director General (Agricultural Education), ICAR, was the Speaker on this occasion and delivered a thought-provoking and insightful lecture on "Preparing Youths for 'Viksit Bharat' through Agricultural Higher Education."

To commemorate the day, a series of activities were also organized, including a quiz competition for NCR school students, a field day for the prenursery and nursery children of Nehru Experimental Centre, Pusa, and an awareness program organized by the Agricultural Extension Division at the Government Senior Secondary School, Village-Amarpur, Palwal district, which brought new dimensions to education.

IARI Alumni Meet and National Symposium organized by IARI Alumni Association: The newly elected Executive Committee of IARI Alumni Association organized IARI Alumni Meet which includes the felicitation of eminent alumni, Alumni Students interaction, GB meeting and National Symposium on "Transforming IARI into a Global Leader in Agricultural Research and Education: An Alumni Perspective" on June 22, 2024 at Bharat Ratna Dr. C. Subramaniam Auditorium, NASC Complex, Pusa, New Delhi. During the symposium, a panel discussion on IARI towards a Global University and an Open session on Mobilizing Resources for IARI to be a Global University were also organized.

During the inaugural function, Shri Shivraj Singh Chouhan, Hon'ble Union Minister of Agriculture & Farmers Welfare graced the function as Chief Guest and urged the scientific community to prioritize the

Dignitaries during IARI Alumni Meet

interests of small and marginal farmers and bring revolution in Indian agriculture. He also emphasized the need to make India self-reliant in pulses and oilseeds. The Alumni meeting was held under the chairmanship of Dr. R.S. Paroda, President of IARI Alumni Association.

IARI Alumni Association's 1st Foundation Day Lecture: The IARI Alumni Association (IAA) organized its First Foundation Day Lecture on December 2, 2024, through virtual mode. Prof. Govindarajan Padmanaban, Former Director of the Indian Institute of Science (IISc), Bengaluru, delivered the lecture on "60+ Years of Science at IISc," offering a glimpse into the evolution of scientific research and its impact on society.

IAA Foundation Day Lecture

Visit of Prof. Rattan Lal, World Food Prize laureate and Padma Shri: In the IARI Alumni Association (IAA) Lecture and Interactive Session Series, a lecture has been delivered by the internationally acclaimed Soil Scientist and notable alumnus of IARI, Prof. Rattan Lal, World Food Prize laureate and Padma Shri Awardee and Director, Carbon Management and Sequestration Centre, The Ohio State University, USA on December 11, 2024 in the Assembly Hall of Agricultural Engineering Division, ICAR-IARI, New Delhi through hybrid mode.

9.1.4 International Exposure

The excellence of IARI is recognized internationally. IARI has played a key role in the establishment of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Afghanistan.

ANASTU programme

- ANASTU is being developed in collaboration with ICAR-IARI and ICAR-IVRI under bilateral cooperation between India and Afghanistan and with the support of the Ministry of External Affairs, Government of India.
- IARI helped develop a detailed plan to establish ANASTU as a leading University for agricultural research in Kandahar, Afghanistan, in 2013-14.
- Under the ANASTU program, so far, three batches of MSc Agronomy and one batch each of MSc Horticulture, MSc Plant Protection and MSc Animal Husbandry have already graduated, and the 4th Batch of MSc Agronomy is expected to graduate in January 2025. The teaching of animal science courses is being done in collaboration with the ICAR-IVRI. The first two batches of MSc Agronomy were awarded MSc degrees of ANASTU in 2016 and 2018, but the subsequent batches were awarded joint ANASTU-IARI or ANASTU-IVRI degrees. The COVID-19 pandemic caused a setback; otherwise, by now, the students of the 4th batch of MSc Agronomy would have also completed their degree program.
- 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. And Animal Science. The MEA has also approved the start of online teaching of the fresh MSc Courses in the following five disciplines based on the 10-year plan of ANASTU: 1. Soil Science and Water Management, 2. Agriculture economics, 3. Agricultural extension, 4. Livestock production management, and 5. Plant breeding.

Screenshot of the ZOOM Meeting with the Chancellor and Vice-Chancellors of ANASTU held on August 28, 2024 to discuss the progress of ANASTU Programme and admission of fresh batches of students. A representative of the Indian Mission in Kabul also joined the meeting.

- The Ministry of Higher Education, Government of Afghanistan is conducting tests to admit students of ANASTU for MSc degree in the nine disciplines listed above. The online teaching of the fresh batches will start as soon as the newly admitted students join ANASTU.
- Syllabi for various courses have been developed and arrangements for concurrent online teaching of various courses have been made, utilizing the tele-education facility developed under the ANASTU programme, and also the facilities available in various Divisions of the IARI.

9.2 LIBRARY AND LEARNING RESOURCES

IARI Library was established in the year 1905 in Pusa Bihar; since its inception, the library has been catering to the literature requirement of the scientific community for more than 119 years. In its early collection, there were only 5000 publications which were donated by the secretary, Department of Agriculture, Govt of India, In the year 1934, due to a devastative earthquake on January 15, 1934. The library, along with the Institute, was shifted to the present campus in Delhi on July 29, 1936. As a tribute to Prof MS Swaminathan, the eminent scientist and father of the Green Revolution of India, the name of IARI Library was re-named "Prof MS Swaminathan Library on April 29, 2016. In pursuance of the Library Advisory Committee (LAC) 2019 meeting recommendation, the status of Prof. MS Swaminathan Library has been upgraded, henceforth the Prof. MS Swaminathan Library is designated as "Prof. MS Swaminathan National Agricultural Science Library" w.e.f. January 17, 2020.

Prof. MS Swaminathan Library is playing the role of National Repository for Agriculture-related literature in India. The library is one of the largest and finest agro-biological libraries in South East Asia, housing over four lakh 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 the lead centre to all ICAR sister institutes/SAUs and International institutes. The library has on its role 1610 active registered members viz scientists, students, and technical/administrative staff. Apart from registered members, the library served approximately 50 to 100 users per day from different Agricultural Universities/ ICAR Institutes/SAUs who consult approximately 50 to 100 library publications/articles online/offline every day. The Library provides reference services, bibliographical services, documentation services, online international abstracting database search services, etc.

9.2.1 Books/ Serials

During the period library procured 4302 Books. The Library also acquired 199 Books on Gratis/Gift Gratish journals/Annual reports/) publications, 71 Hindi books, Advances/ Annual Reviews 51/510 Ph.D./MSc. Received IARI Thesis PhD/MSc 510 CDs. Uploaded 1053 Thesis CDs on Krishikosh. During the period, the library procured 68 Indian Journals, 26 Foreign Journals, Gratis Journal 10, Annual Reports 47, Bulletins 7 and Newsletters/Magazines 70.

9.2.2. Online Database

J-Gate (Complete) Database covering 59124+ journals Covering Major Disciplines for 2024-25. Total login session 525, Searches 2634, Full Text and Abstract views 2,344.

9.2.3. Library e- Resources Available on the IARI Website

- CABI Digital Library
- Online Journal 2022
- Books Catalogue
- DOAJ (e-Resources)
- E-Resources
- World e-Book Library
- E-resources from CeRA
- e-Books of ASAP
- 183 Taylor & Francis e-Books
- CSIRO Journals
- CeRA Journals
- Krishikosh@IARI
- 196 Ebooks by CUP
- 228 E-books by Wiley
- CABI E-BOOKS (2000-2023)
- National Digital Library of India
- RemotLog

9.2.4. Resource Management

Apart from 1610 active registered members, the Library served 50 to 100 users per day who come from different agricultural universities/ICAR Institutes and consulted approximately 50 to 100 documents every day. Registered 354 new members. During the period under report, 924 publications were issued and 761 publications returned. Under the Inter Library Loan System, 12 documents were issued to various institutions. Also 381 No dues Certificates were issued.

9.2.5. Document Delivery Service

The resource Management Section of the Library provides Document Delivery Services to different users of the Agricultural field through CeRA. Total number of hits 6,513. Total login session: 727, Searches: 2322 Full Text and Abstract views: 980. The total number of requests received was 325 through CeRA and uploaded requested articles in J-Gate.

9.2.6. Krishikosh

Krishikosh provides a ready software platform to implement all aspects of the open access policy, similar to 'Cloud Service' for individual institution's self-managed repository with central integration. These two products of e-Granth (i) Krishikosh and (ii) IDEAL are being used by all SAUs/DUs/CUs & ICAR Institutes. Up to Dec, 2024. Total IARI Publications on Krishikosh 13085. Total theses are 6911.

9.2.7. e-Language Lab

With the help of the library Strengthening program Language lab was established with a seating capacity of about 50 participants to facilitate English language classes for IARI foreign/Indian students with modern facilities like 30 computers with internet facility, interactive board, visualizes, interactive panel, headphones, etc. From time to time the language lab is also used for conducting training, LIS Courses, summer and winter school courses of different Divisions and Directorate for the benefit of Scientists/Technical staff.

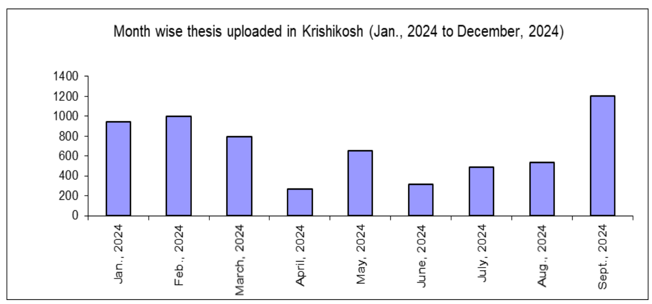
9.2.8. LIS Course

The Library is actively involved in the Post Graduate teaching program 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 & literature search tools.

9.3 AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

9.3.1 Krishikosh a Digital Repository

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 to open access policy of ICAR. Its a central open-access agricultural information platform benefitting students, researchers, policymakers and farmers, having 55 million pages (thesis, research papers, datasets, articles, etc.). There were 107 contributor institutions with an average of 20,000 daily views. Currently, this digital repository has 3,25,000 items (207,000 theses across all NARES Institutions) content for research, farming, and educational purposes on the open-access portal. Google analytics of Krishikosh from Oct. 2018 to Dec. 2024 indicates that more than 30.0 million hits are on the Krishikosh repository and viewed by 125 countries. The month-wise thesis submitted in the Krishikosh repository is given below:



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 2023 (ISSN: 0972-6136)
- IARI NEWS, October-December 2023, January-March 2024, April-June 2024 and July-September 2024
- IARI Current Events (Monthly) - 12 issues (Available only on IARI website)

10.1.2 नियमित प्रकाशन (हिन्दी)

- पूसा सुरभि (अर्धवार्षिक) (ISSN : 2348-2656)
- वार्षिक रिपोर्ट 2023 (ISSN : 0972-7299)
- पूसा समाचार, अक्टूबर- दिसम्बर, 2023, जनवरी-मार्च 2024, अप्रेल – जून, 2024 एवं जुलाई – सितम्बर, 2024
- 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 No.
1.	Technical Writing and Communication	Agricultural Extension	January 24, 2024	ISBN 978-93-83168-76-7
2.	The Undergraduate Handbook (Yellow Book)	Agricultural Extension	January 31, 2024	ISBN 978-93-83168-77-4
3.	Post Graduate Course Curriculum	Agricultural Chemicals	February 02, 2024	ISBN 978-93-83168-78-1
4.	IARI Brand Book	Agricultural Chemicals	February 02, 2024	ISBN 978-93-83168-79-8
5.	Souvenir Pusa *Krishi Vigyan Mela*- 2024: Agricultural Entrepreneurship-Prosperous Farmer" and "पूसा कृषि विज्ञान मेला स्मारिका-2024: कृषि उद्यमिता-समृद्ध किसान	Agricultural Extension	February 19, 2024	ISBN 978-93-83168-80-4
6.	अधेयता एवं नवोन्मेषी किसान I एक परिचय (Fellow and Innovative farmers- An Introduction)" 2024	CATAT	February 22, 2024	ISBN 978-93-83168-81-1
7.	प्राकृतिक खेती एवं श्री अन्न उत्पादक	CATAT	February 22, 2024	ISBN 978-93-83168-82-8
8.	पूसा संस्थान की उन्नत कृषि प्रौद्योगिकीयां	ATIC	February 28, 2024	ISBN 978-93-83168-83-5
9.	Pre and postharvest Modulations- A Value Chain Approach	Food Science & Post Harvest Technology	March 18, 2024	ISBN 978-93-83168-84-2
10.	Community Nutrition and Education: A Ready Rackoner	Agricultural Extension	March 22, 2024	ISBN 978-93-83168-85-9

11.	कृषि ड्रोन तकनीकी: सिद्धांत एवं प्रयोग	Agricultural Engineering	March 27, 2024	ISBN 978-93-83168-86-6
12.	Good Agricultural Practices: An Approach for Efficient Resources Utilization	Agronomy	September 30, 2024	ISBN 978-93-83168-87-3
13.	रबी फसलों की उन्नत खेती	प्रकाशन इकाई	November 27, 2024	ISBN 978-93-83168-88-0
14.	खरीफ फसलों की उन्नत खेती	प्रकाशन इकाई	November 27, 2024	ISBN 978-93-83168-89-7
15.	राष्ट्रीय राजधानी हेतु उन्नत कृषि तकनीक	CATAT	December 05, 2024	ISBN 978-93-83168-90-3
S.NO.	**Title of Publication**	**Division/ Regional Station/PD**	**Date**	**ICN Number**
1.	Glimpse of Startups Ecosystem Precision Agriculture in India	ZTM & BPD Unit	January 29, 2024	TB-ICN: 316/2024
2.	Climate Resilient Technologies	ZTM & BPD Unit	January 29, 2024	TB-ICN: 317/2024
3.	Novel Food Markets	ZTM & BPD Unit	January 29, 2024	TB-ICN: 318/2024
4.	Book of Proceeding & Extended Abstracts of National Conference on Industry Problems-Academia Solutions Conclave (iPAS-2023)	Water Technology Centre	February 06, 2024	TB-ICN: 319/2024
5.	Recommendations of National Conference on Industry Problems-Academia Solutions Conclave (iPAS-2023)	Water Technology Centre	February 06, 2024	TB-ICN: 320/2024
6.	Preservation of Rice Germplasm and Productivity Enhancement through Mechanization	Genetics	February 07, 2024	TB-ICN: 321/2024
7.	Cultivars Released from ICAR-IARI, New Delhi, 2023	Genetics	February 08, 2024	TB-ICN: 322/2024
8.	Major Pests and Diseases of Capsicum	CPCT	February 22, 2024	TB-ICN: 323/2024
9.	Application of Molecular and Genomic tools for Biofortification in Crops	Genetics	February 27, 2024	TB-ICN: 324/2024
10.	Advanced Seed Production Technologies in Wheat, Barley and Mustard	Regional Station, Karnal	February 28, 2024	TB-ICN: 325/2024
11.	Low Shelf-Life of Pearl Millet Flour- Strategies to Un-mask the Popularity of Pearl Millet for Developing Smart Food for Future	Biochemistry	February 28, 2024	TB-ICN: 326/2024
12.	Gluten-Free Alternatives for Improving Pearl Millet Dough Quality	Biochemistry	February 29, 2024	TB-ICN: 327/2024
13.	Food Matrix Bulletin: Decoding the Nutritional Complexities	Biochemistry	March 01, 2024	TB-ICN: 328/2024
14.	Milletopia – A Flavourful Voyage of Nutrition	Biochemistry	March 01, 2024	TB-ICN: 329/2024
15.	Production Technology of Potential Fruit Crops for Cultivation in Darjeeling and Kalimpong hills of West Bengal	Regional Station, Kalimpong West Bengal	March 01, 2024	TB-ICN: 330/2024
16.	PearlOmics-Decoding the Mysterious Cobweb of Rancidity	Biochemistry	March 06, 2024	TB-ICN: 331/2024
17.	Food matrix characterization techniques: nutrients to nutrient bioavailability	Biochemistry	March 12, 2024	TB-ICN: 332/2024

18.	Measurement of Soil Hydraulic Properties for Irrigation Water Management	WTC	March 15, 2024	TB-ICN: 333/2024
19.	Genomics and Innovative Breeding Approaches for Economically Important and Futuristic traits in Vegetable Crops	Vegetable Science	March 20, 2024	TB-ICN: 334/2024
20.	Water Driven Simulation Model and Software	Water Technology Centre	March 28, 2024	TB-ICN: 335/2024
21.	Annual Report 2023	Seed Science & Technology	June 03, 2024	TB-ICN: 336/2024
22.	Genomics of Agriculturally Important Pathogens, Microbes, and Insects	Plant Pathology	July 16, 2024	TB-ICN: 337/2024
23.	Recent Advances in Analyzing Quantitative and Qualitative Data in Social Sciences	Agricultural Economics	July 31, 2024	TB-ICN: 338/2024
24.	Innovative Processing Technologies and Functionalized Food Products	Food Science & Post Harvest Technology	August 01, 2024	TB-ICN: 339/2024
25.	Seed Production, Testing and Storage in Field and Vegetable Crops	Seed Science & Technology,	September 05, 2024	TB-ICN: 340/2024
26.	Vacuum Frying: A Gainful Process Delivering Healthy Snacks	Food Science & Post Harvest Technology,	October 09, 2024	TB-ICN: 341/2024
27.	Food Beyond Satiety for Holistic Life	Food Science & Post Harvest Technology,	October 09, 2024	TB-ICN: 342/2024
28.	Divine Dough-Richness of Resistant Starch, Iron, Zinc and Fibre	Biochemistry	October 16, 2024	TB-ICN: 343/2024
29.	Annual Report 2023, Division of Environment Science	Environmental Science	October 29, 2024	TB-ICN: 344/2024
30.	Floral Biology and Hybridization Techniques in Important Vegetable Crops	Vegetable Science	October 30, 2024	TB-ICN: 345/2024
31.	Annual Report 2021	Fruit & Horticultural Technology	October 30, 2024	TB-ICN: 346/2024
32.	Annual Report 2022	Fruit & Horticultural Technology	October 30, 2024	TB-ICN: 347/2024
33.	Annual Report 2023	Fruit & Horticultural Technology	October 30, 2024	TB-ICN: 348/2024
34.	Technical Education and Skill Development through Practical Exposure in Floriculture	Floriculture and Landscaping	December 10, 2024	TB-ICN: 349/2024
35.	Divisional Annual Report-Entomology	Entomology	December 10, 2024	TB-ICN: 350/2024
36.	Managing Carbon to Improve Soil Health and Combat Climate Change	Soil Science and Agricultural Chemistry	December 24, 2024	TB-ICN: 351/2024

क्र.सं.	तकनीकी प्रकाशन (हिन्दी)-2024			
1.	फ्लोरीकल्चर एंड लैंडस्केपिंग	Floriculture and Landscaping	February 16, 2024	ICN: H-213/2024
2.	मशरूम खेती पर तकनीकी प्रकाशन	Plant Pathology	February 16, 2024	ICN: H-214/2024
3.	कृषि उपज का प्रसंस्करण और मूल्य संवर्धन	Food Science and Post-harvest Technology	March 11, 2024	ICN: H-215/2024
4.	बाजरा: बाजार की ओर	Biochemistry	March 11, 2024	ICN: H-216/2024
5.	उद्यमशीलता हेतु उन्नत कृषि प्रोद्योगिकियाँ	Ag. Extension	March 21, 2024	ICN: H-217/2024
6.	शिमला मिर्च के प्रमुख कीट एवं रोग	CPCT	March 28, 2024	ICN: H-218/2024
7.	प्रसंस्करण एवं मूल्य संवर्धन द्वारा महिला सशक्तिकरण एवं उद्यमिता विकास	CATAT	August 07, 2024	ICN: H-219/2024
8.	माईक्रोग्रीन्स स्वास्थ्य के लिये न्यूट्रीग्रीन्स	Biochemistry	November 07, 2024	ICN: H-220/2024
9.	हल्लूर: नरम बाजरा आटा	Biochemistry	November 07, 2024	ICN: H-221/2024
10.	डिवाइनडॉफ: रेसिस्टेंट स्टार्च, आयरन, जिंक और फाइबर की प्रचुरता के साथ	Biochemistry	November 07, 2024	ICN: H-222/2024
11.	विविध परिस्थितियों में बारानी खेती के लिये पोषक तत्वों का समग्र प्रबंधन	Soil Science & Agricultural Chemistry	November 07, 2024	ICN: H-223/2024
12.	भारत के शुष्क क्षेत्र: स्थाई खाद्य सुरक्षा के लिये एक महतवपूर्ण आधार	Soil Science & Agricultural Chemistry	November 07, 2024	ICN: H-224/2024
13.	अधिक लाभ लेने व लागत कम करने हेतु कृषि की आधुनिक तकनीकियाँ	Soil Science & Agricultural Chemistry	November 07, 2024	ICN: H-225/2024

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	**1199**
	b.	Symposia/conference papers	**311**
2.		**Books/Book Chapters**	
	a.	Books	**38**
	b.	Chapters in books	**203**
3.		**Popular Articles**	**319**
4.		**Training Manuals**	**43**

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. *Frontiers in Sustainable Food Systems* **7**: 1230207
- Aditya S, Aggarwal R, Bashyal B M, Gurjar M S Saharan, M S and Aggarwal S. 2024. Unraveling the dynamics of wheat leaf blight complex: isolation, characterization, and insights into pathogen population under Indian conditions. *Frontiers in Microbiology* **15**: 1409209
- Ali A, Das B, Dhakar M K, Naik S K, Patel V B and Mishra G P. 2024. Enhancing soil health and fruit yield through *Tephrosia* biomass mulching in rainfed guava (*Psidium guajava* L.) orchards. *Scientific Reports* doi: org/10.1038/s41598-024-64814-x
- Anand R, Parray R A, Mani I, Khura T K, Kushwaha H, Sharma B B, Sarkar S and Godara S. 2024. Spectral data driven machine learning classification models for real-time leaf spot disease detection in brinjal crops. *European Journal of Agronomy* **161**: 127384
- Arunachalam T, Gade K, Mahadule PA, Soumia P S, Govindasamy V, Gawande S J and Mahajan V. 2024. Optimizing plant growth, nutrient uptake, and yield of onion through the application of phosphorus solubilizing bacteria and endophytic fungi. *Frontiers in Microbiology* 15. doi: 10.3389/fmicb.2024.1442912

- Ayyagari R, Amooru H, V Jayasri, Sreeramanan S, Mallikarjuna B P, Raju D, Lal S K and Rajendran A. 2024. Calmodulin: Coping with biotic and abiotic stresses in soybean (*Glycine max* (L.) Merr.). *Plant Stress* **14**: 100602
- Bag K, Kumari S, Roy D, Vashisth A, Krishnan P, Mukherjee J, Meena M C, Biswakarma N and Rathore P. 2024. Delayed sowing and its ramifications: biophysical, yield and quality analysis of wheat cultivars in the northwest Indo-Gangetic plains. *Journal of the Science of Food and Agriculture* doi.org/10.1002/jsfa.13512
- Bag T K, Dutta P, Hubballi M, Kaur R, Mahanta M, Chakraborty A, Das G, Kataky M and Waghunde R. 2024. The destructive *Phytophthora* on orchids: Current knowledge and future perspectives. *Frontiers in Microbiology* doi: 10.3389/fmicb.2023.1139811
- Bahadur A, Akshay Kumar H M, Singh A and Debnath P. 2024. First report of *Rhizoctonia* blight caused by *Rhizoctonia solani* on Chinese cabbage (*Brassica rapa* subsp. *chinensis*) in India. *Plant Diseases* doi.org/10.1094/PDIS-06-23-1046-PDN
- Bana R S, Choudhary A K, Nirmal R, Kuri B R, Sangwan S, Godara S, Bansal R, Singh D and Rana D S. 2024. High-value crops' imbedded groundnut-based production systems vis-à-vis system-mode integrated nutrient management: Long-term impacts on system productivity, system profitability and soil biofertility indicators in semi-arid climate. *Frontiers in Plant Science* 1298946
- Barman A, Pooniya V, Zhiipao RR, Biswakarma N, Kumar D, Das T K, Shivay Y S, Rathore S S, Das K, Babu Subhash, Saikia N, Meena M C and Bhatia A. 2024. Integrated crop management for long-term sustainability of maize-wheat rotation focusing on productivity, energy and carbon footprints. *Energy* doi.org/10.1016/j.energy.2024.133304
- Barman D, Kumar R, Ghimire O P, Ramesh R, Gupta S, Nagar S, Pal M, Dalal M, Chinnusamy V and Arora A. 2024. Melatonin induces acclimation to heat stress and pollen viability by enhancing antioxidative defense in rice (*Oryza sativa* L.). *Environmental and Experimental Botany* **220**: 105693
- Basak P, Gurjar M S, Kumar T P J, Kashyap N, Singh D, Jha S K and Saharan M S. 2024. Transcriptome analysis of *Bipolaris sorokiniana - Hordeum vulgare* provides insights into mechanisms of host-pathogen interaction. *Frontiers in Microbiol*ogy **15**: 1360571
- Bhardwaj A, Kokila V, Prasanna R, Bavana N, Nivedha R M, Bharti, A, Rudra S G, Singh A K, Reddy K S and Shivay Y S. 2024. Devising cyanobacteria-mediated nutri-fertigation strategies to enhance fruit quality, soil nutrient availability and crop productivity in cherry tomato. *Journal of Plant Growth Regulation* **43**: 1902–1918
- Bhargavi H A, Singh S P, Goswami S, Yadav S, Naveen A P, Shashikumara Singhal T S, Sankar S M, Danakumara T, Hemanth S, Kapoor C and Singh N. 2024. Deciphering the genetic variability for biochemical parameters influencing rancidity of pearlmillet (*Pennisetum glaucum* L. R. Br.) flour in a set of highly diverse lines and their categorization using rancidity matrix. *Journal of Food Composition and Analysis* doi.org/10.1016/j.jfca.2024.106035
- Biswas S, Kundu A, Suby S B, Kushwah A S, Patanjali N, Shasany A K, Verma R, Saha S, Mandal A, Banerjee T, Kumar A and Singh A. 2024. *Lippia alba*—a potential bioresource for the management of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Frontiers in Plant Science* **15**: 1422578
- Chakrabarty S, Shashank P R, Deb, C K, Haque M A, Thakur P, Kamil D, Marwaha S and Dhillon M K. 2024. Deep learning-based accurate detection of insects and damage in cruciferous crops using YOLOv5. *Smart Agricultural Technology* **9**(1): 100663
- Chakraborty R, Sharma V K, Das D, Biswas D R, Mahapatra P, Shahi D K, Barman M, Chobhe K A and Chakraborty D. 2024. Change in phosphorus availability, fractions, and adsorption-desorption by 46-years of long-term nutrient management in an Alfisol of eastern India. *Soil & Tillage Research* **236**: 105940

- Chandel R, Kamil D, Kumar A, Taak Y, Khar A. 2024. Morpho-cultural and molecular variability of *Stemphylium vesicarium* causing *Stemphylium* leaf blight in tropical onions. *Heliyon* **10**(20): e39107
- Chinnathambi V, Panwar S, Singh K P, Namita, S. Lekshmy, Mallick N, Mehraj U. 2024. *In vitro* androgenesis for isolation of haploid and ploidy analysis in marigold (*Tagetes patula* L.). *Scientia Horticulturae* **330**: 112962
- Choudaker K R, Singh V K, Kashyap A S, Patel A V, Sameriya K K, Yadav D, Manzar N, Kamil D, Prasad L and Saharan M S. 2024. Evaluating the efficacy of microbial antagonists in inducing resistance, promoting growth, and providing biological control against powdery mildew in wheat. *Frontiers in Microbiology* **15**: 1419547
- Danakumara T, Kumar N, Patil B S, Kumar T, Bharadwaj C, Jain P K, Nimmy M S, Joshi N, Parida S K, Bindra S, Kole C and Varshney R K. 2024. Unraveling the genetics of heat tolerance in chickpea landraces (*Cicer arietinum* L.) using genome-wide association studies. *Frontiers in Plant Science* **15**: 1376381
- Darjee S, Singh R, Dhar S, Pandey R, Dwivedi N, Sahu P K, Rai M K, Alekhya G, Padhan S R, Ramalingappa P L and Shrivastava M. 2024. Empirical observation of natural farming inputs on nitrogen uptake, soil health, and crop yield of rice-wheat cropping system in the organically managed Inceptisol of Trans Gangetic plain. *Frontiers in Sustainable Food Systems* **8**: 1324798
- Das A, Purakayastha T J, Ahmed N, Bhaduri D, Das R and Biswas S. 2024. Imprint of clay mineralogy, sesquioxides, and crop residue addition for evaluation of soil organic carbon stability and associated microbial activity in dominant soil orders of Indian subcontinent. *Environmental Geochemistry and Health* doi.org/10.1007/s10653-024-01873-z
- Das B, Pooniya V, Shivay YS, Zhiipao RR, Biswakarma N, Kumar D, Saikia N, Kumar A, Govindasamy P, Barman A and Critykar J. 2024. Twenty-one years' impact of using organic amendments on the productivity of rice-wheat rotation and soil properties. *Field Crops Research* **309**: 109311
- Das S, Biswas S, Ramakrishnan B, Das T K, Purakayastha T J, Gawade B H, Singh P, Ghorai, P S, Tripathy S and Sinha K. 2024. Biological soil health with conventional and qPCR-based indicators under conservation agriculture based rice-wheat cropping system in Indo-Gangetic Plain. *Applied Soil Ecology* **193**: 105128
- Deeksha M G, Nebapure S M, Sagar D, Bhattacharya R, Dahuja A, Subramanian S. 2024. Revealing the role of CYP346 family genes on phosphine resistance in Indian populations of *Tribolium castaneum*. *Frontiers in Bioscience-(Landmark Ed)* **29**(6): 203
- Deepika D D, Sharma V, Mangal M, Srivastava A, Pandey C, Mehta H, Abhishek G J, John R, Bharti H, Bharadwaj R, Gautam R K, Rana J C, Singh G P and Sharma V K. 2024. NIR spectroscopy prediction model for capsaicin content estimation in chili: A rapid mining tool for trait-specific germplasm screening. *Journal of Food Composition and Analysis* **137**: 106915
- Duo H, Zunjare R U, Mishra S J, Muthusamy V, Selvakumar T, Kumar S, Kasana R K, Gopinath I, Sharma G, Chhabra R, Sarma G R, Katral A, Ravikesavan R and Hossain F. 2024. Genetic analysis on composition of sulfur-containing amino acids: methionine and cysteine in subtropical maize. *Journal of Food Composition and Analysis* doi.org/10.1016/j.jfca.2024.106774
- Dutta T K, Akhil V S, Kundu A, Dash M, Phani V, Sirohi A and Somvanshi V S. 2024. Induced knockdown of *Mg-odr-1* and *Mg-odr-3* perturbed the host seeking behavior of *Meloidogyne graminicola* in rice. *Heliyon* **10**(4): 26384
- Garg K, Dhar S, Azman E A, Sharma V K, Meena R P, Hashim M, Rajawat M V S, Ali G, Hindoriya P S, Kumar Y, Athnere S, Kumar S, Om H, Tuti M D, Kumar B and Kumar S. 2024. Exploring the

potential of enhanced organic formulations for boosting crop productivity, nutrient utilization efficiency, and profitability in baby corn-kabuli gram-vegetable cowpea cropping system. *Frontiers in Sustainable Food Systems* **8**: 1380279

- Godara R, Kaushik P, Tripathi K, Kumar R, Rana V S, Kumar R, Mandal A, Shanmugam, V, Pankaj and Shakil N A. 2024. Green synthesis, structure–activity relationships, *in silico* molecular docking and antifungal activities of novel prenylated chalcones. *Frontiers in Chemistry* **12**: 1389848
- Gopinath I, Hossain F, Thambiyannan S, Sharma N, Duo H, Kasana R K, Katral A, Devlash R, Veluchamy S S K R, Zunjare R U, Sekhar J C, Guleria S K, Rajasekaran R and Muthusamy V. 2024. Unraveling popping quality through insights on kernel physical, agro-morphological, and quality traits of diverse popcorn (*Zea mays* var. everta) inbreds from indigenous and exotic germplasm. *Food Research International* doi.org/10.1016/j.foodres.2024.114676
- Gouda H S, Singh Y V, Shivay Y S, Biswas D R, Bana R S, Poornima S, Manu S M, Maitra S, Sairam, M, Salmen S H, Alharbi S A, Ansari M J and Hossain A. 2024. Root parameters and water productivity of rice and wheat in a rice–wheat cropping system as influenced by enriched compost and crop establishment methods. *Journal of Agriculture and Food Research* doi: org/10.1016/j.jafr.2024.101317
- Gouda M N R and Subramanian S. 2024. Variations in the expression of odorant binding and chemosensory proteins in the developmental stages of whitefly *Bemisia tabaci* Asia II-1. *Scientific Reports* **14**: 15046
- Gouda M R, Naga K C, Nebapure S M and Subramanian S. 2024. Unravelling the genomic landscape reveals the presence of six novel odorant-binding proteins in whitefly *Bemisia tabaci* Asia II-1. *International Journal of Biological Macromolecules* **279**: 135140
- Hamdy S A, Prabha R, Singh D P and Farag M A. 2024. Cardamom seed bioactives: A review of agronomic factors, preparation, extraction and formulation methods based on emerging technologies to maximize spice aroma economic value and applications. *Food Chemistry* **462**: 141009
- Hasanain M, Singh V K, Rathore S S, Meena V S, Meena S K, Shekhawat K, Singh R K, Dwivedi B S, Singh R, Babu S, Upadhyay P K, Kumar A, Kumar A, Fatima A, Verma G and Kumar S. 2024. Crop establishment and nutrient management options: Optimizing productivity, maximize profitability and mitigating adverse climatic conditions in the maize-based production system of Northwest India. *Field Crops Research* doi.org/10.1016/j.fcr.2024.109606
- Ishwarya, Lakshmi K S, Dhillon M K, Mukri G, Mahendra K R, Gowtham K V and Tanwar A K. 2024. Induced biochemical variations in maize parental lines affect the life table and age specific reproductive potential of *Spodoptera frugiperda* (J.E. Smith). *Frontiers in Plant Science* **15**:1517848
- Jha G K, Praveen K V, Bhatia A, Laishram C, Kumar D, Begho T and Eory V. 2024. Transitioning towards sustainable agriculture: analysing the factors and impact of adopting multiple sustainable inputs by paddy farmers in India. *Frontiers in Sustainable Food Systems* **8**: 144793
- Jha G K, Velayudhan P K, Bhatia A, Laishram C, Kumar D, Begho T and Eory V. 2024. Transitioning towards sustainable agriculture: analysing the factors and impact of adopting multiple sustainable inputs by paddy farmers in India. *Frontiers in Sustainable Food Systems* doi: 10.3389/fsufs.2024.1447936
- Kalwani M, Kumari A, Rudra S G, Chhabra D, Pabbi S and Shukla P. 2024. Application of ANN-MOGA for nutrient sequestration for wastewater remediation and production of polyunsaturated fatty acid (PUFA) by *Chlorella sorokiniana* MSP1. *Chemosphere* **349**: 140835
- Kamble U, He X, Navathe S, Kumar M, Patial M, Kabir M R, Singh G, Singh G P, Joshi A K and Singh P K. 2024. Genome-wide association mapping for

field spot blotch resistance in South Asian spring wheat genotypes. *The Plant Genome* https://doi.org/10.1002/tpg2.20425

- Kapoor C, Anamika S, Sankar M, Singh S P, Singh N and Kumar S. 2024. Omics-driven utilization of wild relatives for empowering pre-breeding in pearl millet. *Planta* **259**: 155
- Karishma P, Verma P, Zimik M, Kaur C, Vasudev S and Khar A. 2024. Morphological, biochemical and molecular characterization of short-day tropical Indian garlic (*Allium sativum* L.). *Heliyon* **10**(18): e37553
- Katral A, Hossain F, Zunjare R U, Mishra S J, Ragi S, Kasana R K, Chhabra R, Thimmegowda V, Vasudev S, Kumar S, Bhat J S, Neeraja C N, Yadava D K and Muthusamy V. 2024. Enhancing kernel oil and tailoring fatty acid composition by genomics-assisted selection for *dgat1-2* and *fatb* genes in multi-nutrient-rich maize: new avenue for food, feed and bioenergy. *The Plant Journal* doi: 10.1111/tpj.16926
- Katral A, Hossain F, Zunjare R U, Ragi S, Kasana R K, Duo H, Gopinath I, Mehta B K, Guleria S K, Thimmegowda V, Vasudev S, Kumar B, Karjagi C G, Pandey S, Neeraja C N, Yadava D K and Muthusamy V. 2024. Maize genotypes with favourable *dgat1-2* and *fatb* alleles possess stable high kernel oil and better fatty acid health and nutritive indices. *International Journal of Biological Macromolecules* doi.org/10.1016/j.ijbiomac.2024.134848
- Kaur R, Bana R S, Singh T, Meena S L, Raj R, Dass A, Govindasamy P, Gill J S, Kumar S, Sen S, Kumar S, Choudhary A K and Das T K. 2024. Sequential herbicide application coupled with mulch enhances the productivity and quality of winter onion (*Allium cepa* L.) while effectively controlling the mixed weed flora. *Frontiers in Sustainable Food Systems* **7**: 1271340
- Kaur S, Godara S, Singh N, Kumar A, Pandey R, Adhikari S, Jaiswal S, Singh S K, Rana J C, Bharwdaj R, Singh B K, Riar A. 2024. Multivariate data analysis assisted mining of nutri-rich genotypes from North Eastern Himalayan germplasm collection of Perilla (*Perilla frutescens* L.). *Plant Foods for Human Nutrition* doi: org/10.1007/s11130-024-01220-8.
- Khan Z A, Sharma S K, Gupta N, Diksha D, Thapa P, Mailem Y S, Prajapati M R, Nabi S U, Watpade S, Verma M K and Baranwal V K. 2024. Assessing the *de novo* assemblers: a metaviromic study of apple and first report of citrus concave gum-associated virus, apple rubbery wood virus 1 and 2 infecting apple in India. *BMC Genomics* **25**: 1057
- Kishor N, Khanna M, Rajanna G A, Singh M, Singh A, Singh S, Banerjee T, Patanjali N, Rajput J and Kiruthiga B. 2024. Soil water distribution and water productivity in red cabbage crop using superabsorbent polymeric hydrogels under different drip irrigation regimes. *Agricultural Water Management* **295**: 108759
- Kumar D, Venkadesan S, Prabha R, Begam S, Dutta B, Mishra D C, Chaturvedi K K, Jha G K, Solanke A U and Sevanthi A M. 2024. Rice MetaSys: Drought-miR, a one-stop solution for drought-responsive miRNAs-mRNA module in rice. *Database* **2024**: baae076
- Kumar K, Parihar C M, Nayak H S, Sena D R, Godara S, Dhakar R, Patra K, Sarkar A, Bharadwaj S, Ghasal P C, Meena A L, Reddy K S, Das T K, Jat S L, Sharma D K, Saharawat Y S, Singh U, Jat M L and Gathala M K. 2024. Modeling maize growth and nitrogen dynamics using CERES-Maize (DSSAT) under diverse nitrogen management options in a conservation agriculture-based maize-wheat system. *Scientific Reports* doi:10.1038/s41598-024-61976-6
- Kumar K, Parihar C M, Sena D R, Godara S, Patra K, Sarkar A, Reddy K S, Ghasal P C, Bharadwaj S, Meena A L, Das T K, Jat S L, Sharma D K, Saharawat Y S, Ghatala M K, Singh U and Nayak H S. 2024. Modeling the growth, yield and N dynamics of wheat for decoding the tillage and nitrogen nexus in 8-years long-term conservation agriculture-based maize-wheat system. *Frontiers in Sustainable Food Systems* **8**: 1321472

- Kumar P, Basak B B, Patel V J, Senapati N, Ramani V P, Gajbhiye N A and Kalola A D. 2024. Enriched soil amendments influenced soil fertility, herbage yield and bioactive principle of medicinal plant (*Cassia angustifolia* Vahl.) grown in two different soils. *Heliyon* **10**: e24874
- Kumari A, Singh D K, Sarangi A, Hasan M and Sehgal V K. 2024. Optimizing wheat supplementary irrigation: Integrating soil stress and crop water stress index for smart scheduling. *Agricultural Water Management* **305**: 109104
- Kumari K, Parray R A, Basavaraj Y B, Godara S, Mani I, Kumar R, Khura T, Sarkar S, Ranjan R and Mirzakhaninafchi H. 2024. Spectral sensor-based device for real-time detection and severity estimation of groundnut bud necrosis virus in tomato. *Journal of Field Robotics* **42(1)**: 5-19
- Kumawat A, Kumar D, Shivay Y S, Yadav D, Sadhukhan R, Gawdiya S and Jat R A. 2024. Sustainable basmati rice yield and quality enhancement through long-term organic nutrient management in the Indo-Gangetic Plains. *Field Crops Research* **310**: 109356
- Kundu M, Krishnan P, Prasad S and Chawla G. 2024. Green nanosensor for precise detection of formaldehyde in fruits and vegetables extract. *Food Chemistry* **443**: 138520
- Kundu R, Shakil N A, Narayanan N, Kamil D, Rana V S, Tripathi K P and Kaushik P. 2024. Novel indazolylchromones: synthesis, fungicidal evaluation, molecular docking and aquatic toxicity prediction. *Frontiers in Chemistry* **12**: 1411187
- Labanya R, Srivastava P C, Pachauri S P, Shukla A K and Shrivastava M. 2024. Kinetics of micronutrients and S adsorption onto phyto-biochars: influence of pyrolysis temperatures and properties of phyto-biochars. *Biomass Conversion and Biorefinery* **14**(4): 4957-4971
- Lakhani K G, Hamid R, Gupta S, Prajapati P, Prabha R, Patel S, Suthar K P. 2024. Exploring the therapeutic mechanisms of millet in obesity through molecular docking, pharmacokinetics, and dynamic simulation. *Frontiers in Nutrition* **11**: 1453819
- Lone J K, Pandey R and Gayacharan. 2024. Microgreens on the rise: Expanding our horizons from farm to fork. *Heliyon* **10**: e25870
- Malkani P, Mani I, Sahoo P K, Parray R A, Swain S S, Asha K R, Chowdhury M, Rathod S K, Al-Qahtani W H, Salem A and Elbeltagi A. 2024. Development and evaluation of a sensor enabled smart herbicide applicator for inter row crops. *Smart Agricultural Technology* doi.org/10.1016/j.atech.2024.100649
- Mandi M, Shivay Y S, Chakraborty D, Shrivastava M, Nayak S, Baral K and Reddy K S. 2024. Fifteen-years of continuous application of organic materials improve the soil aggregation, organic carbon status and sustain the productivity of the basmati rice-wheat system. *Soil & Tillage Research* **239**: 106058
- Mangal M, Srivastava A, Mandal B, Solanki V, Mirajkar S J, Shashank P R, Kalia P, Rana J C and Sharma V K. 2024. Exploring Host Resistance against Chilli Leaf Curl Disease in a Tolerant Chilli Genotype. *Plants* **13**(12): 1647
- Manjunatha N, Pokhare S S, Agarrwal R, Singh N V, Sharma J, Mallikarjun M H and Marathe R A. 2024. Possible biocontrol of bacterial blight in pomegranate using native endophytic *Bacillus* spp. under field conditions. *Frontiers in Microbiology* **15**: 1491124
- Meena R S, Lal R, Kumar S, Pradhan G, Srinivasarao CH, Singh A K, Pathak H, Abhilash P C, Kumar A, Sharma S K, Jat M L. 2024. Potential of Indian agriculture for capturing atmospheric CO_2 and monetizing carbon credits to the farmers: An overview and policy framework. *Advances in Agronomy* **188**: 101-206
- Meena R S, Pradhan G, Nalani, Kumar S, Singh A K, Verma S K, Mina K K, Kumar S and Chaturvedi R K. 2024. Diversified cropping modules designed for soil restoration, CO_2 sequestration, and generating carbon credits. *Land Degradation & Development* **35**(14): 4314-29.
- Meena R S, Pradhan G, Singh K, Kumar S, Singh

A K, Shashidhar K S, Mina K K and Rao C S. 2024. Agriculture models for restoring degraded land to enhance CO_2 bio-sequestration and carbon credits in the Vindhyan region of India. *Science of The Total Environment* **929**: 172661

- Menaka M, Asrey R, Singh D, Meena N K, Vinod B R and Ahamad S. 2024. Preserving functional properties and inhibiting postharvest peel browning in guava during cold storage via 24-epibrassinolide application. *Postharvest Biology and Technology* doi.org/10.1016/j.postharvbio.2024.113033
- Menaka M, Asrey R, Vinod B R, Ahamad S, Meena N K, Bhan C and Goswami A. 2024. UV-C irradiation enhances the quality and shelf-life of stored guava fruit *via*. boosting the antioxidant systems and defense responses. *Food and Bioprocess Technology* doi.org/10.1007/s11947-024-03338-8
- Mitra R and Kumar P. 2024. Physiological basis and mitigation strategies for improving tolerance to heat stress in Mung bean [*Vigna radiata* [L.] Wilczek]. *Russian Journal of Plant Physiology* doi: 10.1134/S1021443724605421
- Mondal P C, Rajna S, Kumar V, Kaushik P, Shakil N A, Pankaj and Rana V S. 2024. Aphidicidal activity of nano-emulsions of spearmint oil and carvone against *Rhopalosiphum maidis* and *Sitobion avenae*. *Scientific Reports* **14**: 24226
- Msango K, Gouda M R, Ramakrishnan B, Kumar A and Subramanian S. 2024. Variation and functional profile of gut bacteria in the scarab beetle, *Anomala dimidiata*, under a cellulose-enriched microenvironment. *Scientific Reports* **14**(1): 22400
- Nagargade M, Singh M K, Tyagi V, Govindasamy P, Choudhary A K, Rajpoot K, Kumar A, Singh P and Sarangi D. 2024. Ecological weed management and square planting influenced the weed management, and crop productivity in direct-seeded rice. *Scientific Reports* **14**: 10356
- Nallathambi P, Umamaheswari C, Reddy B, Aarthy B, Javed M, Ravikumar P and Kumar A. 2024. Deciphering the Genomic Landscape and Virulence Mechanisms of the Wheat Powdery Mildew Pathogen *Blumeriagraminis* f. sp. *tritici Wtn1*: Insights from Integrated Genome Assembly and Conidial Transcriptomics. *Journal of Fungi* **10**(4): 267
- Nayak H S, Mkondiwa M, Patra K, Sarkar A, Reddy S, Kumar P, Bharadwaj S, Singh R and Parihar C M. 2024. Risk-return trade-offs in diversified cropping systems under conservation agriculture: Evidence from a 14-year long-term field experiment in north-western India. *European Journal of Agronomy* **162**: 127436
- Nivedha R M, Bhardwaj A, Prasanna R, Bavana N, Kokila V, Nishanth S, Rudra S G, Singh A K, Reddy K S, Shivay Y S. 2024. Enhancing fruit quality and yield in tomato through cyanobacterium-mediated nutri-fertigation. *Biocatalysis and Agricultural Biotechnology* **61**: 103344
- Nivetha N, Asha A D, Krishna G K, Chinnusamy V and Paul S. 2024. Rhizobacteria *Bacillus* spp. mitigate osmotic stress and improve seed germination in mustard by regulating osmolyte and plant hormone signaling. *Physiologia Plantarum* **176**(1): e14202
- Pandey R, Sharma S, Mishra A, Sakhare A S, Meena S K and Vengavasi K. 2024. Dual-nutrient stress tolerance in wheat is regulated by nitrogen and phosphorus uptake, assimilation, reutilization and differential expression of candidate genes. *Plant and Soil* 1-26
- Pappula-Reddy S P, Kumar S, Pang J, Chellapilla B, Pal M, Millar A H and Siddique K H M. 2024. High-throughput phenotyping for terminal drought stress in chickpea (*Cicer arietinum L.*). *Plant Stress* **11**: 100386
- Parida C, Sahoo P K, Nasir R, Waseem L A, Tariq A, Aslam M and Hatamleh W A. 2024. Exergy assessment of infrared assisted air impingement dryer using response surface methodology, back propagation-artificial neural network and multi-objective genetic algorithm. *Case Studies in Thermal Engineering* **53**: 103936
- Patil B L and Tripathi S. 2024. Differential

expression of microRNAs in response to *Papaya ringspot virus* infection in differentially responding genotypes of papaya (*Carica papaya* L.) and its wild relative. *Frontiers in Plant Science* **15**: 1398437

- Patil M, Navathe S, He X, Kamble U, Kumar M, Joshi A K and Singh P K. 2024. Novel resistance loci for quantitative resistance to *Septoria tritici* blotch in Asian wheat (*Triticum aestivum*) *via*. genome-wide association study. *BMC Plant Biology* **24**: 846.
- Paul A, Dutta A, Kundu A, Ghosh A, Chawla G and Saha S. 2024. Adsorption-guided purification of rose petal anthocyanins. *Biomass Conversion and Biorefinery* doi.org/10.1007/s13399-024-06331-5
- Pradhan N K, Sahoo P K, Khushwaha D K, Bhalekar D, Mani I, Kumar K, Singh A, Kumar M, Makwana Y, Krishnan S and Aruna T N. 2024. ANN-PID based automatic breaking control system for small agricultural tractors. *Journal of Field Robotics* doi.org/10.1002/rob.22393
- Prakash N R, Kumar K, Muthusamy V, Zunjare R U and Hossain F. 2024. Unique genetic architecture of prolificacy in 'Sikkim Primitive' maize unraveled through wholegenome resequencingbased DNA polymorphism. *Plant Cell Reports* doi.org/10.1007/s00299-024-03176-0
- Praveen K V, Sivalingam N, Jha G K, Singh A and Pathak H. 2024. Nitrogen budget of Indian agriculture: trends, determinants and challenges. *Environment, Development and Sustainability* **26**(4): 10225-10242
- Premakumar, Mohanapure P, Chavhan M, Singh D, Yadav J, Somvanshi V S, Krishnan S G, Vinod K K, Bhowmick P K, Bollinedi H, Singh A K, Rao U, Ellur R K. 2024. Identification of a promising novel genetic source for rice root-knot nematode resistance through markers associated with trait-specific Quantitative Trait Loci. *Plants* **13**: 2271
- Purakayastha, Bera T J, Dey T, Pande S, Kumari P S and Bhowmik A. 2024. Biochar aided priming of carbon and nutrient availability in three soil orders of India. *Scientific Reports* **14**: 8420
- Raigond P, Singh N V, More A K, Parashuram S, Giri N A, Awachare C, Sowjanya R, Patil P G, Babu K D, Marathe R A. 2024. Impact of PGRs, polyamines and potassium to improve pomegranate flowering behaviour, fruit set and fruit quality. *Biocatalysis and Agricultural Biotechnology* **61**: 103355
- Rajamanickam V, Sevanthi A M, Swarbreck S M, Gudi S, Singh N, Singh V K, Wright T I C, Bentley A R, Muthamilarasan M, Das A, Chinnusamy V and Pandey R. 2024. High throughput root phenotyping and association analysis identified potential genomic regions for phosphorus use efficiency in wheat (*Triticum aestivum* L.). *Planta* **260**: 142
- Rajarushi C N, Nebapure S M, Rajna S, Biswas A and Subramanian S. 2024. Contact toxicity of insecticides against rice weevil, *Sitophilus oryzae* L. and its effect on progeny production. *Scientific Reports* **14**: 28404
- Rajput J, Singh M, Lal K, Khanna M, Sarangi A, Mukherjee J, Singh S, Dimple. 2024. Development of single and dual crop coefficients for drip-irrigated broccoli using weighing type field lysimeters in semi-arid environment. *Environment, Development and Sustainability* doi: org/10.1007/s10668-024-05416-5
- Ramya S, Kour B, Sudheer K, Kumar MB and Ramakrishnan B. 2024. Seed priming alters the microbial community composition in seedlings of rice (*Oryza sativa* L.). *Journal of Plant Growth Regulation* doi.org/10.1007/s00344-024-11534-1
- Rane P, Thakre M, Verma M K, Kumar C, Srivastava P J V, Shashank P R, Niranjana, M, Chawla G, Mandal P K, Kumar H, Jadhav A K, Varghese E, Patel V B and Singh S K. 2024. Studies on pollen micro-morphology, pollen storage methods and cross-compatibility among grape (*Vitis* spp.) genotypes. *Frontiers in Plant Sciences* doi.org/10.3389/fpls.2024.1353808.
- Rani K, Biswas D R, Basak B B, Bhattacharyya R, Biswas S, Das T K, Bandyopadhyay K K, Kaushik R, Das A, Thakur J K and Agarwal B K. 2024. Exploring waste mica as an alternative potassium source

using a novel potassium solubilizing bacterium and rice residue in K deficient Alfisol. *Plant and Soil* doi.org/10.1007/s11104-024-06879-1

- Rathore S S, Babu S, Shekhawat K, Kumar V, Gairola A, Wani O A, Singh V K. 2024. Exploring sustainable agricultural production models to coordinate the system productivity, soil biological health and eco-efficiency in the semi-arid region. *Environmental and Sustainability Indicators* https://doi.org/10.1016/j.indic.2024.100480.
- Rathore S S, Sharma K C, Shekhawat K, Babu Subhash, Sanketh G D, Singh V K Singh R K, Upadhyay P K, Hashim M, Rameti J and Singh H. 2024. Sulfonated nitrogen and added-sulfur sources influence productivity, quality and nutrient acquisition of soybean-wheat cropping system. *Heliyon* **10**(5): e26815
- Rojaria V, Hossain F, Zunjare R U, Bhatt V, Katral A, Kasana R K, Mishra S J, Basu S, Singh A K and Muthusamy V. 2024. Development and characterization of *lpa1* and *lpa2*-based low phytate double mutants in maize for enhancing the nutritional quality of food and feed. *Journal of Food Composition and Analysis* doi.org/10.1016/j.jfca.2024.106771
- Roy D, Vashisth A, Krishnan P, Mukherjee J, Meena M C, Biswakarma N, Rathore P, Bag K and Kumari S. 2024. Delayed sowing and its ramifications: biophysical, yield, and quality analysis of wheat cultivars in the North-west Indo-Gangetic Plains. *Journal of The Science of Food and Agriculture* doi: 10.1002/jsfa.13512: 1-13
- Rudra Gouda M N and Subramanian S. 2024. Decoding the genomic terrain: functional insights into 14 chemosensory proteins in Whitefly *Bemisia tabaci* Asia II-1. *Scientific Reports* **14**: 26252
- Sachin K S, Dass A, Dhar S, Rajanna G A, Singh T, Sudhishri S, Sannagoudar M S, Choudhary A K, Kushwaha H L, Praveen B R, Prasad S, Sharm, V K, Pooniya V, Krishnan P, Khanna M, Singh R, Varatharajan T, Kumari K, Nithinkumar K, San A A and Devi A D. 2024. Sensor-based precision nutrient and irrigation management enhances the physiological performance, water productivity, and yield of soybean under system of crop intensification. *Frontiers in Plant Science* **15**: 1389386
- Saha N D, Kumari P, Das B, Sahoo R N, Kumar R, Golui D, Singh B, Jain N, Bhatia A, Chaudhary A, Chakrabarti B, Bhowmik A, Saha P, Islam S. 2024. Vis-NIR spectroscopy based rapid and non-destructive method to quantitate microplastics: An emerging contaminant in farm soil. *Science of Total Environment* **927**: 172088
- Sahoo R N, Rejith R G, Gakhar S, Verrelst J, Ranjan R, Kondraju T, Meena M C, Mukherjee J, Dass A, Kumar S, Kumar M, Dhandapani R and Chinnusamy V. 2024 Estimation of wheat biophysical variables through UAV hyperspectral remote sensing using machine learning and radiative transfer models. *Computers and Electronics in Agriculture* **221**: 108942
- Sahu S, Bishnoi S, Sharma P R, Satyapriya, Mahra G S, Burman R R, Barua S, Misha Madhavan M, Sangeetha V, Sinha S K, Singh R, Wason M, Joshi P and Sharma S. 2024. Exploring popular information sources and determinants of farmers' access to agricultural extension services in the Indo-Gangetic plains. *Frontiers in Sustainable Food Systems* **8**: 1339243
- Sandra N and Mandal B. 2024. Emerging evidence of seed transmission of begomoviruses: implications in global circulation and disease outbreak. *Frontiers in Plant Science* **15***:* 1376284
- Sarkar A, Maity P P, Ray M and Kundu A. 2024. Inclusion of fractal dimension in machine learning models improves the prediction accuracy of hydraulic conductivity. *Stochastic Environmental Research and Risk Assessment* doi.org/10.1007/s00477-024-02793
- Sarkar M, Gupta D, Singh O W, Paul S, Kumar R, Mandal B and Roy A. 2024. Identification of pathogenicity determinants in ToLCNDV and their RNAi-based knockdown for disease management in *Nicotiana benthamiana* and tomato plants. *Frontiers in Microbiology* **15**: 1481523

- Sathee L, Suriyaprakash R, Barman D, Adavi S B, Jha S K and Chinnusamy V. 2024. Nitrogen at the crossroads of light: integration of light signalling and plant nitrogen metabolism. *Journal of Experimental Botany* **76:** 803-818
- Sawant S, Sharma P K, Mani I, Nain L and Satheesh N. 2024. Optimization of ohmic parameters in enzyme-assisted aqueous extraction for better physicochemical properties of the black cumin seed oil. *Industrial Crops & Products* **208**: 117892
- Shankar K, Awasthi O P, Saha S, Prakash J, Pandey R, Murugan T, Dolatabadin. 2024. Unravelling metabolomics and antioxidant potential of sweet orange cultivar Pusa Sharad grafted on various citrus rootstocks under sodium chloride stress. *Plant Stress* **14:** 100562
- Sharma N, Singh B, Krishnan S G, Bollinedi H, Mandal P K, Lal M K, Jha P K, Anand A, Prasad P V V. 2024. Higher grain filling rate in inferior spikelets of tolerant rice genotype offset grain weight loss under post-anthesis high night temperature. *Rice Science* doi: org/10.2139/ssrn.4689366.
- Sharma N, Vittal H, Dubey A K, Sharma R M, Singh S K, Sharma N, Singh N, Khandelwal A, Gupta D K, Mishra G P and Meena M C, Pandey R and Singh N K. 2024. Physiological and molecular insights into the alternate bearing in mango (*Mangifera indica* L.) using next-generation sequencing approaches. *Journal of Experimental Botany* doi: 10.1093/jxb/erae403
- Sharma S, Bindraban P S, Dimkpa C O and Pandey R. 2024. Phosphorus fertilizer: from commodity to speciality – from fertilizing the field to fertilizing the plant. *Current Opinion in Biotechnology* **90**: 103198
- Sharma S, Raviteja D H, Kumar T, Bindraban P S and Pandey R. 2024. Nutrient remobilization and C: N: P stoichiometry in response to elevated CO_2 and low phosphorus availability in rice cultivars introgressed with and without Pup1. *Plant Physiology and Biochemistry* **210**: 108657
- Sharma S, Yadav G K, Shakouka M A, Yadav M K, Gopala Krishnan S, Saharan M S, Gupta A K and Bashyal B M. 2024. Assessing the long-term survival of bakanae pathogen *Fusarium fujikuroi* in rice-wheat cropping system in Northern India using advanced metagenomic and qPCR techniques. *Plant Stress* **14**: 100690
- Shivaswamy G, Rudra S G, Dorjee L, Kundu A, Gogoi R and Singh A. 2024. Valorisation of raw mango pickle industry waste into antimicrobial agent against postharvest fungal pathogens. *Current Research in Microbial Sciences* doi.org/10.1016/j.crmicr.2024.100243
- Sibananda D, Singh R, Dhar S, Pandey R, Dwivedi N, Sahu P K, Rai M K, Alekhya G, Padhan S R, Ramalingappa P L and Shrivastava M. 2024. Empirical observation of natural farming inputs on nitrogen uptake, soil health, and crop yield of rice-wheat cropping system in the organically managed Inceptisol of Trans Gangetic plain. *Frontiers in Sustainable Food Systems* doi=10.3389/fsufs.2024.1324798
- Singh D P, Maurya S, Satnami L, Renu, Prabha R, Sarma B K and Rai N. 2024. Roots of resistance: Unraveling microbiome-driven plant immunity. *Plant Stress* **14**: 100661
- Singh D P, Rai N, Farag M A, Maurya S, Yerasu S R, Bisen M S, Prabha R, Shukla R and Behera T K. 2024. Metabolic diversity, biosynthetic pathways and metabolite biomarkers analysed *via*. untargeted metabolomics and the antioxidant potential reveal for high temperature tolerance in tomato hybrid. *Plant Stress* **11**: 100420
- Singh J, Rawat K, Duhan D S, Kumar R and Ranebennur H. 2024. First report of a '*Candidatus* Phytoplasma asteris' related strain (16SrI) associated with phyllody and witches' broom symptoms in *Pisum sativum* in Hisar, India. *Plant Disease* **108**(3): 781
- Singh K, Ranebennur H, Rawat K, Meena V S, Choudhary M, Chalam V C and Singh G P. 2024. First report of '*Candidatus Phytoplasma asteris*'(16SrI-B) associated with phyllody disease of Mothbean in World. *Plant Disease* **108**(2): 513

- Singh N, Kaur S, Jain A, Kumar A, Bhardwaj R, Pandey R and Riar A. 2024. Comparative analysis of deep learning and machine learning-based models for simultaneous prediction of minerals in perilla (*Perilla frutescens* L.) seeds using near-infrared reflectance spectroscopy. *Journal of Food Composition and Analysis* **136**: 106824
- Singh N, Panda K K, Bhardwaj R, Gopala Krishnan S, Bhowmick P K, Nagarajan M, Vinod K K, Ellur R K, Singh A K and Bollinedi H. 2024. Exploring the glycaemic impact and culinary qualities of rice through genome-wide association studies on starch composition and viscosity profiles. *Food Bioscience* **59**: 103919
- Soni K, Durgesh K, Anjoy P, Srivastava H, Tribhuvan K, Sevanthi A M, Singh A, Prabha R, Sharma S, Joshi R, Jain P K, Singh N and Gaikwad K. 2024. Transcriptional reprogramming and allelic variation in pleiotropic QTL regulates days to flowering and growth habit in pigeonpea. *Plant, Cell and Environment* doi: 10.1111/pce.15322
- Sonu, Nandakumar S, Singh V J, Pandey R, Gopala Krishnan S, Bhowmick P K, Ellur R K, Bollinedi H, Harshitha B S, Yadav S, Beniwal R, Nagarajan M, Singh A K and Vinod K K. 2024. Implications of tolerance to iron toxicity on root system architecture changes in rice (*Oryza sativa* L.). *Frontiers in Sustainable Food Syst*em **7**: 1334487
- Sukumaran S, Purakayastha T J, Sarkar B, Chakrabarti B, Bandyopadhyay K K, Kumar D, Yadav R K, Viswanath T, Rout K K, Shirale S T and Rajani A V. 2024. Assessment of carbon carrying capacities of Alfisols and Vertisols under long-term manuring and fertilization. *Soil and Tillage Research* **238**: 105994
- Swain S S, Khura T K, Chobhe K A, Rajput J, Bandyopadhyay K, Sahoo P K, Parray R A and Malkani P. 2024. Modelling and optimization of urea super granule (USG) placement depth in paddy cultivation under check basin irrigation using HYDRUS-2D model. *Soil and Tillage Research* **241**: 106104
- Debnath T, Bandyopadhyay T K, Vanitha K, Bobby M N, Tiwari O N, Bhunia B and Muthuraj M. 2024. Astaxanthin from microalgae: A review on structure, biosynthesis, production strategies and application. *Food Research International* **176**:113841
- Talaviya H, Singh A, Singh N, Manna S and Banerjee T. 2024. Development and validation of LC-MS/MS method for trace analysis of acrylamide, acrylic acid and N, N-methylene bis acrylamide in sandy loam soil. *Journal of Chromatography A* 465012. doi.org/10.1016/j.chroma.2024.465012
- Thakur R K, Rudra S G, Dikshit H K, Dash S, Bhardwaj R, Vinutha T, Kumar S and Chopra S. 2024. Baked crisps from Indian biofortified lentils: effect of seed coat on rheology, texture and composition. *Applied Food Research* **4**(1): 100380
- Thapa P, Diksha D and Sharma S K. 2024. Understanding the dissemination of viruses and viroids identified through virome analysis of major grapevine rootstocks and RPA-based detection of prevalent grapevine virus B. *Scientia Horticulturae* **337**: 113538
- Thenappan D P, Pandey R, Hada A, Jaiswal D K, Chinnusamy V, Bhattacharya R and Annapurna K. 2024. Physiological basis of plant growth promotion in rice by rhizosphere and endosphere associated *Streptomyces* isolates from India. *Rice* **17**(1): 60
- Thorat Y E, Dutta T K, Jain P K, Subramaniam K and Sirohi A. 2024. A nematode-inducible promoter can effectively drives RNAi construct to confer *Meloidogyne incognita* resistance in tomato. *Plant Cell Reports* **43**: 3
- Tippannanavar M, Banerjee T, Shekhar S, Sahu S R and Rudra S G. 2024. Eco-scale based greenness assessment of a validated multi-residue method for the quantification of 103 pesticides in cookies sample. *Journal of Food Composition and Analysis* **134**: 106474
- Upadhyay P K, Dey A, Singh V K, Dwivedi B S, Singh R K, Rajanna G A, Babu S, Rathore S S, Shekhawat K, Rai P K, Choudhury N K, Budhlakoti

N, Mishra D C, Rai A, Singh A, Bhardwaj A K and Shukla G. 2024. Changes in microbial community structure and yield responses with the use of nano-fertilizers of nitrogen and zinc in wheat–maize system. *Scientific Reports* doi.org/10.1038/s41598-023-48951-3

- Vathsala V, Singh S P, Bishnoi M, Varghese E, Saurabh V, Khandewal A and Kaur C. 2024. Ultrasound-assisted extraction (UAE) and characterization of citrus peel pectin: Comparison between pummelo (*Citrus grandis* L. Osbeck) and sweet lime (*Citrus limetta* Risso). *Sustainable Chemistry and Pharmacy* **37**: 101357
- Verma R, Verma A and Tripathi S. 2024. First report of cucurbit aphid-borne yellows virus infecting five cucurbits in India. *Plant Disease* **108**(2): 540-540
- Vinod V R, Asrey R, Meena N K, Sethi S, Prakash J, Chawla C, Menaka M and Ahamad S. 2024. Ozonized water treatment enhances quality and storage life of Red Lady papaya fruits during cold storage. *Scientia Horticulturae* **328**: 112859
- Vishnu A, Vikono K, V Kar, Varghese E, Vasudev and Charanjit S K. 2024. Encapsulation efficiency and fatty acid analysis of chia seed oil microencapsulated by freeze-drying using combinations of wall material. *Food Chemistry* **430**: 136960
- Vishwakarma H, Sharma S, Panzade K P, Kharate P S, Kumar A, Singh N, Avashthi H, Rangan P, Singh A K, Singh A, Angadi U B, Siddique K H M, Singh K, Singh G P, Pandey R and Yadav R. 2024. Genome-wide analysis of the class III peroxidase gene family in sesame and *SiPRXs* gene validation by expression analysis under drought stress. *Plant Stress* **11**: 100367
- Wani O A, Sharma V, Babu S, Kumar S S, Sharma K R, Dar S R, Malik A R, Yadav D, Singh R and Rathore S S. 2024. Effect of land-use management on soil erosion under two distinct climates of Indian Himalayas. *Land Degradation and Development* doi.org/10.1002/ldr.5423
- Wani O A, Sharma V, Kumar S S, Malik A R, Pandey A, Devi K, Kumar V, Gairola A, Yadav D, Valente D, Petrosillo I and Babu S. 2024. Geostatistical modelling of soil properties towards long-term ecological sustainability of agroecosystems. *Ecological Indicators* doi.org/10.1016/j.ecolind.2024.112540
- Watpade S, Lal M K, Tiwari R K, Kumar R, Naga K C, Kumar R, Pramanick K K, Kumari H, Devi E and Pal D. 2024. *Fusarium* core rot disease affects physicochemical and pathophysiological attributes of apple (Malus × domestica Borkh.) fruit. *Postharvest Biology and Technology* **208**: 112648
- Wen Y M, Shashank P R, Godfrey R K, Plotkin D, Parker B M, Wist T and Kawahara A Y. 2024. Evolutionary genomics of three agricultural pest moths reveals rapid evolution of host adaptation and immune-related genes. *Giga Science* **13**: 103
- Yadav A, Babu S, Krishnan P, Kaur B, Bana R S, Chakraborty D, Kumar V, Joshi B and Lal S K. 2024. Zinc oxide and ferric oxide nanoparticles combination increase plant growth, yield, and quality of soybean under semiarid region. *Chemosphere* **352**: 141432
- Yadav D, Singh D, Babu S, Madegowda M, Singh D V, Mandal D, Rathore A C, Sharma V K, Singhal V, Kumawat A, Yadav D K, Yadav R K and Kumar S. 2024. Intensified cropping reduces soil erosion and improves rainfall partitioning and soil properties in the marginal land of the Indian Himalayas. *International Soil and Water Conservation Research* doi.org/10.1016/j.iswcr.2023.10.002
- Yadav D, Singh D, Madhu M, Singh D V, Islam S, Kumar G, Gupta A K, Mandal D, Babu S, Barh A, Kumawat A, Dubey R, Pati K, Bhargavi B and Yadav D K. 2024. Interplanted crops and rainfall variability regulate soil erosion in rainfed maize of the Indian Himalayas. *Land Degradation & Development* doi.org/10.1002/ldr.5221
- Yadav R K, Purakayastha T J, Bhaduri D, Das R, Dey S, Sukumaran S, Walia SS, Singh R, Shukla V K, Yadava M S and Ravisankar N. 2024. Development of unique soil organic carbon stability index under

influence of integrated nutrient management in four major soil orders of India. *Journal of Environmental Management* **360**: 121208

- Yadav S, Yadava Y K, Meena S, Kalwan G, Bharadwaj C, Paul V, Kansal R, Gaikwad K and Jain P K. 2024. Novel insights into drought-induced regulation of ribosomal genes through DNA methylation in chickpea. *International Journal of Biological Macromolecules* **1**(266): 131380
- Zerouali B, Bailek N, Islam ARMT, Katipoğlu O M, Ayek A A E, Santos C A G, Rajput J, Wong Y J, Abda Z, Chettih M and Elbeltagi A. 2024. Enhancing groundwater potential zone mapping with a hybrid analytical method: The case of semiarid basin. *Groundwater for Sustainable Development* doi: org/10.1016/j.gsd.2024.101261
- Zhang L, Yadav V, Zhu H, Shi Y, Hu X, Wang X, Zhou X, Babu S, Kang Y. 2024. Climate drivers of litterfall biomass dynamics in three types of forest stands on the Loess Plateau. *Ecological Indicators* doi.org/10.1016/j.ecolind.2024.112088

11. IP MANAGEMENT, PATENTS, TECHNOLOGY COMMERCIALIZATION AND AGRIBUSINESS INCUBATION ACTIVITIES

11.1 TECHNOLOGY COMMERCIALIZATION

During the year 2024, under the Lab to Land initiative, 60 innovative technologies of ICAR-IARI were transferred to 202 industry partners resulting in revenue generation of ₹ 3,90,38,254. These technologies included the Bitter gourd c.v. Pusa Hybrid 5, Bitter gourd Lines DBGS-100-0, Bitter gourd Lines DBGS-21-06, Brinjal c.v. Hara Bangain 1, Brinjal c.v. Pusa saphed Bangain-1, Broccoli c.v. Pusa Purple Broccoli-1, Carrot C.V. Pusa Prateek, Chilli c.v. DLS-161-1, chilli c.v. Pusa Jawala, Cucumber c.v. Pusa Gynoecious, Cucumber Hybrid -18, Guava Pusa ARUSHI, Wheat HD 3086, HD 3385, HD 3386, HD 3390, HD 3410, HI-1650, HQPM 1 Improved, HQPM 5 Improved, Marigold c.v. Pusa Bahar, Marigold c.v. Pusa Narangi Gainda, Methi c.v. PEB, Onion c.v. Pusa Red, Palak c.v All green, Pusa Basmati 1509, Pusa Basmati 1637, Pusa Basmati 1692, Pusa Basmati 1718, Pusa Basmati 1847, Pusa Basmati 1885, Pusa Basmati 1886, Pusa Basmati 1979, Pusa Basmati 1985, Pigeon pea variety Pusa 1431, Pumpkin c.v. Pusa Vikas, Pusa Arhar 16, Pusa Arhar 2017-1, Pusa Arhar 2018-4, Pusa Battery operated, Variable height platform, Pusa Biofortified Maize Hybrid 1, Pusa Biofortified Maize Hybrid 2, Pusa Biofortified Maize Hybrid 3, PUSA CUE FLY KIT, Pusa HM4 Male Sterile Baby Corn (Shishu), Pusa Manav, Pusa Manohari, Pusa Me Fly Kit,Pusa Mustard 28, Pusa Mustard 31, Pusa Mustard 32, Pusa Mustard 33, Pusa Pratiksha, Pusa Purple Seedless, Pusa Samba-1853, Pusa Vivek QPM 9 Improved, Renewal of MoA for Pusa STFR Meter, Renewal of MoA for Wheat HD 3086, Super Sweet corn 1, Vegetable Multiple Pistillate Gynoecious Parthenocarpic Cucumber line, DPaC-42 and Pusa Whitefly Attractant.

Technologies commercialized by the Division of Agricultural Engineering

S. No.	Technology Name	Company Name	License fee (₹ Lakhs)
1.	Manual Multicrop planter	Dharti Agro-industries	0.17
2.	Pusa Mini Electric Agri Prime Mover	M/S Venkatesh Agro Engineering	0.65
3.	Pusa Battery Powered Variable Height Platform	M/s Sakoon Solution Pvt Ltd, Ghaziabad, India	0.25

11.2 CORPORATE MEMBERSHIP

To create strong and meaningful relationships with the industry and commercial enterprises for dissemination of the varieties/technologies of IARI for the benefit of the society and farmers, ZTM & BPD Unit welcomes partnership through 'Corporate Membership'. Fifty-four new corporate members have been enrolled so far in the year 2024, 122 renewals of existing memberships. This created a total number of 176 corporate members, generating a revenue of ₹ 8,60,000 only.

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 (12 filed and 6 granted)	202411000969	Field performance measuring instrument for farm implement	January, 2024	Filed
	202411029084	Rapid Nucleic Acid Extraction from Crude Samples for The Detection of Filamentous Fungi in RPA Assay	April, 2024	Filed
	202411033343	A Rapid, Sensitive, Specific & Field Deployable Diagnostic Process for Chilli Leaf Curl Virus	April, 2024	Filed
	202411038851	Handheld Nitrogen Assessment & Prescription Device & Method thereof for Cereal Crops	May, 2024	Filed
	202411043525	Zinc Loaded Bentonite Polymer Based Controlled Release Formulations for Perpetual Zinc Supply SSAC	June, 2024	Filed
	202411050820	A Telerobotic Target-Specific Pesticide Applicator for Greenhouse and Open-Field	July, 2024	Filed
	202411053291	Water Soluble Powder Formulation of Xanthophylls And Process Thereof	July, 2024	Filed
	202411054900	Biosurfactant Formulation for Degradation of Hydrocarbons in Soil and Method of Preparation Thereof	July, 2024	Filed
	202411069043	Electronic Safety Alarm and Brake Device for Chaff Cutter	September, 2024	Filed
	202411067511	Energy Based Custom Hiring Monitoring Meter for Tractor	September, 2024	Filed
	202411084010	Variable Height Real Time Cutting and Plucking Force Measurement Device for Fruits and Vegetables	November, 2024	Filed
	202411085869	Cumin Harvester	November, 2024	Filed
	1608/DEL/2015	Device for Recommending A Crop Yield Enhancer	January, 2024	Granted
	2019 11014982	Natural Carrier Based Anthocyanin Formulation for Targeted Release in Git and Process Thereof	February, 2024	Granted
	2020 11030310	Off-Grid Batteryless Solar Refrigerated Evaporatively Cooled Mesh Fabric Structure for Storage of Perishable	March, 2024	Granted
	202011028155	UAN cum seed applicator	July, 2024	Granted
	2020 11035828	Efficient Methodology for Natural Vitamin E Extraction from Edible Vegetable Oils	February, 2024	Granted
	201911051754	The 3′ polymorphic primers for species-specific detection of begomovirusPlant Pathlogy	June, 2024	Granted

IPRs	Application No./ Registration No./ Grant No.	Name of Innovation/ Technology/ Product/ Variety	Date of Filing/ Registration/ Grant	Application Filed/Granted/ Registered**
Trademarks (6 filed)	6354486	PUSABEEJ-wordmark class 31	March, 2024	Filed
	6354486	PUSABEEJ-wordmark class 35	March, 2024	Filed
	6354486	PUSABEEJ- wordmark class 42	March, 2024	Filed
	6354487	PUSABEEJ-Devicemark class 31	March, 2024	Filed
	6354487	PUSABEEJ- Devicemark class 35	March, 2024	Filed
	6354487	PUSABEEJ- Devicemark class 42	March, 2024	Filed
Copyrights (4 filed and 4 registered)	12633/2024-CO/ SW	Software titled- Pusa N doctor	April, 2024	Filed
	20789/2024-C0/L	A book titled 'Wings of Agri Innovations'	June, 2024	Filed
	20809/2024-CO/L	A book titled 'Startup Book'	June, 2024	Filed
	33743/2024-CO/ SW	Software titled- Algorithm on maturity detection of tomatoes	October, 2024	Filed
	4410/2024-CO/L	A book titled 'Cradling Sustainable Agricultural Innovations'	February, 2024	Registered
	15424/2024-C0/ SW	Software titled- Sugar Coaster	May, 2024	Registered
	15702/2024-CO/ SW	Software titled- Drought Predictor	May, 2024	Registered
	19336/2024-CO/ SW	Software titled- Nitrogen Assessment	June, 2024	Registered

Intellectual property rights from the Division of Genetics

IPR	Variety	Details	Date of registration
PPVFRA	HD 3385		
PPVFRA	Pusa HQPM1 Improved	RG/2024/0096	December 06, 2024
PPVFRA	Pusa HM4 Male Sterile Baby Corn (Shishu)	RG/2024/0097	December 06, 2024
PPVFRA	Pusa Biofortified Maize Hybrid-1 (APH1)	RG/2024/0095	December 05, 2024
PPVFRA	Pusa Biofortified Maize Hybrid-2 (APH2)	RG/2024/0374	December 06, 2024
PPVFRA	Pusa Biofortified Maize Hybrid-3 (APH3)	RG/2024/0375	December 06, 2024
PPVFRA	AH7043	RG/2022/0012	December 06, 2024

Intellectual property rights from the Division of Biochemistry

S. No.	Technology/Process/ Methodology Developed or Patent granted
Copyright granted	
1.	Sugar Coaster - Sugar Coaster-a nutritional web-based board game to alert the Glycemic Index of food. No-SW-19179/2024
Patent Granted	
2.	Efficient methodology for natural vitamin E extraction from edible vegetable oils. (Inventors: Vinutha T and Shelly Praveen. (2024). Patent grant Number (512733)

Intellectual property rights from the Division of Agricultural Engineering

Patents filed

Application No.	Name of Innovation
544047	UAN cum Seed Applicator (Patent Granted)
490756	Powered integral Equipment (Patent Granted)
530129	Off Grid Batterless Solar Refrigerated Evaporatively Cooled Mesh Fabric Structure for Storage of Perishables (Patent Granted)
421978-001	Polypropylene reinforced jute bag (Design Patent)
413096-001	Nitrogen prescription device for cereal crops (Design Patent)
2024411069043	Electronic Safety Alarm and Brake Device for Chaff Cutter- Patents filed
202411050820	Remote Controlled Pesticide Applicator Suitable for Greenhouse and Open Field- Patents filed
202411000969	Field performance measuring apparatus for farm implements
202411085869	Cummin Harvester

Copyrights

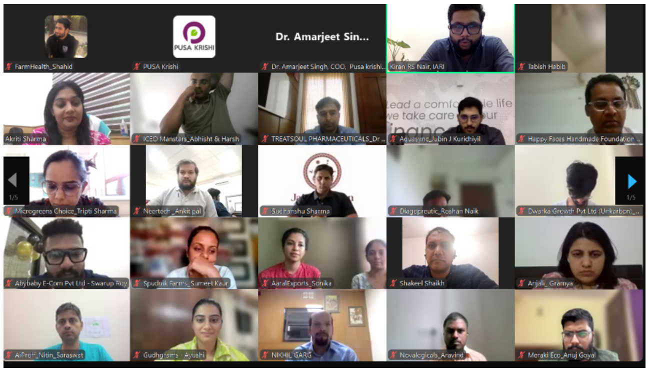
Application No.	Name of Innovation
19435/2024	Nitrogen assessment and prescription in rice-wheat cropping systems (Registered)
SW-17290/2023	Code for the remote control system for small tractors (Registered)
SW-18304/2024	Code for the LIDAR based check row planter (Registered)

Certification of Divisional Technology by ICAR: Multi-crop Ridger Planter; Tractor-drawn raised bed pulse planter for precision sowing; Solar Powered variable swath herbicide applicator robot for high-value vegetable crop; Field performance measuring apparatus for farm implements; Electronic safety alaram and brake device for chaff cutter; Pusa electronic seed metering retrofit module (ESMM) for cultivators; Control volume sprayer for grape clusters; Farm Sunfridge-off-grid battery-less solar refrigerated evaporatively cooled mesh fabric structure for storage of perishables; Pusa rotatable tray infrared dryer/processor; Manual multi-crop planter; Cumin harvester

11.4 INCUBATION ACTIVITIES

11.4.1. UPJA (Seed Stage), ARISE 2024 (Pre-Seed Stage)

UPJA 2024 (Seed Stage) and ARISE 2024 (Pre-Seed Stage) incubation programs were launched on April 1, 2024, to support innovation and entrepreneurship in India's agri-startup ecosystem. This year, over 1,300 applications were received under both the programs. From May 27 to June 27, 2024, selected startups underwent a one-month training and mentoring phase. During this period, they received comprehensive support, including technical mentoring and validation, financial management, intellectual

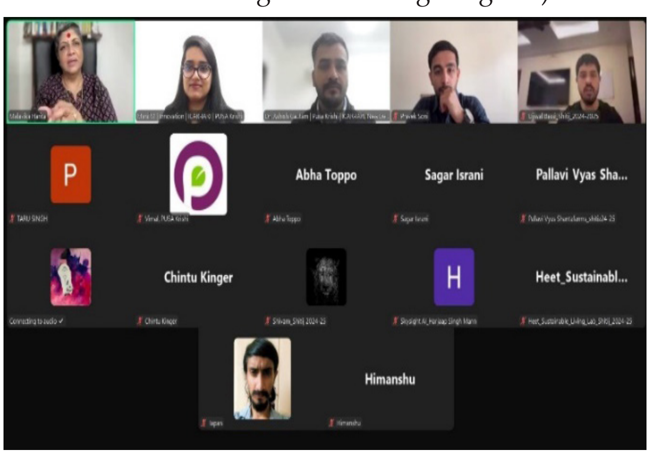


property management, industry connections, business mentoring, pilot opportunities, investment facilitation and guidance for building a sustainable business. Following this training, the RAFTAAR Incubation Committee (RIC) meeting was held from July 4-10, 2024 to select pre-seed and seed-stage startups for further rounds. Soon after that, the Selection & Investment Committee (SIC) was conducted from July 22-24, 2024 to make final recommendations for funding these startups. This year, 42 startups have been selected for the grant.

11.4.2. SHITIJ 2024

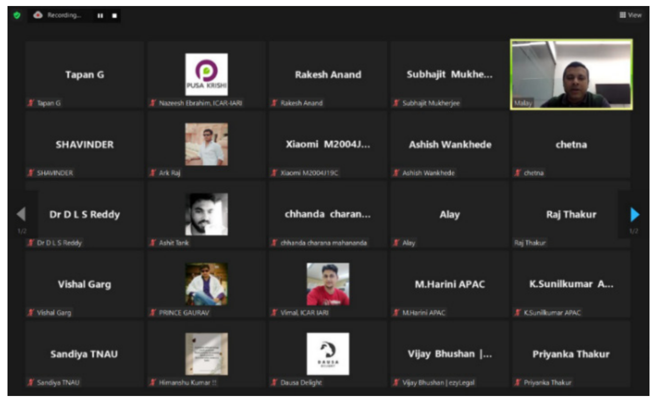
SHITIJ 2024, a year-long incubation program that supports early-stage startups by providing comprehensive capacity building, infrastructure and essential resources to tackle major challenges in agriculture through innovative solutions, was launched on July 20, 2024. The program is basically divided into two phases:

- Phase 1: Technical + Business Mentorship (15-Day Extensive Training & Mentoring Program)



- Phase 2: 4 months primer (Learning + Technical Sessions) (1-Year Incubation Program)

SHITIJ 2024 covered a wide range of topics, such as creating pitch decks, securing funding, working capital management, branding, pitching and startup compliance. The program also explored critical areas such as design thinking, intellectual property rights, and business strategy, offering practical insights into government schemes, as well as startup and MSME registration processes and much more.



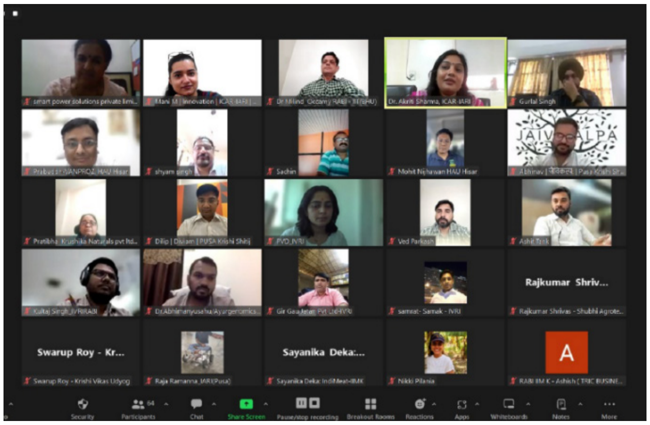
11.4.3. BEEJ 2024

BEEJ 2024, a groundbreaking online pre-incubation initiative by PUSA Krishi was launched on December 2, 2023, to nurture and support emerging entrepreneurs and startups in India's thriving agriculture and allied sectors. The two-week program, held from January 2-12, 2024, featured expert-led workshops on agricultural innovation, startup strategies, market research, and intellectual property. It provided participants with valuable insights and strategies essential for success in the agricultural sector.

1.1.4 Other Activities

11.4.4.1 PUSA Krishi masterclass series for RABI startups

As a Knowledge Partner of the Ministry of Agriculture and Farmers Welfare (MoA&FW) under the RKVY-RAFTAAR scheme, PUSA Krishi has been committed to supporting startups of the nine RABIs (RAFTAAR Agri-Business Incubators) in the northern zone. To further this mission, PUSA Krishi hosted the



'Masterclass Series for startups of RABIs' from April 1-12, 2024. This two-week online program marked a significant milestone in nurturing innovation and growth within the agricultural sector. The intensive sessions provided startups with valuable insights and expert guidance across various key areas, helping them build a strong foundation for success. Through comprehensive discussions led by industry experts, participants gained a well-rounded understanding of the critical aspects needed to scale and thrive in the agri-tech space.

11.4.4.2 SAMARTH 2023-24 & 2024-25

PUSA Krishi organized two significant workshops under its flagship SAMARTH initiative to empower agri-incubators across India. The first, "SAMARTH 2023-24 – Empowering the Incubators," held from February 20-22, 2024, at the NASC Complex, focused on building the capacity and skills of incubation managers from 29 KPs and RABIs under the RKVY-RAFTAAR scheme with respect to enhancing market access, exploring new funding opportunities and fostering impactful partnerships. Following this, the "SAMARTH 2024-25 Workshop: Nurturing the Indian Agri Startup Ecosystem" took place on November 6-7, 2024, offering a platform for collaborative discussions on incubator sustainability, best practices for running successful incubation programs and different kinds of incubation models by getting expertise from IITs and other established sector agnostic incubators. Both events aimed to strengthen the agri-startup ecosystem and drive innovation across India.

2023-24

2024-25

11.4.4.3 Brinjal & Chilli Field Day

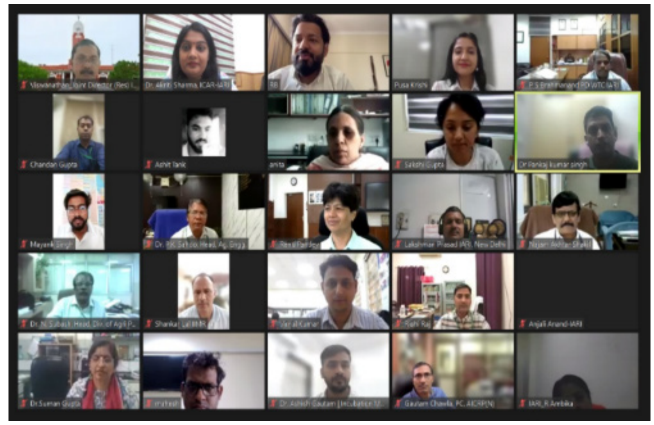
The Division of Vegetable Science in collaboration with the ZTM & BPD Unit at ICAR-IARI New Delhi organized Brinjal & Chilli Field Day on October 25, 2024. A key event showcasing innovative developments in vegetable farming. The event presented advanced brinjal and chili varieties and hybrids, specifically bred to address critical challenges faced by farmers today, such as resistance to pests and diseases, enhanced tolerance to heat stress and improved market adaptability.

11.4.4.4 PARICHAY 2024 – Startup Meet & Greet Event

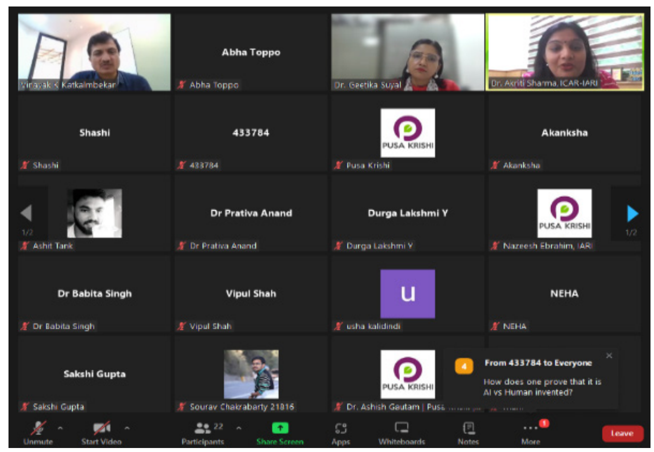
PUSA Krishi, ICAR-IARI hosted ‘Parichay 2024’ an event dedicated to fostering connections and celebrating collaboration among startups incubated under the Department of Science & Technology’s (DST) program - SHITIJ. The meticulously curated event by PUSA Krishi promised a day of insightful discussions, networking opportunities and showcasing innovative solutions shaping the future of agriculture. ‘Parichay 2024’ took place on May 13, 2024 at the Virology Hall, Division of Plant Pathology. Eminent IARI scientists, Incubation Ecosystem Partners – EIP, Social Alpha, FAAD, Equity360, Pedal Start, along with over 20 pioneering agri startups, attended the event. During the event, participants showcased their ideas and products, engaging with investors for potential funding and support to drive their ventures forward.

11.4.4.5 IPR trainings

The ZTM & BPD unit organized two thought-provoking webinars that explored the intersection of Intellectual Property (IP) and Artificial Intelligence (AI), as well as the role of Intellectual Property Rights (IPR) in promoting innovation and sustainability. The first webinar, held on March 19-20, 2024, covered a wide range of topics, offering valuable insights into the ethical considerations of AI advancements and the legal complexities of intellectual property rights. The second webinar, conducted on April 26, 2024, focused on the role of IPR in fostering sustainable innovation, while also addressing the challenges and opportunities in maintaining sustainable innovations.



Webinar on Crossroads of Intellectual Property & Artificial Intelligence



Webinar on Intellectual Property Rights-promoting Innovation and Creativity for a Sustainable Future

11.5 MoUs/AGREEMENTS SIGNED

In 2024, 269 MOAs were signed for 58 technologies with 199 industry partners, generating revenue of ₹ 3,88,17,054, including seven renewals. In addition, nine incubation MOUs were signed, generating revenue of ₹ 9,34,314.

11.5.1 TECHXCHANGE 2024: Empowering Industry with Innovation

In a pioneering initiative aimed at fostering agricultural innovation, the ZTM & BPD unit, ICAR-IARI, New Delhi hosted “TechXchange 2024 - Empowering Industry with Innovation” on April 30, 2024, at the B.P. Pal Auditorium, Pusa Campus, New Delhi. The main objective of the event was the formal signing of a Memorandum of Agreement (MoA)

between the ZTM & BPD unit of IARI and over 100 seed companies, primarily from U.P., Punjab and Haryana, for the licensing of HD 3386 Wheat Variety.

11.5.2 Strategic MoUs to Boost Agri-Tech Innovation and Startup Ecosystem in 2024

In 2024, Pusa Krishi signed several strategic MoUs to strengthen the agri-tech startup ecosystem. Pusakrishi partnered with Pilani Innovation & Entrepreneurship Development Society (PIEDS) and Evergreen Innovation Platform (EIP) to support startups in agriculture, climate and sustainability through technical validation, market access and collaborative events on May 13 and June 6, 2024 respectively. The partnership with Yamaha Motors Solutions India, executed on July 19, focuses on incubation, market access, pilot demonstrations. Additionally, Pusa Krishi joined hands with the Indian STEPs and Business Incubators Association (ISBA) on June 7 to offer mentorship, R&D and networking opportunities for startups. These collaborations aim to empower entrepreneurs, promote cutting-edge technologies, and drive impactful solutions in agriculture.

MoUs Signed by Pusa Krishi signed several MoUs

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, and 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 the 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, and 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 phenomics-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, 2024 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. UP Council of Agricultural Research (UPCAR) 11. Rashtriya Krishi Vikas Yojna (RKVY) 12. Defense Research & Development Organization (DRDO) 13. Ministry of Electronics & Information Technology (Meity) 14. Central Pulp and Paper Research Institute (CPPRI) 15. Central Council for Research in Ayurvedic Sciences (CCRAS) 16. Ministry of Agriculture & Farmers Welfare (MoAFW) 17. National Horticulture Board (NHB) 18. Rashtriya Uchattar Shiksha Abhiyan (RUSA) 19. Ministry of Environmental Forest & Climate Change (MoEFCC) 20. Department of Environment Science & Technology (DEST) 21. Central Sericulture Research and Training (CSRT) 22. Central Council for Research in Homeopathy (CCRH) 23. Indian Institute of Technology, Kharagpur (IIT) 24. Indian Council of Agricultural Research (ICAR)	194

Outside India 1. Bill & Melinda Gates Foundation & UK Department of International Development (DFID) 2. Borlaug Institute of South Asia (BISA)-Japan International Cooperation Agency (JICA) 3. Borlaug Institute of South Asia (BISA) 4. ICAR-International Rice Research Institute (IRRI) 5. United Kingdom Research & Innovation (UKRI) 6. International Center for Agricultural Research in the Dry Areas (ICARDA) 7. SPUN, USA 8. Centre for Agriculture and Bioscience International (CABI), United Kingdom 9. Heinrich Heine University (HHU), Germany 10. CIMMYT, Mexico 11. International Fertilizer Development Centre (IFDC), USA	16
Total	**210**

13. AWARDS AND RECOGNITION

Name of Scientist	Awards/Recognitions
Dr. Ch. Srinivasa Rao, Director	• Dr. N.S. Randhawa Memorial Award 2023-24 from NAAS, New Delhi • Coromandel Plant Nutrition Award 2024 from Fertilizer Association of India (FAI), Delhi • Dhiru Morarjee Award 2024 from Fertilizer Association of India (FAI), Delhi • Platinum Jubilee Commemoration Award 2024 from Indian Society of Soil Science (ISSS), New Delhi
Dr. C Viswanathan, Joint Director(Research)	• NAAS Recognition Award 2023-2024
Dr. P.S. Brahmanand, Project Director,	• Eminent Scientist Award-2024 from AgriVision • Eminent Water Resources Scientist Award - from Indian water Resources Society, IIT, Roorkee • Member, National Steering Council on Per Drop More Crop (PDMC) of Ministry of Agriculture and Farmers Welfare, GOI
Division of Genetics	
Dr. Gopala Krishnan S, Head	• NARES-IIRI Fellowship
Dr. Firoz Hossain, Principal Scientist	• Fellowship from the Maize Technologist Association of India (MTAI) • AB Joshi Memorial Award (2024) by ISGPB • Dr. SK Vasal Award by MTAI • Dr. SK Vasal Award by TAAS
Dr. Haritha Bollinedi, Scientist	• ISGPB Fellow • NAAS Associateship
Dr. Rajkumar U. Zunjare, Scientist	• NAAS Associate -2024 • Dr. R. Sai Kumar Memorial Award by MTAI
Dr. Prolay Kumar Bhowmick, Senior Scientist	• ISGPB Fellowship
Dr. Ganapati Mukri, Senior Scientist,	• ISGPB Fellow
Dr. Naveen Singh, Principal Scientist	• Dr. P.R. Kumar Outstanding Brassica Researcher Award by Society for Rapeseed-Mustard Research, Bharatpur
Dr. Vignesh Muthusamy, Senior Scientist	• Fellow and Dr. N. N. Singh Young Scientist Award by MTAI
Dr. Muraleedhar Aski, Senior Scientist	• ISGPB Fellow
Dr. Akshay Talukdar, Principal Scientist	• Lifetime achievement award in the field of Plant science by Assam University, Silchar, Assam
Division of Seed Science and Technology	
Dr. Gyan P. Mishra, Head	• NAAS Recognition Award 2023-2024 • NAAS Fellow-2024 • Fellow- ISVS, Varanasi • Honorary Fellow- SHRD, UP • 5th Dr PN Bahl Biennium Award (2020-21), Division of Genetics, IARI

Dr. D. Vijay, Principal Scientist	• Regional Representative, India -International Society for Seed Science, London, UK
Division of Vegetable Science	
Dr. B. S. Tomar, Head	• Lifetime Achievement Award in R&D in Horticulture from the Society for Horticulture Research & Development, UP
Dr. Shyam Sundar Dey, Principal Scientist	• NAAS Fellow-2024
Dr. Awani Kumar Singh, Principal Scientist	• Outstanding Horticultural Scientist Award, Society for Horticulture Research & Development, UP
Dr. Manisha Mangal, Principal Scientist	• Outstanding Women Horticultural Scientist Award, Society for Horticulture Research & Development, UP
Dr. Suman Lata, Scientist	• Young Horticultural Scientist Award, Society for Horticulture Research & Development, UP
Division of Fruits and Horticultural Technology	
Dr. O.P. Awasthi, Head	• Outstanding Teacher Award for the year 2021-2022 from Indian Society for Horticulture Research and Development, Uttarakhand
Dr. N.V. Singh, Senior Scientist	ICAR Technology Award
Division of Floriculture and Landscaping	
Dr. Markandey Singh, Head	• Lotus Puraskar by Indian Society of Ornamental Horticulture, New Delhi • Distinguished Horticultural Scientist Award from the Society for Horticulture Research & Development, UP
Dr. Ritu Jain, Principal Scientist	• Fellow- Society for Horticulture Research & Development, UP
Dr. Sapna Pawar, Senior Scientist	• Young Horticultural Scientist Award, Society for Horticulture Research & Development, UP
Division of Food Science and Post-harvest Technology	
Dr. Dinesh Kumar, Head	• Honorary Fellow- Society for Horticulture Research & Development, UP
Dr. Ram Asrey, Principal Scientist	• Fellow, Indian Society of Horticultural Research and Development
Dr. Alka Joshi, Scientist	• Outstanding Women Horticultural Scientist Award, Society for Horticulture Research & Development, UP
Division of Agronomy	
Dr. Sanjay Singh Rathore, Head	• Fellow- NAAS-2024 • Fellow- NADS -2024
Dr. Subhash Babu, Senior Scientist	• Fellow- NAAS-2024
Dr Y.S. Shivay Principal Scientist	• XXIII Sukumar Basu Memorial Award for the Biennial 2021-22 of ICAR-IARI New Delhi
Dr. Vijay Pooniya, Senior Scientist	• Associateship of NAAS-2024
Dr. C.M. Parihar, Principal Scientist	• Dr. S.K. Vasal Award by MTAI
Division of Agricultural Physics	
Dr. Rabi N. Sahoo, Principal Scientist	• Member, VAIBHAV Steering Committee DST, Govt of India
Dr. V.K. Sehgal, Principal Scientist,	• Fellow-Indian Society of Agrophysics
Division of Soil Science and Agricultural Chemistry	
Dr. B.B. Basak, Senior Scientist	• ISSS–Dr. J.S.P. Yadav Memorial Award -2024
Dr. Debasis Golui, Scientist	• IASWC Budding Scientist Award (2024) by the Indian Association of Soil and Water Conservationists, Dehradun, India

Dr. M.C. Meena, Principal Scientist	• Fellow, the National Academy of Biological Sciences (NABS), Chennai
Dr. Nayan Ahmed, Principal Scientist	• Gold Medal Award-2023 from the Soil Conservation Society of India, New Delhi
Division of Environmental Science	
Dr. S. Naresh Kumar, Head	• Member, Steering Council, Agricultural Model Intercomparison and Improvement Programme (AgMIP), NASA, GISS, Columbia University, USA • Member, Panel on Standards for Environmental Services, Bureau of Indian Standards, GoI; IPCC
Dr. D.K Sharma, Principal Scientist	• Expert Member, CPCB, National Green Tribunal
Dr. Ranjan Bhattacharrya, Principal Scientist	• Fellow-The Royal Society of Biology-2024, UK
Dr. Ashish Khandelwal, Scientist,	• Young Scientist Award from Society for Science of Climate Change and Sustainable Environment, New Delhi
Division of Agricultural Engineering	
Dr. Pramod Kumar Sahoo, Head,	• K C Das Memorial award by The Institutions of Engineers (India), Bhubaneswar
Dr. Satish Devram Lande, Senior Scientist	• ISAE Distinguished Service Award-2024
Water Technology Centre	
Dr. Susama Sudhishri, Principal Scientist,	• Commendation medal award by ISAE
Dr. V.K. Prajapati, Scientist	• Best Rajbhasha Nodal officer in ICAR-IARI, New Delhi for 2023-24
Division of Plant Pathology	
Dr. M. S. Saharan, Head	• Golden Pen Award, 2024 from ISMPP, Udaipur
Dr. Bishnu Maya Bashyal, Senior Scientist,	• S. Sinha Memorial Award, IPS (2024)
Dr. Ravindra Kumar, Senior Scientist	• Fellow-National Academy of Biological Sciences, Chennai
Dr. Amlendu Ghosh, Senior Scientist	• Fellow, from the Royal Entomological Society (FRES), London
Dr. Pankhuri Singhal, Scientist	• IARI Merit Gold Medal, 2024
Division of Entomology	
Dr. M. K Dhillon, Head,	• Member - Technical Advisory Committee (TAC) on Vector Borne Diseases, Ministry of Health & Family Welfare, Govt of India, New Delhi
Dr. S. Subramanian, Principal Scientist	• Fellow-Plant Protection Association of India
Dr. Suresh Nebapure, Scientist	• Young Entomologist Award-2022, Entomological Society of India, New Delhi
Division of Biochemistry	
Dr. Veda Krishnan, Senior Scientist,	• INSA - Young Associate 2024 • Member-NASI in Biological Sciences
Division of Plant Physiology	
Dr. Soham Ray, Senior Scientist	• Prof. M. Udayakumar Memorial Young Scientist Award, Indian Society of Plant Physiology, New Delhi
Division of Agricultural Economics	
Dr. Akriti Sharma, Scientist (SS)	• Entrepreneurship Leadership Award at the UP-State Agriculture Conclave 2024

Dr. Renjini V R, Scientist	• Uma Lele Mentorship Award, 2024, by the Agricultural & Applied Economics Association (AAEA) & Agricultural Economics Research Association (India)
Division of Agricultural Extension	
Dr. Satyapriya, Head,	• Fellow-2024, Society for Community Mobilization for Sustainable Development
Dr. Girijesh Mahra, Scientist	• Best Extension Professional Award, Society for Community Mobilization for Sustainable Development
Dr. Sitaram, Scientist	• Young Scientist Award, Society for Community Mobilization for Sustainable Development
Dr. Subhashree Sahu, Scientist	• Young Women Scientist Award, Society for Community Mobilization for Sustainable Development
Regional Stations/KVK	
Dr. Anil Khar, Head, IARI Regional Station, Pune	• Fellow- Indian Society of Genetics and Plant Breeding
Dr. Chander Parkash, Head, IARI Regional Station, Katrain	• Thiruvalluvar Global Award-2024, Ministry of Social Justice and Empowerment, Government of India
Dr. Vijay Singh Meena, Sr Scientist	• Top Agri-food Pioneers (TAP) by the World Food Foundation during August, 2024
Dr. J. Nanjundan, Senior Scientist	• SRMR Fellow by Society for Rapeseed-Mustard Research, Bharatpur
Team Awards	
Dr. H. K. Dikshit, Principal Scientist Dr. C. Bhardwaj, Principal Scientist and Team	• ICAR Best Centre Award for *rabi* pulses to IARI New Delhi by AICRP on Rabi Pulses

14. BUDGET ESTIMATES & UTILIZATION

(₹ In Lakhs)											
		B.E. 2024-25					**R.E. 2024-25**				
S. No.	**Head**	**Other than NEH & TSP**	**NEH**	**TSP**	**SCSP**	**Grand Total**	**Other than NEH & TSP**	**NEH**	**TSP**	**SCSP**	**Grand Total**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Grants for creation of Capital Assets (CAPITAL)											
1	Works										
	A. Land										
	B. Building										
	i. Office building	1600.00				**1600.00**	2037.76				**2037.76**
	ii. Residential building	384.00				**384.00**	0.00				**0.00**
	iii. Minor Works	600.00				**600.00**	403.71				**403.71**
2	Equipments	600.80				**600.80**	378.33				**378.33**
3	Information Technology	250.00				**250.00**	122.76				**122.76**
4	Library Books and Journals	100.00				**100.00**	99.59				**99.59**
5	Vehicles & Vessels	100.00				**100.00**	60.55				**60.55**
6	Livestock	3.00				**3.00**	2.10				**2.10**
7	Furniture & fixtures	0.00				**0.00**	0.00				**0.00**
A	**Total – CAPITAL (Grants for creation of Capital Assets)**	**3637.80**	**12.00**	**42.20**	**500.00**	**4192.00**	**3104.80**	**12.00**	**42.20**	**300.00**	**3459.00**
	Grants in Aid - Salaries (REVENUE)										
1	Establishment Expenses										

	Salaries									
	i. Establishment Charges	25760.00				25760.00	26036.28			26036.28
	ii. Wages	0.00								
	iii. Overtime Allowance	0.00								
	Total – Establishment Expenses (Grant in Aid - Salaries)	**25760.00**				**25760.00**	**26036.28**			**26036.28**
Grants in Aid - General (REVENUE)										
1	**Pension & Other Retirement Benefits**	24630.00				**24630.00**	28057.40			**28057.40**
2	**Traveling Allowance**									
	A. Domestic TA / Transfer TA	80.00				**80.00**	138.47			**138.47**
	B. Foreign TA	0.00				**0.00**	0.00			**0.00**
	Total – Traveling Allowance	**80.00**				**80.00**	**138.47**			**138.47**
3	**Research & Operational Expenses**					**0.00**				**0.00**
	A. Research Expenses	600.00				**600.00**	712.54			**712.54**
	B. Operational Expenses	1400.00				**1400.00**	1435.23			**1435.23**
	Total - Research & Operational Expenses	**2000.00**				**2000.00**	**2147.77**			**2147.77**
4	**Administrative Expenses**									
	A. Infrastructure	3500.00			0.00	**3500.00**	3627.49			**3627.49**
	B. Communication	20.00			0.00	**20.00**	11.98			**11.98**
	C. Repairs & Maintenance				0.00	**0.00**	0.00			**0.00**
	i. Equipments, Vehicles & Others	500.00			0.00	**500.00**	254.52			**254.52**

	ii. Office building	300.00			0.00	**300.00**	1331.94				**1331.94**
	iii.Residential building	300.00			0.00	**300.00**	335.70				**335.70**
	iv. Minor Works	100.00			0.00	**100.00**	219.81				**219.81**
	D. Others (excluding TA)	1432.80			0.00	**1432.80**	1325.41				**1325.41**
	Total - Administrative Expenses	**6152.80**			**49.00**	**6152.80**	**7106.85**				**7106.85**
5	**Miscellaneous Expenses**					**0.00**					
	A. HRD	15.00			0.00	**15.00**	15.53				**15.53**
	B. Other Items (Fellowships, Scholarships etc.)	1600.00			0.00	**1600.00**	1181.06				**1181.06**
	C. Publicity & Exhibitions	40.00				**40.00**	64.04				**64.04**
	D. Guest House – Maintenance	120.00				**120.00**	94.22				**94.22**
	E. Other Miscellaneous	250.00			200.00	**250.00**	356.06				**356.06**
	Total - Miscellaneous Expenses	**2025.00**			**0.00**	**2025.00**	**1710.91**				**1710.91**
	Total Grant in Aid-General	**10257.80**	**601.90**	**250.00**	**1000.00**	**12109.70**	**11104.00**	**537.49**	**250.00**	**1000.00**	**12891.49**
	Total (Pension+ General)	**34887.80**	**0.00**	**0.00**	**0.00**	**36739.70**	**39161.40**				**40948.89**
B	**Total Revenue (Grants in Aid - Salaries +Pension+ General)**	**60647.80**		**0.00**	**0.00**	**62499.70**	**65197.68**				**66985.17**
	Grand Total (Capital + Revenue)	**64285.60**	**0.00**	**0.00**	**0.00**	**66691.70**	**68302.48**				**70444.17**
	Grand Total (Capital +General)	**13895.60**	**0.00**	**0.00**	**0.00**	**16301.70**	**14208.80**	**0.00**	**0.00**	**1100.00**	**16350.49**

Note: Sub Head wise allocation under Revised Estimate 2024-25 is tentative and is subject to change based on final expenditure figures.

15. STAFF POSITION, APPOINTMENTS, PROMOTIONS AND TRANSFERS

(As on 31.12.2024)

Sl. No.	Category	No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	05	04
2)	Principal Scientist	61	47
3)	Senior Scientist/Scientist (S.G.)	128	79
4)	Scientist	373	289
	Total	**567**	**419**
B.	**TECHNICAL STAFF**		
1)	Category III	11	09
2)	Category II	265	127
3)	Category I	288	236
	Total	**564**	**372**
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	30	24
2)	Group B	277	189
3)	Group C	110	66
	Total	**417**	**279**
D.	**SKILLED SUPPORT STAFF**	**730+337***	**371**

*Additional post for regularization for DPL's

15.1 TECHNICAL STAFF

15.1.1 Appointments

Name of the Employee	Name of the Post	Place of Posting	Date of Appointment
Ms. Beera Bhavya	STO(T-6)	Genetics	08.08.2024
Ms. Neha	STO(T-6)	KVK, Shikohpur	18.07.2024
Sh. Hemant Sejwal	Technician (T-1)	Entomology	16.04.2024
Sh. Adarsh Patel	Technician (T-1)	Genetics	18.04.2024
Sh. Deepak Kumar	Technician (T-1)	FOSU	18.04.2024
Sh. Ramakant Gautam	Technician (T-1)	FS&PHT	19.04.2024
Sh. Abhishek Mani Tripathi	Technician (T-1)	CPCT	19.04.2024

Sh. Dilip Kumar	Technician (T-1)	CATAT	19.04.2024
Sh. Ankit Kumar	Technician (T-1)	Agril. Chemicals	19.04.2024
Sh. Kishor Kumar Kashyap	Technician (T-1)	AKMU	19.04.2024
Sh. Krishan Kumar	Technician (T-1)	SSAC	22.04.2024
Sh. Manish Kapoor	Technician (T-1)	FHT	22.04.2024
Sh. Rupesh Kumar	Technician (T-1)	Vegetable Science	22.04.2024
Sh. Anuj Kumar	Technician (T-1)	Agril. Engineering	22.04.2024
Sh. Chetan Prakash Meena	Technician (T-1)	FLS	22.04.2024
Ms. Rashmi Varshney	Technician (T-1)	Biochemistry	22.04.2024
Sh. Ankit Mishra	Technician (T-1)	Plant Pathology	23.04.2024
Sh. Nitin Bhaskar	Technician (T-1)	PME Cell	23.04.2024
Sh. Monti Kumar	Technician (T-1)	Agronomy	24.04.2024
Sh. Ankit Kumar	Technician (T-1)	Environment Science	25.04.2024
Sh. Shyamsundar Bhunya	Technician (T-1)	RS Adhthurai (TN)	23.04.2024
Sh. Rajat Mishra	Technician (T-1)	Agril. Engineering	26.04.2024
Sh. Bharat Sharma	Technician (T-1)	WTC	29.04.2024
Sh. Sudhir Kumar Jha	Technician (T-1)	Agril. Economics	29.04.2024
Sh. Suchit Kumar	Technician (T-1)	FLS	29.04.2024
Sh. Jitendra	Technician (T-1)	SST	29.04.2024
Sh. Ram Niwas Kumar	Technician (T-1)	SPU	30.04.2024
Sh. Manish Prakash	Technician (T-1)	CCUBGA	01.05.2024
Sh. Ravendra Pratap Singh	Technician (T-1)	Veg. Science	01.05.2024
Sh. Aakash Kasana	Technician (T-1)	Microbiology	01.05.2024
Sh. Pawan Choudhary	Technician (T-1)	Nematology	03.05.2024
Sh. Banwari Lal	Technician (T-1)	Agril. Physics	03.05.2024
Sh. Rakesh Kumar	Technician (T-1)	Genetics	06.05.2024
Md. Shahid Afridi	Technician (T-1)	Agronomy	06.05.2024
Ms. Pragya Singh	Technician (T-1)	Microbiology	06.05.2024
Sh. Sudhir Kumar	Technician (T-1)	Agril. Extension	06.05.2024
Sh. Harendra Singh	Technician (T-1)	Agronomy	06.05.2024
Sh. Atal Gandhi	Technician (T-1)	Genetics	06.05.2024
Sh. Chandan Kumar Jha	Technician (T-1)	RS, Indore, MP	29.04.2024
Sh. Vishnu Dev Kumar	Technician (T-1)	SS&AC	08.05.2024
Sh. Suraj Kumar	Technician (T-1)	Central Photo Lab (Directorate)	08.05.2024
Sh. Ashutosh Gupta	Technician (T-1)	RS, Katrain, HP	30.04.2024
Sh. Chandan Kumar	Technician (T-1)	RS, Kalimpong, WB	06.05.2024
Sh. Shanshi Bhushan Kumar	Technician (T-1)	RS, Shimla, HP	03.05.2024
Sh. Aniket Kumar	Technician (T-1)	Plant Physiology	09.05.2024
Sh. Shubham Yadav	Technician (T-1)	Microbiology	09.05.2024
Sh. Yuraj	Technician (T-1)	SPU	27.05.2024

15.1.2 Promotions

Name of the Employee	Name of the Post	Post after Promotion	Date of Promotion
Sh. Dhiraj Singh	Ex-CTO(T-9)	Adv. Inc. in (T-9)	01-01-2020
Dr. Praveen Sachdeva	CTO(T-9)	Adv. Inc. in (T-9)	24-02-2023
Sh. Mahesh Kumar	CTO(T-9)	Adv. Inc. in (T-9)	01-07-2023
Dr. B.K. Meena	ACTO(T-7/8)	CTO(T-9)	17-11-2021
Dr. Rahul Singh	ACTO(T-7/8)	CTO(T-9)	04-05-2022
Sh. Kamlesh Kumar	ACTO(T-7/8)	CTO(T-9)	12-01-2023
Sh. Uday Vir Singh	ACTO(T-7/8)	CTO(T-9)	04-05-2023
Smt. Meera Pandey	ACTO(T-7/8)	CTO(T-9)	10-06-2023
Sh. Ram Bihari Shukla	STO (T-6)	ACTO(T-7/8)	16-03-2023
Smt. Geetanjali Joshi	STO(T-6)	ACTO(T-7/8)	01-09-2023
Sh. Sandeep Kumar	TO(T-5)	STO (T-6)	20-10-2022
Sh. Laxmi Narayan Yadav	TO(T-5)	STO (T-6)	21-01-2023
Sh. Rameshwar Dayal Meena	STA(T-4)	TO(T-5)	24.09.2022
Sh. Tarun Rai	STA (T-4)	TO(T-5)	16.10.2022
Sh. Shiv Kumar Singh	STA(T-4)	TO(T-5)	25.10.2022
Smt. Ainmisha	STA(T-4)	TO(T-5)	29.10.2022
Sh. Jitender Kumar	STA(T-4)	TO(T-5)	30.10.2022
Sh. Sandeep Rohilla	STA (T-4)	TO(T-5)	30.10.2022
Sh. Jitender Kumar	STA (T-4)	TO(T-5)	31.10.2022
Sh. Digvender Pal	STA(T-4)	TO(T-5)	20.11.2022
Sh. Satish Kumar	STA(T-4)	TO(T-5)	21.11.2022
Sh. Hari Narayan Gupta	STA (T-4)	TO(T-5)	01.12.2022
Sh. Rajesh Sharma	STA (T-4)	TO(T-5)	02.12.2022
Sh. Parmod Kumar Vatsa	STA (T-4)	TO(T-5)	03.12.2022
Sh. Om Prakash Meena	STA(T-4)	TO(T-5)	06.12.2022
Sh. Suresh Kumar Meena	STA(T-4)	TO(T-5)	07.12.2022
Sh. Rajesh Kumar Meena	STA(T-4)	TO(T-5)	07.12.2022
Sh. Manjit Singh	STA (T-4)	TO(T-5)	10.12.2022
Sh. Chhote Lal	STA(T-4)	TO(T-5)	24.12.2022
Dr. Shilpi Aggarwal	STA(T-4)	TO(T-5)	26.12.2022
Mohammad Athar	STA(T-4)	TO(T-5)	27.12.2022
Dr. Ravish Chaudhary	STA(T-4)	TO(T-5)	31.12.2022

Smt. Sangeet Upadhyay	STA(T-4)	TO(T-5)	01.01.2023
Smt. Shilpi Kumari	STA(T-4)	TO(T-5)	11.01.2023
Smt. Manisha Saini	STA(T-4)	TO(T-5)	17.01.2023
Sh. Ishwar Prakash	STA(T-4)	TO(T-5)	12.02.2023
Sh. Vikas Kumar	STA (T-4)	TO(T-5)	19.03.2023
Sh. Dinesh Kumar Diwakar	STA(T-4)	TO(T-5)	06.08.2023
Sh. Ganesh Rai	STA(T-4)	TO(T-5)	05.10.2023
Sh. Dileep Kumar	TA(T-3)	STA(T-4)	04.01.2023
Sh. Raj Kishor Singh	TA(T-3)	STA(T-4)	17.01.2023
Sh. Mahavir Ram	TA(T-3)	STA (T-4)	19.05.2023
Sh. Jai Prakash Lal	TA(T-3)	STA (T-4)	19.05.2023
Sh. Ramchander Paswan	TA(T-3)	STA (T-4)	20.05.2023
Sh. Raj Kumar	TA(T-3)	STA (T-4)	21.05.2023
Sh. Bishan Dev	Ex-T-I-3	STA(T-3)	03.02.2005
Sh. Des Raj	ST(T-2)	TA(T-3)	22.08.2021
Sh. Jai Narayan	ST(T-2)	TA(T-3)	23.10.2022
Sh. Vipin Kumar	ST(T-2)	TA(T-3)	29.11.2022
Sh. Manoj Kumar	ST(T-2)	TA(T-3)	01.12.2022
Sh. Ramesh Kumar	ST(T-2)	TA(T-3)	12.11.2022
Sh. Surendra Kumar Rai	ST(T-2)	TA(T-3)	28.12.2022
Sh. Anil Kumar	ST(T-2)	TA(T-3)	10.01.2023
Sh. N. Mahendran	ST(T-2)	TA(T-3)	18.01.2023
Sh. Pradeep Kumar Choudhary	ST(T-2)	TA(T-3)	19.01.2023
Sh. Krishan Kanhiya	ST(T-2)	TA(T-3)	28.01.2023
Sh. Rakesh Kumar	ST(T-2)	TA(T-3)	31.01.2023
Sh. Surender Kumar	ST(T-2)	TA(T-3)	01.02.2023
Sh. Bhavesh Kumar	ST(T-2)	TA(T-3)	04.02.2023
Sh. Rajesh Kumar Meena	ST(T-2)	TA(T-3)	15.02.2023
Sh. Sunil Kumar	ST(T-2)	TA(T-3)	06.03.2023
Sh. Pintu Ram Bairwa	ST(T-2)	TA(T-3)	20.03.2023
Sh. Mukesh Kr. Mawliya	ST(T-2)	TA(T-3)	26.04.2023
Sh. Rajendra Rai	ST(T-2)	TA(T-3)	21.05.2023
Sh. Arvind	ST(T-2)	TA(T-3)	14.11.2023
Sh. Umesh Kumar	Technician (T-1)		28.02.2023

15.1.3 Transfer and Retirement

Name of the Employee	Name of the Post	Place of Transfer	Date of Transfer
Sh. Ram Baros Meena	STA (T-4)	SS&AC Division	19.04.2024
Sh. Siyaram Kumar	Technician (T-1)	WTC	19.04.2024
Sh. Sumit	Technician (T-1)	WTC	19.04.2024
Sh. Mohinder Pal	ACTO(T-7/8)	WTC	19.04.2024
Sh. Sanjay Sirohi	STA (T-4)	FHT Division	19.04.2024
Sh. Ajit Kumar Das	TA(T-3)	Agril. Extension	19.04.2024
Sh. Sunil Kumar	TA(T-3)	Plant Physiology	19.04.2024
Smt. Jyoti Tomer	Technician (T-1)	Plant Physiology	19.04.2024
Sh. Nitin Kumar	TA(T-3)	SST	19.04.2024
Smt. Neha Pandey	Technician (T-1)	Agril. Extension	19.04.2024
Sh. Praveen	Technician (T-1)	Agril. Extension	19.04.2024
Sh. Vikas Kumar	STA (T-4)	FOSU	19.04.2024
Sh. Sonu Olla	TA(T-3)	M.E. Unit	19.04.2024
Md Shahid Afridi	Technician (T-1)	Plant Pathology	19.04.2024
Sh. Lalit Kumar	STA (T-4)	Microbiology	06-06-2024
Sh. Ram Chander Paswan	STA (T-4)	Transport Section	28-06-2024
Sh. Dharm Chand Meena	TO(T-5)	FOSU	28-06-2024
Sh. Munish Bhatt	TO(T-5)	FOSU	07-10-2024
Sh. Tarun Rai	TO(T-5)	MOHR	09-10-2024
Sh. Bijay Singh	TO(T-5)	Genetics	29-11-2024
Sh. Batti Lal Meena	STO(T-6)	SS&AC	29-11-2024
Sh. Mitra Kumar Rasailey	TA(T-3)	RS, Kalimpong	29-11-2024
Sh. Dinesh Kumar	TA(T-3)	RS, Bihar	29-11-2024

15.2 ADMINISTRATIVE STAFF

15.2.1 Appointments

Name of Employee	Post	Place of Posting	Date of Appointment
Sh. Vivek Shankar	Assistant	Genetics	01.10.2024
Sh. Himanshu	Assistant	Store Section, Directorate	01.10.2024
Sh. Pradeep Singh	Assistant	Audit Wing	01.10.2024
Sh. Lalit Kumar Meena	Assistant	Environment Science	01.10.2024
Miss Sapna Sharma	Assistant	Audit Wing	01.10.2024
Sh. Ankit Lamba	Assistant	Personal -II Section	01.10.2024
Sh. Kamaljeet Singh	Assistant	Pension Admin. Section	01.10.2024
Sh. Sourodipta Chakraborty	Assistant	PME Cell	01.10.2024
Miss Yamini Singh	Assistant	Nematology	01.10.2024

Miss Subhashini Pandey	Assistant	Personal-III Section	01.10.2024
Sh. Moon	Assistant	OMV Section	01.10.2024
Sh. Raja Ram Jha	Assistant	Ag. Engineering	01.10.2024
Sh. Rahul Dalal	Assistant	Personal-I Section	01.10.2024
Sh. Narender	Assistant	Plant Physiology	01.10.2024
Miss Aditi Ghalot	Assistant	Ag. Physics	01.10.2024
Mohd Adil Husain	Assistant	SSAC	01.10.2024
Sh. Ujjawal Kumar	Assistant	FOSU	01.10.2024
Sh. Praveen Kumar Verma	Assistant	Ag. Chemicals	01.10.2024
Sh. Mayank Singh	Assistant	Microbiology	01.10.2024
Sh. Lakshay	Assistant	Plant Pathology	01.10.2024
Sh. Sachin	Assistant	Security Section	01.10.2024
Sh. Mohit Bhankhar	Assistant	Works Section	01.10.2024
Sh. Lalit Kumar Kanawat	Assistant	Ag. Extension	01.10.2024
Sh. Saatvik Bhadoria	Assistant	M.S. Swaminathan Library	01.10.2024
Sh. Rahul Singh	Assistant	Regional Station, Karnal	01.10.2024
Sh. Gaurav Rajora	Assistant	The Graduate School	03.10.2024
Sh. Shivani Sharma	Assistant	Entomology	01.10.2024
Sh. Amit Kumar	Assistant	Audit Wing	10.10.2024
Sh. Kartik	Assistant	IMC, RTI, Section	11.10.2024
Miss Ritu Bisht	Assistant	Personnel-III Section	16.10.2024
Sh. Ankit Kumar	Assistant	The Graduate School	22.10.2024
Sh. Kaushal	Assistant	ME Unit	23.10.2024
Miss Shweta	Assistant	Audit Wing	04.11.2024
Sh. Alok Sharma	Assistant	Audit Wing	04.11.2024

15.2.2 Promotions

Name of the Employee	Name of the post	Post after Promotion	Date of promotion
Sh. Nitin Kant Suraj	Assistant	AAO	01.03.2024
Smt. Ruchi Aggarwal	Assistant	AAO	01.07.2024
Sh. Punit	Assistant	AAO	24.09.2024
Sh. Meghraj Meena	Assistant	AAO	24.09.2024
Smt. Shivani Vidhuri	Assistant	AFAO	22.08.2024
Smt. Suruchi Bhagchandani	Assistant	AFAO	22.08.2024
Smt. Jyotsna Jha	Assistant	AFAO	22.08.2024
Sh. Deepak Kumar Mahlawat	Assistant	AFAO	22.08.2024

16. POLICY DECISIONS AND ACTIVITIES UNDERTAKEN FOR THE BENEFIT OF DIFFERENTLY-ABLED PERSONS

16.1 POLICY DECISIONS FOR 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 percent 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 2024-25, 40 physically challenged students (10 UG, 14 M.Sc./M.Tech. and 16 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 to fill 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, 2024, are as follows:

Category	Total number of beneficiaries	Number of beneficiaries with disability	Percentage (%)
Technical	372	06	1.61
Administrative	279	11	3.94
Skilled Support Staff	371	05	1.35

17. OFFICIAL LANGUAGE (RAJBHASHA) IMPLEMENTATION

Article 343 of the Constitution states that Hindi shall be the Official Language (OL) of the Union Government. To implement the objectives in letter and spirit, ICAR-IARI is making consistent progress in using OL in agricultural research, education, extension and 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. The Institute Official Language Implementation Committee has been reconstituted from 13.12.2024 in which Joint Directors, PD WTC, Head, Division of Seed Science and Technology, Head of divisions from Agronomy, Division of Floriculture and Landscaping, Division of Fruits and Horticultural Technology, Comptroller and Hindi translator are ex-officio members with Chief Administrative Officer as its member-secretary. During the period under report, the meeting of this committee was organized regularly in each quarter and necessary suggestions and instructions were given for promoting the use of Hindi in various official/research activities for the effective implementation of the Official Language. To ensure follow-up action on the decisions taken in these meetings, subcommittees were also constituted in different Divisions, Regional Stations and the Directorate.

17.2 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 (Research), ICAR-IARI, New Delhi. 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 14 OLIC Inspections were conducted during the period reported upon.

17.3 AWARD SCHEMES/COMPETITIONS

During the year 2024, many competitions/award schemes were also initiated to motivate the employees of the Institute to do their maximum work in Hindi. A large number of officers and employees of different categories of staff participated in these activities. The following activities were organized:

17.3.1 Award for Doing Maximum Official Work in Hindi

This award scheme of the Department of Official Language, Ministry of Home Affairs, Govt. of India, was implemented as per the directives of the Department. Employees of the Institute were given cash awards for doing their maximum official work in Hindi for the whole year. For the year 2023-24 first cash prize of ₹ 5000/- was given to Ms. Jyotsana Gonnade, Assistant, P-II section and Mr. Ranbir Singh, ACTO, Division of Agronomy; the second cash prize of ₹ 3000/- was given each to Mr. B.S. Rawat, PS, Publication Unit, Mrs. Sunita Gulati, Assistant, IMC Section and Mrs. Madhu Bala, Assistant, Pay Bill section. A third cash prize of ₹ 2000/- was given each to Mr. Mukesh Kumar, Assistant, E&P section and Dr. Virendra Kumar, ACTO, WTC.

17.3.2 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 doing maximum work in Hindi during the whole year. In the period 2023-24, the evaluation committee constituted under the chairmanship of Joint Director Administration and Senior Registrar gave the prizes to WTC and Division of Biochemistry amongst the Divisions, Personnel-II Section amongst the Unit/Section and Pune & Katrain amongst the Regional Stations.

17.3.3 Best Rajbhasha Nodal Officer Award Competition

To implement the Official Language more effectively, Rajbhasha Nodal Officers are nominated in each Division and Regional Centre by their HoDs and Heads, Regional Stations, respectively. This award is given based on work done by Rajbhasha, nodal officer, to look after the implementation of the official language, Hindi in their Divisions/Regional stations. Dr. Vijay Prajapati, Scientist, WTC was awarded a cash prize of ₹ 5000/-.

17.3.4 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, to promote the officers to give maximum dictation in Hindi throughout the year. During the reported period, Dr. Alka Singh, Head, Division of Agricultural Economics and Mrs. Satinder Kaur, AAO, WTC were given cash prizes of ₹ 2500/- each.

17.3.5 Awards for Popular Science Writing in Hindi in Different Journals

A competition for Popular Science Writing was organized for scientists/technical officers of the Institute and winners were awarded first, second and third prizes of ₹ 7000/-, 5000/- and 3000/-, respectively and three incentive awards of ₹ 2000/- for their published articles in different journals. During the reported period, the first cash Prize was given to Dr. Pratibha Joshi, Senior Scientist, CATAT, Dr. Girijesh Singh Mehra, Scientist, Division of Agriculture Extension, and Dr. Geetanjali Joshi, STO, AKMU, for their article 'Agriculture Solar Energy: Current Status, Challenges and Prospects (Cover Story). The second prize was given to Dr. Ranbir Singh, ACTO, Division of Agronomy, for his article entitled 'Use of Artificial Intelligence in Agriculture' Zero Cost Natural Farming *vs* Organic Farming. The third cash prize was given to Dr. Veerendra Kumar, ACTO, WTC, for his article 'Agricultural Waste Management'. The Ist Incentive prize was given to Dr. Chirag Maheshwari, Scientist, Division of Biochemistry for his article 'Shri Ann: A Nutritious Grain' IInd Incentive prize to Dr. Ravish Chaudhary, STO, Division of Seed Science and Technology. The third Incentive prize was to Dr. Gyan Prakash Mishra, Head, Dr. Ravish Chaudhary, STO, Dr. Sangita Yadav, Principal Scientist, Mr. Dharmpal Singh, STO, Division of Seed Science & Technology, Dr. Shiv Kumar Yadav, Head, RS Karnal and Dr. Dharmendra Singh, Principal Scientist, Division of Genetics for their article 'Quality lentil seed production and its management'.

17.3.6 Pusa Vishisht Hindi Pravakata Puraskar

Pusa Vishisht Hindi Pravakta Puraskar is given to scientists for their outstanding lectures in different training programs. This award carries a cash prize of ₹ 10000/-. During the reporting period, this cash prize was given to Dr. Indu Chopra, Senior Scientist, Division of Soil Science and Agriculture Chemistry.

17.4 HINDI *CHETNA MAAS*

The month of September was celebrated as Hindi *Chetna Maas* by ICAR-IARI, New Delhi and the inauguration ceremony was held on September 01, 2024. Dr. Viswanathan Chinnusamy, Joint Director (Research) and Dr. P.S. Brahamanand, PD (WTC), graced the occasion. Mrs. Seema Chopra, Ex-Director (Official Language), ICAR and Shri Saraswat Mohan Manishi, noted poet, 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 *viz*. Poetry recitation, extempore speech in three different categories, *i.e.* for Scientific, Administrative & Technical, RA/SRF/JRF/YP/Project Assistant/Contractual Office Assistant/Contractual Stenographer, Prashn-Manch, story or poetry writing based on the picture, dictation, noting and drafting, general knowledge competition (descriptive) (for MTS), Hindi typing were organized during the Hindi *Chetna MAAS*. Besides, the Hindi Day/fortnight event was also organized by many divisions/regional centers of the Institute.

Glimpses of Hindi *Chetna Maas*

Lighting of lamps at the inauguration of Hindi *Chetna Maas*

Participant at extempore speech competition

17.5 HINDI COMPETITIONS ORGANIZED BY DIVISIONS OF THE INSTITUTE

17.5.1 Division of Seed Science and Technology

Division of Seed Science and Technology organized Hindi Day to promote the use of Hindi and to encourage more government work to be conducted in Hindi. Various competitions were held as part of the event, in which the division's scientists, technical officers, students, and research personnel on contract (Y.P.-1, J.R.F., field workers, etc.) and their children participated. The Hindi Day and Award Distribution Ceremony was held on September 30, 2024. Dr. Sudhakar Pandey (Assistant Director General, Horticulture, ICAR), graced the occasion as the Chief Guest. To promote Hindi as the official language, the program was conducted by Miss Hina H. Kosar, a student from the 'C' region of the Hindi Language and Dr. Ravish Chaudhary (Technical Officer). The following competitions were held:

(a) Hindi Quiz Competition

(b) Shorthand Writing Competition

Competitions for the children of officers and employees working in the division:

(a) Hindi Quiz Competition for Primary Class Level

(b) Hindi Quiz Competition for Secondary Class Level Dictation Competition

The winners of the first, second and third places and consolation prizes in all three competitions were honored with mementos and certificates.

17.5.2 Division of Genetics

A Hindi Shorthand Competition and a Hindi General Knowledge Competition were organized on September 18, 2024, in the Division of Genetics. The Division's Rajbhasha Nodal Officer, Dr. Nivedita, welcomed all the participants including the distinguished guests and provided a brief overview of the remarkable work/achievements related to Hindi in the Division. During the event, the panel of judges, Dr. Rajendra Kumar, Principal Scientist, Dr. Sanjay Kumar Singh, Principal Scientist and Chief Administrative Officer, Piyush Shukla, expressed their views on the importance of Hindi as the official language and its contribution to the progress of the nation. They urged all the personnel to contribute to the promotion of the official language.

17.5.3 Division of Nematology

Hindi *Chetna Maas* 2024 was organized in the Division of Nematology during the month of September. Different competitions such as - Poetry Recitation, PowerPoint Presentation, Impromptu Speech, Quiz, Handwriting were organized. The award distribution ceremony was chaired by Dr. Pankaj, Head of the Division and the winners on the occasion.

Participant reciting poetry at poetry recitation competition

17.5.4 Division of Biochemistry

Various Hindi competitions (General Knowledge Quiz, Impromptu Speech, and Quiz) were organized at the Divisional level in the Division of Biochemistry on September 12, 2024. The distinguished guests for the competition included Dr. Ajay Arora, Principal Scientist, Division of Plant Physiology and Shri Shiv Kumar, Technical Officer, Division of Genetics, who also served as members of the jury. The program began with an opening by Mrs. Prachi Tyagi, Hindi Nodal Officer, Division of Biochemistry. The Head of the Division, Dr. Arun Tyagi, delivered the welcome address, sharing her thoughts and welcoming all the guests and attendees. The first prize for the quiz competition was awarded to Shri Harish Dhal, a Ph.D. student and Dr. Arun Tyagi and Mrs. Krishna Bisht jointly secured the second prize. The first prize for impromptu speech was awarded to Dr. Archana Singh (Principal Scientist) and Dr. Navita Bansal (Assistant Chief Technical Officer) and the second prize to Shri Ashok Kumar and Shri Brijesh Yadav, while the third prize went to Miss Sonal and Shri Deepak Patel. In the Quiz Competition, the team of Dr. Ajay Arora, Miss Muskaan and Shri Shiv Kumar secured the first position. The second position was awarded to the team of Shri Brijesh Yadav, Shri Ashok Kumar and Shri Bhola Mahato, while the third position went to the team of Dr. Arun Tyagi, Dr. Suresh Kumar, and Shri Bharat.

Hindi Competition program at the Division of Biochemistry

17.5.5 Division of Agricultural Chemicals

A one-day Hindi Day event was organized on September 10, 2024, in the Division of Agricultural Chemicals. Various competitions, including extempore speech, Hindi translation, dictation and calligraphy, were held as part of the event, in which all the division staff participated.

Glimpse of Hindi program at Division of Agricultural Chemicals

17.5.6 CATAT

The Hindi Day program organized by the Divisional Official Language Implementation Committee was held on September 30, 2024 in the seminar hall at CATAT. Five competitions were conducted including debate, poetry recitation, dictation, memoir writing (for MTS, DPL & Contractual Staff) and extempore speech as part of the event, in which all staff from CATAT, ATIC and the Pusa Agricultural Product Sales Center participated. A special award was given for participation of staff from non-Hindi-speaking regions.

Joint Director (Extension) awarding prizes to winners

17.5.7 Division of Microbiology

Hindi competitions, such as a quiz for DPL staff, application writing for administrative, technical, and MTS staff, an Extempore speech for all staff, a debate for all staff, including project employees and students, and Antakshari were organized at the Division.

17.6 HINDI ANNUAL PRIZE DISTRIBUTION FUNCTION

The Hindi prize distribution ceremony and a lecture on "New era of technological innovations and official language Hindi" was organized at the Institute on May 02, 2024. Mr. Balendu Sharma Dadhich, a national awardee Senior Technology professional, author and speaker, was the Chief Guest for the function. He is also a Microsoft spokesperson on Indian language technologies and is working as Director of Local Language & Accessibility. Dr. A.K. Singh, Director and Chairman of the Official Language Implementation Committee welcomed the Chief Guest. The 22nd issue of PUSA SURABHI, the six-monthly Rajbhasha Patrika of the Institute, was released on the occasion. The winners of various competitions organized during Hindi Awareness Month and in other year-round competitions were awarded prizes during the event. Also, two Divisions and Sections were awarded a shield for doing maximum work in Hindi during the whole year. Cash prizes were also awarded for popular science writing in Hindi. The Chief Guest appreciated the progress of the official language of the Institute and discussed the different innovations in *Rajbhasha*. He apprised the audience on availability of various tools in communication, collaboration, social media, content development, eBooks, publication and media, multimedia, graphics, internet search, video, maps, skill development, web development, software development, mobile development, data analytics in *Rajbhasha*.

Dignitaries releasing 22nd issue of Pusa Surabhi

18. DIRECT DELIVERY OF IARI SEEDS, OTHER INPUTS AND SERVICES TO THE FARMERS AND OTHER STAKEHOLDERS

18.1 SEED PRODUCTION IN FIELD CROPS (JANUARY 01 TO DECEMBER 31, 2024)

18.1.1 Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seeds of 72 varieties of cereals, pulses, and oilseeds was 1309.533 tons, which encompasses nucleus seeds (9.715 tons), breeder seeds (149.918 tons) and TFL/IARI seeds (1149.90 tons, 27.601 tons and 1122.299 tons at the Institute farm and under the farmer participatory seed production program, respectively).

Seed production of crops at Seed Production Unit & Farmer's field

Crop	Total number of varieties	Classes of seeds (in tons)				Total production (tons)
		NS (ton)	BS (ton)	IARI seeds/(TFL) (ton)		
				At Institute	Under FPSP	
Wheat	15	7.32	142.03	11.000	518.573	678.923
Paddy	20	0.020	1.875	5.709	571.059	578.663
Chickpea	12	1.840	0.226	0.734	6.481	9.281
Pigeonpea	03	0.045	0.796	1.257	0.000	2.098
Lentil	03	0.200	0.362	1.200	2.600	4.362
Moong	03	0.200	0.935	0.235	5.889	7.259
Mustard	07	0.090	2.468	7.374	17.697	27.629
Maize	05	-	0.219	-	-	0.219
Bajra	01	-	-	0.092	-	0.092
Soybean	03	-	1.007	-	-	1.007
Total	**72**	**9.715**	**149.918**	**27.601**	**1122.299**	**1309.533**

*NS-Nucleus Seed, BS-Breeder Seed, TFL- Truthful Label Seed (IARI Seed), FPSP- Farmers Participatory Seed Production

***Funds generated:** ₹ 11.004 crore/-
(*fund generated included the seed production from field and horticultural crops)

18.1.2 ICAR-IARI Regional Station, Karnal

At ICAR-IARI Regional Station, Karnal, 6105.186 q quality seed of different crop varieties of cereals, pulses, oilseeds and forage crops were produced during *Rabi* 2023-24 and summer/*Kharif* 2024. A total of 30.729 q nucleus, 1355.845 q breeder and 4718.612 q of IARI seed were produced.

Seed production of field crops (*Rabi* 2023-24 and *Summer/Kharif* 2024)

Type	No. of crops	No. of varieties	Seed Production (q)			
			Nucleus	Breeder	IARI	Total
Cereals	6	43	30.12	1301.24	4658.305	5989.665
Pulses	3	8	0.025	22.33	18.4	40.755
Oilseeds	1	4	0	15.85	16.85	32.7
Others (Dhaincha)	1	1	0	0	20.00	20
Total	**11**	**56**	**30.145**	**1339.42**	**4713.555**	**6083.12**

****Funds generated: ₹ 3.5 crore**

(**fund generated included the seed production from field and horticultural crops)

18.1.3 ICAR-IARI, Regional Station, Bihar

In the *kharif* 2024, summer 2024 and *rabi* 2023-24 seasons, a cumulative production of 1589.64 quintals of seeds as achieved across various crops. Noteworthy contributions include paddy (281.62 q), pearl millet (5.31 q), mungbean (17 q), wheat (1226.14 q), lentil (23.40 q), mustard (22.35 q), pea (0.64 q), chickpea (0.42 q) and pigeonpea (11.78 q). Additionally, 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*-2024	Paddy	Pusa Sugandha 5			78.41	78.41
			Pusa -44			54.90	54.90
			Pusa Samba -1850			10.11	10.11
			PNR-381			138.20	138.20
			Total			**281.62**	**281.62**
		Pearl millet	PC701			2.95	2.95
			PC1801			2.20	2.20
			PC383			0.16	0.16
			Total			**5.31**	**5.31**
2	Summer-2024	Mung bean	Pusa Vishal			14.00	14.00
			Pusa 1431			3.00	3.00
			Total			**17.00**	**17.00**
3.	*Rabi*- 2023-24	Wheat	HD 2967	17.16	359.21	189.91	566.28
			HD 3086	3.6	00.00	00.00	3.6
			HD 3249	15.00	188.05	23.59	226.64
			HI 1563	00.00	00.50	00.00	00.50
			HD 3171	2.60	85.88	00.00	88.48
			HI 1612	1.50	86.00	00.00	87.50
			HD 3226	00.00	00.00	54.60	54.60

		Wheat	HP 3298	00.00	65.52	00.00	65.52
			HD 3388	00.00	120.12	00.00	120.12
			HD 2733	2.00	00.00	00.00	2.00
			HD 2985	2.50	00.00	00.00	2.50
			HD 3118	4.00	00.00	00.00	4.00
			HD 1966	3.5	00.00	00.00	3.5
			HI 1563	3.00	00.00	00.00	3.00
			Total	**54.86**	**905.28**	**268.1**	**1227.74**
		Lentil	PSL-9	00.00	00.00	05.40	05.40
			PDL-1	00.00	00.00	03.50	03.50
			L-4717	00.00	00.00	14.50	14.50
			Total	00.00	00.00	**23.40**	**23.40**
		Mustard	Pusa Agrani	00.00	00.00	13.95	13.95
			Pusa -27	00.00	00.00	08.40	08.40
			Total	00.00	00.00	**22.35**	**22.35**
		Pea	Pusa Shree	00.00	00.00	0.23	0.23
			Pusa Pragati	00.00	00.00	0.41	0.41
			Total	00.00	00.00	**0.64**	**0.64**
		Chickpea	C-3043			0.27	0.27
			Pusa-256			0.15	0.15
			Total			**0.42**	**0.42**
		Pigeonpea	Pusa 9			1.71	1.71
			Pusa 151			10.07	10.07
			Total			**11.78**	**11.78**
		Okra	A5			0.68	0.68
		Marigold	Pusa Narangi			0.014	0.014
		Lathyrus	BIOL-2.2			00.30	0.30
			Grand total			**36.55**	**591.25**

*****Fund generated: ₹ 1.36 crore /-**

(***fund generated included the seed production from field and horticultural crops)

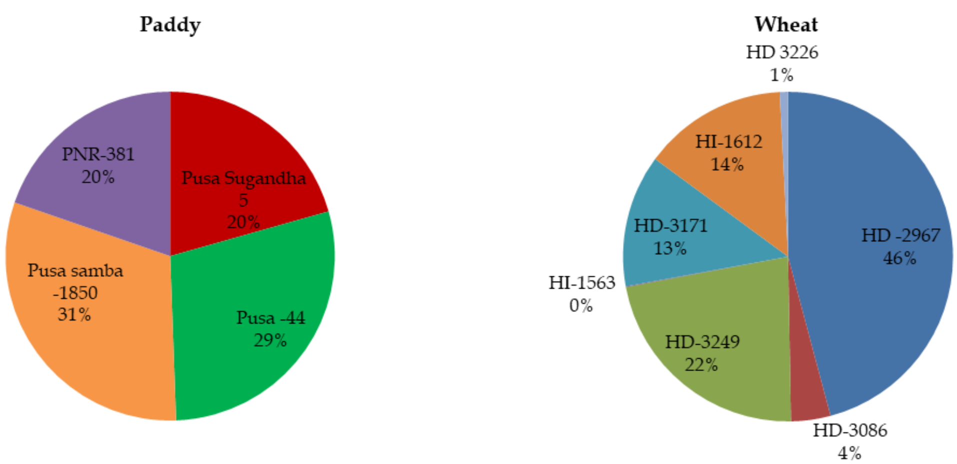


Fig. 1. Contribution of different rice and wheat varieties in total rice and wheat seed production in 2024 and 2023-24

18.1.4 ICAR-IARI, Regional Station, Indore

Crop	Name of Variety	Classes of seeds (tons)				Total seed (tons)	Fund generated (₹ Lakhs)
		NS	BS	IARI Seeds (TFL)			
				At Institute	Under FPSP		
Wheat	HI 1544, HI 1605, HI 1633, HI 1634, HI 1636, HI 1650, HI 1655, HI 8663, HI 8737, HI 8759, HI 8777, HI 8823, HI 8826, HI 8830	12.77	229	3.2	39.6	284.57	165.819

18.1.5 ICAR-IARI, Regional Station, Wellington

Crop	Name of Variety	Classes of seeds (in ton)			
		NS	BS	IARI Seeds /(TFL)	
				At Institute	Under FPSP
Wheat	HW 1098-dicoccum			4.0	

Total Funds generated = ₹ 1.87 lakhs

18.2 SEED PRODUCTION IN HORTICULTURAL CROPS (JANUARY 1 TO DECEMBER 31, 2024)

The production of quality seeds of horticultural crops (vegetables, fruits & flowers) at the Institute farm, Regional Stations and under the Farmer participatory seed production program was carried out. The crop-wise details of the production of various classes of seeds of horticultural crops are given below:

18.2.1 Vegetable Crops

18.2.1.1 Seed Production Unit, ICAR-IARI, New Delhi

The production of quality seeds of 37 varieties of 24 horticultural crops (vegetables & flowers) was 36960.75 kg, which comprised nucleus seeds (133.70 kg), breeder seeds (174.0 kg) and IARI seeds/TFL seeds 36653.05 kg (2601.80 kg & 34051.25 kg at Institute farm and under farmer participatory seed production program, respectively). Crop-wise details of the production of various classes of seed are given below:

Seed production of flower & 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 /(TFL) (kg)		
				At Institute	Under FPSP	
Palak	02	5.0	20.0	167.0	2518.0	2710.0
Amaranth	02	2.0	10.0	256.0	382.0	650.0
Methi	02	5.0	25.0	475.0	2948.0	3453.0
Bottle gourd	02	1.5	25.0	23.0	2227.0	2276.5
Sponge gourd	01	1.0	5.0	2.50	2306.0	2314.5
Cowpea	01	-	-	-	3900.0	3900.0
Turnip	01	1.0	-	52.0	158.0	211.0
Radish	01	5.0	18.0	117.0	3290.0	3430.0

Carrot	02	5.0	18.0	225.0	2109.0	2357.0
Bathua	01	0.2	-	2.8	-	3.0
Vegetable mustard	01	2.0	-	267.0	1077.0	1346.0
Onion	03	1.0	7.00	-	3030.0	3038.0
Brinjal	02	0.5	0.5	15.0	879.0	895.0
Cherry tomato	01	-	-	3.50	-	3.50
Tomato	01	-	0.50	-	600.0	600.5
Cucumber	01	-	-	-	42.0	42.0
Garden pea	01	100.0	-	730.0	2360.0	3190.0
Okra	01	1.0	15.0	2.0	3689.0	3707.0
Marigold	05	0.5	5.0	1.0	427.25	433.75
Sem	01	3.0	-	80.0	-	83.0
Faba bean	01	-	-	-	940.0	940.0
Coriander	01	-	25.0	183.0	710.0	918.0
Muskmelon	01	-	-		23.0	23.0
Bitter gourd	02	-	-	-	436.0	436.0
Total	**37**	**133.70**	**174.0**	**2601.8**	**34051.25**	**36960.75**

18.2.1.2 ICAR-IARI, Regional Station, Karnal

At IARI-Regional Station, Karnal, 2206.6 kg seed of 44 varieties of 19 vegetable crops were produced during *rabi* 2023-24 and summer/*kharif* 2023. A total of 58.4 kg nucleus, 1642.5 kg breeder and 505.7 kg of IARI seed were produced. Crop-wise details of the production of various classes of seed are given below:

Crop	Variety	Production (kg)			Total (kg)
		Nucleus	Breeder	IARI	
Dolichos bean	Pusa Garima	-	5.70	-	5.70
	PEP	-	9.00	-	9.00
	Pusa Lal Sem	-	7.00	-	7.00
Fenugreek	Kasuri	-	62.00	-	62.00
	PEB	-	259.00	62.00	321.00
Bottle gourd	PSPL	1.20	37.00	-	38.20
	Pusa Naveen	-	35.50	6.20	41.70
Onion	Pusa Vrishti	-	--	8.10	8.10
	Pusa Rudhira	-	18.00	-	18.00
	Pusa Asita	-	25.30	-	25.30
Pea	Pusa Prabal	-	-	315.00	315.00
	Bonneville	-	1.90	-	1.90
	Pusa Pragati	4.40	-	67.00	71.40
	Pusa Shree	4.80	11.50	-	16.30
	Arkel	38.00	875.00	-	913.00

Onion	PWR	-	12.50	-	12.50
	Pusa Riddhi	0.95	-	28.80	29.75
	Pusa Red	6.50	46.00	-	52.50
Cowpea	Pusa Komal	-	55.00	-	55.00
	Pusa Sukomal	-	--	7.00	7.00
	Pusa Dharni	-	14.00	-	14.00
Brinjal	Pusa Upkar	-	0.10	-	0.10
Palak	All Green	-	86.00	-	86.00
Ash gourd	Pusa Ujjwal	-	0.35	-	0.35
Bitter gourd	PDM	-	0.70	-	0.70
	Pusa Vishesh	-	7.00	-	7.00
Pumpkin	Pusa Vishwash	0.10	1.40	-	1.50
Longmelon	Pusa Utkarsh	0.15	-	-	0.15
Cucumber	Pusa Uday	0.70	6.20	1.60	8.50
	Pusa Barkha	0.70	0.40	-	1.10
Muskmelon	Pusa Madhuras	0.20	16.10	-	16.30
	Pusa Madhurima	0.15	3.35	-	3.50
	Pusa Kazri	0.25	0.70	-	0.95
Watermelon	Sugarbaby	0.30	11.60	-	11.90
Okra	Pusa Bhindi- 5	-	4.20	-	4.20
	A-4	-	6.80	-	6.80
	Pusa Sawani	-	5.20	-	5.20
	Pusa Lal Bhindi-5	-	8.00	-	8.00
Ridge gourd	Pusa Nasdar	-	10.00	-	10.00
Marigold	Pusa Basanti	-	-	3.10	3.10
	Pusa Narangi	-	-	3.10	3.10
	Pusa Arpita	-	-	1.40	1.40
	Pusa Bahar	-	-	1.10	1.10
	Pusa Deep	-	-	1.30	1.30
Total (kg)		**58.4**	**1642.5**	**505.7**	**2206.6**

**NS-Nucleus seed BS-Breeder Seed, TL- Truthful Label Seed (IARI Seed)

18.2.1.3 ICAR-IARI, Regional Station, Katrain, Himachal Pradesh

Seed production (kg)				**Revenue generated from seed sale (₹ Lakh)**	**Revenue from others (₹ Lakh)**	**Total revenue generated (₹ Lakh)**
Nucleus	**Breeder**	**IARI-TFL**	**Total**			
120.00	40.88	3094.57	3255.45	27.89	4.36	32.25

18.2.2 Fruit Crops

18.2.2.1 Division of Fruit and Horticultural Technology, ICAR-IARI, New Delhi

Crop & variety	Type of planting material	Quantity
Mango		
Amrapali	Grafted plants & scion	1601
Mallika	Grafted plants & scion	1409
Pusa Arunima	Grafted plants & scion	2134
Pusa Surya	Grafted plants & scion	1085
Pusa Lalima	Grafted plants & scion	1958
Pusa Pratibha	Grafted plants & scion	1183
Pusa Shrestha	Grafted plants & scion	626
Pusa Peetamber	Grafted plants & scion	561
Pusa Manohari	Grafted plants & scion	1536
Pusa Deepshikha	Grafted plants & scion	34
Citrus		
Kagzi Kalan	Sapling (Air layered)	381
Pusa Round	Grafted plants	251
Pusa Sharad	Grafted plants	299
Pusa Abhinav	Sapling & Seedling	82
Pusa Arun	Grafted plants	53
Pusa Lemon-1	Sapling & Seedling	05
Grapes		
Pusa Navrang	Saplings/rooted cuttings and cuttings	2164
Pusa Urvashi	Saplings/rooted cuttings and cuttings	--
Pusa Trishar	Saplings/rooted cuttings and cuttings	773
Pusa Aditi	Saplings/rooted cuttings and cuttings	563
Pusa Swarnika	Saplings/rooted cuttings and cuttings	05
Pusa Purple Seedless	Saplings/rooted cuttings and cuttings	17
Guava		
Pusa Aarushi	Saplings (Grafted plants)	265
Pusa Pratiksha	Saplings (Grafted plants)	428
Papaya		
Pusa Nanha	Seedling	715
Pusa Peet	Seedling	342

Funds generated = ₹ 14.564 lakhs

18.2.2.2 ICAR-IARI Regional Station, Karnal

1443 plants of mango (Amrapali, Mallika, Dashehari, Pusa Arunima & other varieties), guava (Allahabad Safeda), lemon (Kagzi Kalan) and papaya (Pusa Nanha) were propagated.

Propagation of fruit crops during 2023-24

S. No.	Crop	Cultivar	Plants propagated
1.	Mango	Amrapali	83
2.	Mango	Mallika	131
3.	Mango	Dashehari	21
4.	Mango	Pusa Arunima	57
5.	Mango	Pusa Surya	111
6.	Mango	Langra	08
7.	Mango	Ramkela	12
8.	Mango	Pusa Shrestha	36
9.	Mango	Pusa Lalima	193
10.	Mango	Pusa Pitamber	18
11.	Mango	Chausa	05
12.	Mango	Pusa Pratibha	23
13.	Mango	Pusa Manohari	02
14.	Mango	Pusa Deepshikha	02
15.	Lemon	Kagzi Kalan	476
16.	Guava	Allahabad Safeda	66
17.	Papaya	Pusa Nanha	199
	Total		**1443**

18.2.2.3 ICAR-IARI, Regional Station, Pusa, Bihar

In 2024, 7967 seedlings of different fruit crops (papaya, mango, litchi, kagzi lime) and varieties were produced and distributed to various stakeholders.

18.2.3 Ornamental Crops

18.2.3.1 Seed Production Unit, ICAR-IARI, New Delhi

Seed production of flower 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 /(TFL) (kg)		
				At Institute	Under FPSP	
Marigold	05	0.5	5.0	1.0	427.25	433.75

18.2.3.2 ICAR-IARI, Regional Station, Karnal

Crop	Variety	Production of seed (kg)			Total (kg)
		Nucleus	Breeder	IARI	
Marigold	Pusa Basanti	-	-	3.10	3.10
	Pusa Narangi	-	-	3.10	3.10
	Pusa Arpita	-	-	1.40	1.40
	Pusa Bahar	-	-	1.10	1.10
	Pusa Deep	-	-	1.30	1.30
	Total (kg)	**0.00**	**0.00**	**10.00**	**10.00**

18.3 DIVISION OF MICROBIOLOGY

Name of service	Name of item	Total (kg/litres)	Fund generated (₹)
Biofertilizers	PUSA Decomposer	17600 packets of Wettable Powder + 450 litres of Liquid Pusa Decomposer + 750 kits of capsule Pusa Decomposer	23,31,250
	PUSA Mycorrhiza	3682 Kg	2,76,150
	BioPhos (solid and liquid)	48.40 Kg + 277 .85 Litres	4,28,875
	BioPotash (solid and liquid)	16.200 Kg + 276.45 Litres	4,18,725
	BioZinc (solid and liquid)	8 kg + 296.50 Litres	4,46,750
	Rhizobium	46 kg	11,500
	PUSA Sampoorna	94.70 litres	1,42,050
		Total	**₹ 40.55 lakhs**

18.4 PUSA BEEJ SALE PORTAL

Pusa Beej Sale Portal (https://pusabeej.iari.res.in/index.php) is a vibrant online marketplace where our farmers and gardening enthusiasts can explore and buy a diverse range of seeds. Our platform, developed using Core PHP and backed by a robust MySQL database, offers an intuitive shopping experience. The website boasts a clean and user-friendly interface. Farmers can easily navigate through categories, filter by crop and plant type and find detailed product descriptions. Our e-commerce portal prioritizes security. All transactions are encrypted using industry-standard protocols. Registered users can add items to their shopping cart and view their orders with real-time stock updates. Also developed the dynamic online stock databases for seeds availability, price of seeds, sales of seeds, package and practices, etc., which have been integrated with the sales portal. This portal was launched by the Director, ICAR-IARI, New Delhi on February 16, 2024.

19. MISCELLANY

Scientific Meetings Organized	
Workshops	46
Seminars	10
Summer/Winter School	6
Farmers' day (s)	63
Others	45
Total	**170**
Participation of Personnel in Scientific Meetings	
India	
Seminars	151
Scientific meetings	241
Workshops	113
Symposia	74
Others	77
Total	**656**
Abroad	
Seminars	2
Scientific meetings	12
Workshops	13
Symposia	7
Others	4
Total	**38**

III. Ongoing Projects at IARI as on 31.12.2024

(A) Research Projects: 210

School of Crop Improvement	66
School of Plant Protection	32
School of Basic Science	25
School of Natural Resource Management	47
School of Social Science	13
School of Horticultural Science	26
KVK, Shikohpur	01

(B) Number of on-going contract research/ consultancy/contract service projects: 25

School of Crop Improvement	03
School of Plant Protection	02
School of Basic Sciences	01
School of Natural Resource Management	15
School of Social Sciences	-
School of Horticultural Sciences	04

List of sanctioned Contract Research Projects in 2024

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanctioned amount
1.	Dr. P. K. Upadhyay, Scientist, Division of Agronomy	Insight and Field validation of nano fertilizer in wheat	Indian Farmer Fertilizer Cooperative Limited, New Delhi	21.03.2024	21.03.2025	₹ 34.96 lakh
2.	Dr. Rajiv Kumar Singh, Principal Scientist, Division of Agronomy	Long term evaluation of POLY-4 (Polyhalite) for enhanced productivity resource use efficiency and sustainability of Rice-Wheat system under trans IGP	Anglo American Crop Nutrient India Private Limited	22.03.2024	22.03.2027	₹ 70.514 lakh

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanctioned amount
3.	Dr. Ram Asrey, Principal Scientist, Division of Food Science & Post Harvest Technology	Impact of Bensulf SUPERFAST (90% Sulphur) on Bio-efficacy & storage quality of Onion	Mahadhan Agri Tech Ltd	15.04.2024	14.04.2025	₹ 11.99 lakh
4.	Dr. Pankaj, Head, Division of Nematology	Evaluation of ME5382 2% GR against rice root-knot nematode Meloidogynegraminicola	Arysta Life Science Ltd	19.04.2024	19.10.2024	₹ 12.61 lakh
5.	Dr. B.S. Tomar, Head, Division of Vegetable Science	Performance evaluation of hybrids of cucumber, Watermelon and Muskmelon for growth and yield.	M/S Chamunda Agro Private Limited	22.04.2024	22.10.2024	₹ 6.30 lakh
6.	Dr. Arti Bhatia, Principal Scientist, Division of Environment Science	Studies on greenhouse gas emission in rice-wheat and sugarcane-wheat cropping system under different agri-management practices	Varaha Climage Ag Pvt. Ltd	25.06.2024	24.06.2027	₹ 70.95 lakh
7.	Dr. Dinesh Kumar, Principal Scientist, Division of Agronomy	Agronomic field evaluation of nano-DAP in babycorn and mungbean crops	Rashtriya Chemical Fertilizer	07.06.2024	06.6.2025	₹ 9.99 lakh
8.	Dr. Sanjay Singh Rathore, Head, Division of Agronomy	Experimentation on Agronomic efficacy of TSP in predominant cropping systems in diverse locations for enhanced productivity, economics and phosphorous use efficiency in India	OCP Support Services Private Limited	24.07.2024	23.07.2027	₹ 50.51 lakh
9	Dr. Rajiv Kumar Singh, Principal Scientist, Division of Agronomy	Evaluation of SYL, Florastart and Tetrapotassium Pyrophospate on gowth, productivity and profitability of *Kharif* Cucumber (*Cucumis Sativus* L.)	Tradecorp Rovensa India Private Limited	05.08.2024	04.08.2025	₹ 15.34 lakh

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanc-tioned amount
10	Dr. Shalini Gaur Rudra, Senior Scientist, Division of FS & PHT	Development of Convenient and functional Snack from Sweet Corn	Corn Troopers Limited	12.09.2024	12.12.2024	₹ 3.06 lakh
11	Dr. Bhupinder Singh, Principal Scientist, Division of Environment Science	Characterization of iron ore tailing and assessing its suitability for agricultural application	Arcelor Mittal Nippon Steel India Limited	20.09.2024	20.12.2025	₹ 26.52 lakh
12	Dr. Dinesh Kumar, Principal Scientist, Division of Agronomy	Optimizing application of sulphur coated urea in rice-wheat cropping system for enhanced nitrogen use efficiency and profitability	Rashtriya Chemical Fertilizer	26.09.2024	25.09.2026	₹ 23.60 lakh
13	Dr. Arti Bhatia, Principal Scientist, Division of Environment Science	Quantifying Rice Greenhouse Gas Emissions (Queri): Impact of Water Management and Sowing Techniques in Telangana and Punjab, India	Mitti Agri Carbon India Private Limited	15.10.2024	14.10.2025	₹ 25.00 lakh
14	Dr. Seema Sangwan, Principal Scientist, Division of Microbiology	Elevating bio-availability and potash use efficiency using mycorrhizal formulation in maize-wheat cropping system	Indian Potash Limited	15.10.2024	14.10.2027	₹ 49.94 lakh
15	Dr. Awani Kumar Singh, Principal Scientist, Centre for Protected Cultivation Technology	Evaluation of Calcium Magnesium Carbonate on Growth, Yield and Productivity in Okra Crop	Oceana Minerals Asia-Pacific PTE Ltd	Ex-post Facto	30.11.2024	₹ 13.61 lakh
16	Dr. Awani Kumar Singh, Principal Scientist, Centre for Protected Cultivation Technology	Studies on Response of SEFA Fertilizer on Crop Growth, Yield and Crop Economics of Tomato and Capsicum under Protected and Open Conditions	Anglo American Crop Nutrient India Private Limited	26.11.2024	25.11.2026	₹ 40.85 lakh
17	Dr. Veda Krishnan, Senior Scientist, Division of Biochemistry	Mycoceuticals-based product development and their therapeutic validation using in-vitro assays	Funguyz Foods INC	05.12.2024	04.12.2025	₹ 9.85 lakh

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanc-tioned amount
18	Dr. Lakshman Prasad, Principal Scientist, Division of Plant Pathology	Eco-friendly and sustainable management of important diseases of mustard and paddy using Trichoderma asperellum under-hot humid conditions	Mahamaya Lifesciences Private Limited	19.12.2024	18.12.2026	₹ 19.99 lakh
19	Dr. Yashbir Singh Shivay Principal Scientist Division of Agronomy	Evaluation of Asaava&Somrith in rice and wheat crops	Virentiatech Pvt Limited	Ex-post Facto	31.12.2024	₹ 25.53 lakh

List of sanctioned Consultancy Projects in 2024

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanctioned Amount
1.	Dr. M. C. Meena, Senior Scientist, Division of Soil Science and Agricultural Chemistry	Demonstration of the efficacy of FOM and LFOM on crop productivity and soil health under different cropping systems	Verbio India Private Limited	23.10.2024	22.10.2025	₹ 11.80

List of sanctioned Contract Service Projects in 2024

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanctioned Amount
1.	Dr. Y.V. Singh, Principal Scientist, Division of Microbiology	Agronomic field studies on OrgoProm-Phosphate Rich Organic Manure (PROM) Fertilizer on wheat, rice, maize and tomatoes	ORGO SCIENCE, Surat, Gujarat	Ex-Post-facto	06.05.2024	₹ 6.27 lakh
2.	Dr. Santosh Watpade, Senior Scientist, Regional Station, Amartara Cottage, Shimla	Evaluation of Bio efficacy of Triflumizole 15% EC against powdery mildew and scab disease of Apple	Mahindra Summit Agri science Ltd	28.05.2024	27.05.2026	₹ 13.64 lakh
3	Dr. Santosh Watpade, Senior Scientist, Regional Station, Amartara Cottage, Shimla	Evaluation of PIF 320 5% SC against apple diseases	PI Industries Limited	25.06.2024	24.06.2026	₹ 21.35 lakh

4	Dr. Santosh Watpade, Senior Scientist, Regional Station, Amartara Cottage, Shimla	Bio-efficacy of Picoxystrobin 7.05% + Propiconazole11.71% w/w (Picoxystrobin 7.5% + Propiconazole 12.5% w/v SC) against foliar disease of apple	Corteva Agri science Pvt. Ltd	24.07.2024	23.07.2026	₹ 16.47 lakh

List of sanctioned Collaborative Projects under CSR fund in 2024

S. No.	Name of PI	Title of Project	Name of funding agency	Date of Start	Date of End	Sanctioned Amount
1.	Dr. Sanjay Singh Rathore, Head, Division of Agronomy	Evaluation, outreach and up-scaling of fermented organic manures for sustainably enhancing productivity and reducing environmental foot-prints of predominant cropping systems in India	Maruti Suzuki India Limited	25.11.2024 as per Signed MoU	24.11.2029	₹ 4086.68 Lakhs

IV. All India Coordinated Research Projects in Operation during the year January 1 - December 31, 2024

Sl. No.	Name of the project	Division
Project Head Quarters		
1.	All India Coordinated Project on Plant Parasitic Nematodes with integrated Approach for their control.	Division of Nematology
2.	All India Network Project on Pesticide Residues	Division of Agricultural Chemicals
3.	All India Coordinated Research Project on Honey Bees and Pollinators	Division of Entomology
Centers functioning at IARI under AICRP		
1.	All India Network Project on Soil Biodiversity - Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)	Division of Microbiology
2.	All India Coordinated Project on Long-Term Fertilizer Experiments	Division of Soil Science & Agricultural Chemistry
3.	All India Coordinated Research Project on Soil Test Crop Response Correlations	Division of Soil Science & Agricultural Chemistry
4.	All India Coordinated Research Project on Floriculture	Division of Floriculture & Landscaping
5.	All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries	Division of Environmental Sciences
6.	All India Coordinated Research Project on Soybean	Division of Genetics
7.	All India Coordinated Research Project on Fruits	Division of Fruits & Horticultural Technology

8.	All India Coordinated Research Project on N.S.P.(Crops)	Division of Seed Science & Technology and IARI RS, Karnal
9.	All India Coordinated Research Project on Mustard	Division of Genetics
10.	All India Coordinated Research Project on Wheat	Division of Genetics
11.	All India Coordinated Research Project on Rice	Division of Genetics
12.	All India Coordinated Research Project on Pulses	Division of Genetics
13.	All India Coordinated Research Project on Vegetable	Division of Vegetable Science
14.	AINP on Whitegrubs and other Soil Arthropods (AINPWOSA)	Division of Entomology
15.	Front Line Demonstration on Pearl Millet – AICRP Pearl Millet under National Food Security Mission (NFSM)	K.V.K. Shikohpur, Gurgaon
16.	All India Coordinated Research Project on Vegetable Crops	IARI RS, Katrain
17.	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
18.	All India Coordinated Research Project on Ergonomics & Safety in Agriculture (ESA)	Division of Agril. Engineering
19.	All India Coordinated Research Project on Pearl Millet	Division of Agronomy
20.	All India Coordinated Research Project on Rapeseed-Mustard	Division of Agronomy
21.	All India Network Research Program on Onion & Garlic (AINRPOG)	Division of Vegetable Science
22.	Engineering interventions for enhanced nutritional security of pearl millet during milling and storage under AICRP on Pearl Millet	Division of Agricultural Engineering
23.	All India Coordinated Research Project on Fruits-PAPAYA	IARI Regional Station, Pune
24.	AICRP on Rapeseed Mustard Research (Testing Component)	Division of Genetics
25.	AICRP on *Rabi* Pulses	Division of Microbiology

V. Resource Generation

1) Consultancy & other services

Consultancy services: ₹ 5,90,000/-

Contract research: ₹ 10,08, 86,970/-

Contract service: ₹ 1,31,58,133/-

Training:

Total (A): ₹ 11,46,35,103/-

2) Revolving fund

Sale Proceeds Revenue Generated

(a) Seed: ₹ 7, 36, 14,055/-

(b) Commercialization:

(c) Prototype manufacturing:

Total (B): ₹ 7,36,14055/-

3) The Graduate School receipt

Training Programme

(a) Foreigners & Indians: Nil

M.Sc./Ph.D. Program

(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: ₹ **6,42,65,823/-**

(d) Receipt deposited in Director's Account No. 305/17 for Theses Evaluation, PDC & Misc. (does not include refund of IARI scholarship by students): ₹ 4,28,61,873/-

Total (C): ₹ 10,71,27,696/-

Grand Total (A+B+C): ₹11,46,35,103.00+ ₹7,36,14,055.00+ ₹ 10,71,27,696.00 = ₹ 29,53,76,854.00

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, 2024 to December 31, 2024):

- Revision of guidelines for IARI Adjunct Professors and ratification of Director's nominations of renowned scientists as Adjunct Professors.
- Revision of guidelines for the institution of divisional-level Gold Medal Awards for students and approval of the two proposals for instituting divisional-level awards.
- Approval of the proposal for students to startup scheme and IARI-Industry Doctoral Fellowship scheme.
- Ratification of rules for examination and evaluation and nomination of Controller of Examination.
- Introduction of ICAR-IIVR, Varanasi as IARI hub.
- Revision in guidelines of IARI M.Sc./M.Tech. and Ph.D. Merit Medal guidelines.
- Implementation of Sixth Deans' Committee recommendations for four UG disciplines as per NEP-2020.
- Implementation of the Study in India (SII) program in ICAR-IARI.
- Introduction of new courses and course curricula for the ANASTU-IARI Joint Degree program.
- Revision in guidelines for allotment of guides for Master and Doctoral students.

IARI Internship training program

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 (Biotech/Bioinformatics) degree programs on a 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 broaden their horizons and motivate them to take up agricultural research as one of their career options.

Year	No. of persons joined/ completed an internship at IARI	Total Income Generated (₹ in Lakh)
2024	68	11.68

IRC-I MEETINGS & IRC-II MEETINGS (2024)

The Institute Research Council (IRC-I) – 2023-24 meetings were held from June 14, 2024 to August 23, 2024 (with intermittent gaps) under the Chairpersonship of Dr. T.R. Sharma, Director, ICAR-IARI. In this, the individual Scientists made presentations on their achievements during the period as PI/Co-PI. The Institute Research Council (IRC-II) - 2023-24 meetings of the School of Crop Improvement (03.12.2024 to 04.12.2024), School of Social Science (06.12.2024), School of Basic Sciences (10.12.2024) and School of Crop Protection (12.12.2024) were held. In this, the Coordinator of the respective school presented the Action Taken Report of the recommendations of IRC-II (2022-23). This was followed by the project-wise presentations by the PIs of the In-house research projects and Flagship programs. Eminent Resource Persons were invited to the IRC-II meetings and offered valuable and critical inputs for further improvement and strengthening of the research programs of the Institute.

Concluding remarks by Joint Director (Research) at IRC-II meeting

IRC-II meeting of Division of Crop Improvement

S. No.	Details of Visit	Date of Visit
1.	Visit of 38th Batch of Indian Foreign Service Trainees, Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs	March 14, 2024
2.	Visit of Officials of D1 Tech Global Corporation Inc., Headquartered in Vancouver, Canada	March 19, 2024
3.	Visit of 71st PCFD program from Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs	April 30, 2024
4.	Visit of Dr Lee Junwon, Chairman, Korea FAO Association & Hon Regional Representative for Far East Regional Office (FERO) of AARDO	May 01, 2024
5.	Visit of Dr. Brent Wells, USAID & Ms. Kelly Robbins & Ms Lina Stankute-Alexander, PEER program, USA	May 14, 2024
6.	Visit of CIKS, UKZN, Durban, South African Delegation	July 25, 2024
7.	Visit of Togo Delegation	August 19, 2024
8.	Visit of African Development Bank Delegation	August 23, 2024
9.	Visit of delegation of 77th Edition of Know India Programme (KIP), Ministry of External Affairs, GoI	September 20, 2024
10.	Visit of Ohio State University Delegation	October 18, 2024
11.	Visit of German Delegation led by Ms Bettina Stark-Watzinger –Minister, Federal Ministry of Education and Research (BMBF), Germany	October 24, 2024
12.	Visit from SSIFS for the Trainee diplomats of Rwanda, Libya and South Sudan	December 16, 2024
13.	Visit of Media delegation from East & Southern Africa	December 16, 2024

Visit of 38th Batch of Indian Foreign Service Trainees, Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs on March 14, 2024

Visit of Officials of D1 Tech Global Corporation Inc., Vancouver, Canada on March 19, 2024

Visit of 71st PCFD program from Sushma Swaraj Institute of Foreign Service, Ministry of External Affairs on April 30, 2024

Visit of Dr Lee Junwon, Chairman, Korea FAO Association & Hon Regional Representative for Far East Regional Office (FERO) of AARDO, on May 01, 2024

Visit of Dr. Brent Wells, USAID & Ms. Kelly Robbins & Ms Lina Stankute-Alexander, PEER program, USA on May 14, 2024

Visit of CIKS, UKZN, Durban, South African Delegation to IARI on July 25, 2024

Visit of Togo Delegation to IARI on August 19, 2024

Visit of African Development Bank Delegation to IARI on August 23, 2024

Visit of delegation of 77th Edition of Know India Programme (KIP), Ministry of External Affairs, GoI to IARI on September 20, 2024

Visit of Ohio State University Delegation to IARI, New Delhi On October 18, 2024

Visit of German Delegation led by Ms Bettina Stark-Watzinger –Minister, Federal Ministry of Education and Research (BMBF), Germany to IARI, New Delhi on October 24, 2024

Visit from SSIFS for the Trainee diplomats of Rwanda, Libya and South Sudan to ICAR-IARI, New Delhi on December 16, 2024

Visit of Media delegation from East & Southern Africa to IARI, New Delhi on December 16, 2024

Appendix 1
Members of Board of Management of IARI
(As on 31.12.2024)

Chairman

Dr. Ch. Srinivasa Rao
Director, ICAR- IARI, New Delhi

Members

Dr. Viswanathan C.
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, ICAR-IVRI, Izzatnagar, Bareilly (U.P.)

Sh. Badri Narayan
49-Gayatri 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, ICAR-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, HAU, Hisar

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

Sh. Dharmender Singh Lakra
D-60-A, Block-D, Swarn Park, Mundka, District- West Delhi-110 041

Dr. Payal Mago
Principal,
Shaheed Rajguru College of Applied Science for Women
University of Delhi – 110 096

Member - Secretary

Sh. Rajeev Lal
Joint Director (Admn), ICAR-IARI

Appendix 2
Members of Research Advisory Committee of IARI
(As on 31.12.2024)

Chairman
Prof. (Dr.) Sudhir Kumar Sopory
Emeritus Senior Scientist,
International Centre for Genetic Engineering and Biotechnology,
New Delhi

Members
Dr. Surinder Singh Banga
DAE Raja Ramanna Fellow and Professor (Honorary Adjunct),
Department of Plant Breeding and Genetics
PAU, Ludhiana, Punjab

Dr. Kailash Chander Bansal
Former Director
ICAR-NBPGR, New Delhi

Dr. P.S. Naik
Former Director, ICAR-IIVR, Varanasi

Dr. M.R. Dinesh
Former Director, ICAR-IIHR, Bengaluru

Dr. Biswapati Mandal
Former Pro-Vice Chancellor,
BCKV, West Bengal

Dr. Vijay Paul Sharma
Chairman, Commission for Agricultural Costs and Prices (CACP), MoA&FW, GoI, New Delhi

Dr. Surinder Tikko
Co-founder and Director Research,
Breeding and Development,
Hyderabad

Prof. Appa Rao Podide,
Former Vice Chancellor,
University of Hyderabad
Senior Professor, Department of Plant Sciences,
School of Life Sciences, University of Hyderabad, Telangana

Sh. Dharmender Singh Lakra
D-60-A, Block-D, Swarn Park,
Mundka, Dist. West Delhi-110 041

Dr. Payal Mago
Principal
Shaheed Rajguru College of Applied Science for Women,
University of Delhi - 110096

Dr. Ch. Srinivasa Rao
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 31.12.2024)

Dr. Ch. Srinivasa Rao Director		Chairman
Dr. Anupama Singh Jt. Director (Edn.) & Dean		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. R.C. Bhattacharya Director, ICAR-NIPB, New Delhi Dr. C.R. Mehta Director, ICAR-CIAE, Bhopal; Nodal Coordinator, ICAR-IARI Bhopal hub Dr. T.K. Behera 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 Kolkata 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. Ratan Tiwari 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.)	Member	Dr. C. Viswanathan
Joint Director (Extn.)	Member	Dr. R.N. Padaria
Project Director, Water Technology Centre	Member	Dr. P.S. Brahmanand
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. A.K. Singh Former Vice Chancellor RVSKVV, Gwalior, M.P. Dr. A.K. Singh Vice Chancellor Rani Lakshmi Bai Central Agricultural University, Jhansi, U.P.
Associate Dean (UG Affairs)	Member	Dr. Harshawardhan Choudhary
Associate Dean (PG Affairs)	Member	Dr. Atul Kumar

Associate Dean (International Affairs)	Member	Dr. K.K. Vinod
Associate Dean (Hubs/Off Campuses and Sister Institutes/constituent colleges) and Professor, SST	Member	Dr. (Ms.) Monika A. Joshi
Associate Dean (Student Opportunities, Outreach and New Initiatives)	Member	Dr. M.R. Khan
Associate Dean (Placement Cell)	Member	Dr. (Ms.) Arti Bhatia
Controller of Examinations	Member	Dr. Akshay Talukdar
Professors of Teaching Disciplines at IARI	Members	Dr. (Ms.) Suman Gupta Professor, Agricultural Chemicals Dr. Pramod Kumar 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. (Ms.) Sarika Professor, Bioinformatics Dr. Alka Arora Professor, Computer Application Dr. Subramaniam S. Professor, Entomology Dr. D.K. Sharma Professor, Environmental Science Dr. K.P. Singh Professor, Floriculture and Landscaping

		Dr. Radha Mohan Sharma Professor, Fruit Science Dr. H.K. Dikshit Professor, Genetics and Plant Breeding Dr. Rajeev Kaushik Professor, Microbiology Dr. (Ms.) Jasdeep Chatrath Padaria 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 Management Dr. T.J. Purakayastha Professor, Soil Science Dr. R.K. Yadav Professor, Vegetable Science Dr. (Ms.) Susama Sudhishri Professor, Water Science & Technology
Comptroller	Member	Shri Avesh Yadav
Elected Faculty Representatives	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. Sudhir Bhinchar President PGSSU
		Mr. B. Sharatchandra Students' Representative to the Academic Council
Senior Registrar & Joint Director (Admn.)	Member-Secretary	Shri Rajeev Lal

Appendix 4

Members of Extension Council of IARI

(As on 31.12.2024)

Chairman
Dr. Ch. Srinivasa Rao
Director, ICAR-IARI, New Delhi

Five Managerial Scientists representing six schools
Dr. B.S. Tomar, Head, Vegetables Sciences, School Coordinator, Horticultural Sciences

Dr. Pankaj, Head, Nematology and School Coordinator, Plant Protection

Dr. Gopala Krishanan S, Head, Genetics and School Coordinator, Crop Improvement

Dr. Renu Pandey, Head, Plant Physiology & School Coordinator, Basic Sciences

Dr. S.S. Rathore, Head, Agronomy, ICAR-IARI, New Delhi

Five Scientists representative of IARI
Dr. O.P. Awasthi, Head, Fruits and Horticultural Technology, IARI

Dr. Radha Prasanna, Head, Microbiology, IARI

Dr. A. K. Singh, Incharge, CATAT

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. Shiv K. Yadav, Head, IARI Regional Station Karnal

One Representative of Deptt. of Agriculture, MoA
Dr. P.K. Singh, Agril. Commissioner, MOA & FW

Two 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, Izatnagar, Bareilly

Director (Farm Information), Directorate of Extension, MOA
Dr. Shailesh Kumar Mishra, Director (Farm Information Unit) Directorate of Extension, Krishi Vistar Sadan, IARI Campus New Delhi

Dy. Director General (Agricultural Education), ICAR

Dr. R.N. Padaria, Joint Director (Extension), ICAR-IARI, New Delhi Dr. Viswanathan C., Joint Director (Research), ICAR-IARI, New Delhi

Sh. Rajeev Lal, Joint Director (Admn.), ICAR-IARI, New Delhi

Sh. Avesh Yadav, Comptroller, ICAR-IARI, New Delhi

Head, Agricultural Extension, IARI, New Delhi
Dr. Satyapriya, Head, Ag. Extension, IARI, New Delhi (Member-Secretary)

Mr. Rajesh Aggarwal, Managing Director, (Agro-Industry Representative) Insecticide 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 (The Additional Director General Representative)
All India Radio, Akashwani Bhawan

Farmers
Shri. Pritam Singh, Panipat, Progressive Farmer, Haryana

Shri Sukhjeet Singh, Progressive Farmer Sangrur, Punjab

Appendix 5

Members of Institute Research Council (IRC)

(As on 31.12.2024)

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 31.12.2024)

Chairman
Dr. Ch. Srinivasa Rao
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, IARI-Regional Station, Shimla

Comptroller, ICAR-IARI, New Delhi

Secretary (Official Side)
Joint Director (Adm.), ICAR-IARI, New Delhi

Members of the Staff Side (Elected)
Sh. Yogesh Kumar
AAO, Division of Agril. Extension, Secretary (Staff side), IARI, New Delhi

Sh. Pankaj Kumar
Assistant, Directorate

Sh. Ashwani Kumar
Assistant, Directorate

Sh. Raj Kumar
Assistant, Directorate

Sh. Sunil Kumar
Technical Assistant, Division of Agril. Engineering

Sh. Ganesh Rai
Technical Officer, Division of Entomology

Sh. Rakesh Kumar
Technical Assistant, Division of Agril. Engineering

Sh. Bhavesh Kumar
Technical Assistant, Division of Agronomy

Sh. Raj Pal
SSS, Directorate

Sh. Shashi Kant Kamat
SSS, Division of Agril. Physics

Sh. Raju
SSS, Directorate

Appendix 7

Members of Grievance Committee of IARI

(As on 31.12.2024)

Chairman
Dr. P.S. Brahmanand
PD, WTC

Members (Official Side)
Dr. Sanjay Singh Rathore
Head, Division of Agronomy

Sh. A.K. Soni
Chief Admin. Officer, Directorate

Sh. Yogesh Kadian
Sr. Admn. Officer, Directorate

Members of the Staff Side (Elected)
Dr. Indu Chopra, Scientist, Division of SS&AC

Ms. Kanya
Technical Assistant, Division of Plant Physiology

Sh. B. S. Rawat
Private Secretary, Publication Unit

Sh. B.N. Rai
SSS, FHT

Member-Secretary
Smt. Vinita
AAO, IMC

Appendix 8

Personnel

(As on 31.12.2024)

Director
Dr. Cherukumalli Srinivasa Rao

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. Rajeev Lal

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. Suman Gupta

Network Coordinator (Pesticide Residue)
Dr. Vandana Tripathi

Agricultural Economics
Head
Dr. Alka Singh
Professor
Dr. Pramod Kumar

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. Subramanian S

Floriculture and Landscaping
Head
Dr. Markandey Singh
Professor
Dr. K.P. Singh

Fruits and Horticultural Technology
Head
Dr. O.P. Awasthi
Professor
Dr. R.M. Sharma

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. Aundy Kumar

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. A.K. Singh

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. J.P. Sinha

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
Coordinator (Library Services)
Dr. Dinesh Kumar Sharma

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. Sujit Sarkar

IARI Regional Station, Karnal
Head
Dr. Shiv Kumar Yadav

IARI Regional Station, Katrain
Head
Dr. Chander Prakash

IARI Regional Station, Pune
Head
Dr. Anil Khar

IARI Regional Station, Pusa
Incharge (Acting)
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


Prof. M S SWAMINATHAN LIBRARY


17-22 मार्च, 2025
SIXTY THIRD
CONVOCATION
THE GRADUATE SCHOOL
ICAR - Indian Agricultural
Research Institute, New Delhi
March 17-22, 2025

iari.res.in