ICAR- INDIAN AGRICULTURAL RESEARCH INSTITUTE

REPORT OF THE QUINQUENNIAL REVIEW TEAM

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI 110012

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2017-2022

2023

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ICAR-Indian Agricultural Research Institute, New Delhi
Report of the Quinquennial Review Team 2017-2022

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PREFACE

The Quinquennial Review Team (QRT) expresses its gratitude to ICAR for expressing its trust in the committee to conduct the review of the work of IARI, New Delhi vide its letter F. No. CS/16/08/2009-IA-IV (e.no-42673) dated June 5, 2023. The QRT visited different divisions, facilities, a number of Regional Stations of IARI including new campuses at Assam and Jharkhand, and other institutes, RPCAU, Pusa (Bihar) and IIAB, Ranchi (Jharkhand). QRT interacted with scientists, faculty members, administrative and finance officials, technical & skilled supporting staff and a few farmers and entrepreneurs. The scientific, technical, administrative staff and finance wing provided all the information and necessary inputs. We are very thankful to Dr. A. K. Singh, Director, IARI, New Delhi for extending all possible support to the committee in conducting the review. The QRT is also thankful to the Member Secretary of the committee, Dr. Viswanathan C, Joint Director (Research), IARI, New Delhi, who did a commendable job in organizing the visits, ensuring logistics and providing all the inputs for the review process. The assistance provided by Dr. Pramod Kumar, Scientist In-Charge, PME Cell is thankfully acknowledged. The committee tried its best to look into the foreseeable future in existing and emerging national and global scenarios. We have come to logical conclusion and made certain recommendation with a view to ensure that if accepted, appreciated and implemented, IARI would be able to do yet better job to have its leadership role not only in the national context, but also emerge as a major player in developing quality human resource and technologies to remain globally competitive.

Members:

(Manoj Prasad) **(K. K. Narayanan)** **(P. K. Joshi)**

(S. N. Puri) **(J. C. Katyal)** **(S. S. Baghel)**

(Viswanathan C) **(Dr. Mangala Rai)**

EXECUTIVE SUMMARY

The Indian Council of Agricultural Research (ICAR) constituted a Quinquennial Review Team (QRT) with Dr. Mangala Rai, Former Secretary, DARE and DG, ICAR as Chairman to review the progress of research achievements made by the ICAR-Indian Agricultural Research Institute (IARI) during 2017-2022. The QRT consists of Dr. S. S. Baghel, Former VC, CAU, Imphal and AAU, Jorhat; Dr S. N. Puri, Former VC, MPKV Rahuri and CAU, Imphal; Dr. J. C. Katyal, Former DDG (Edn), ICAR and Former VC, CCSHAU, Hisar; Dr. P. K. Joshi, Former Director, NIAP, New Delhi and Director, South Asia – IFPRI; Dr. K. K. Narayanan, Founder and Director, Sthayika Seeds Private Limited, Bengaluru; Dr. Manoj Prasad, Staff Scientist VII, NIPGR, New Delhi as members and Dr. Viswanathan Chinnusamy, Joint Director (Research), ICAR-IARI, as member secretary.

The QRT conducted several meetings between 4th July and 7th December 2023 at IARI, New Delhi and its regional stations at Indore, Wellington and Karnal, and IARI-Assam and IARI-Jharkhand. The Director, School coordinators and HoDs presented the significant achievements made during the reporting period. The QRT also met scientific, technical, administrative and finance staff, students, farmers, and other stakeholders. After the thorough assessment assessed the action taken report (ATR) on the recommendations of the previous QRT, background information report provided the IARI, available human resource, physical infrastructure and financial resources and future needs of the nation, the QRT came out with the recommendations.

The Institute functions through a network of 18 discipline-based divisions, one project directorate, and seven service units in New Delhi, eight regional stations and two regional centres. It also has a Krishi Vigyan Kendra at Shikohpur. These divisions, centres and regional stations are organized into six schools namely, 1) School of Crop Improvement, 2) School of Horticultural Science, 3) School of Basic Sciences, 4) School of Plant Protection, 5) School of Natural Resources Management and 6) School of Social Science.

During 2017-22, the School of Crop Improvement developed and released 71 improved crop cultivars (17 hybrids and 54 varieties) through integrated conventional and genomics-assisted breeding for the benefit of the farmers. It includes wheat (22), rice (10), maize (16), pearl millet (1), chickpea (6), pigeon pea (5), lentil (5), mung bean

(3), Indian mustard (2) and soybean (1). Of these, 25 varieties were biofortified with different nutrients/ free from anti nutritional factors, while 23 of these improved cultivars were developed through molecular marker assisted breeding for incorporation of resistance to biotic/ abiotic stresses or improvement of nutritional quality. Noteworthy varieties which made significant impact in farmers' field include short duration Basmati rice variety, Pusa Basmati 1692 (PB 1692); bacterial blight and blast resistant Basmati varieties namely, PB 1847, PB 1885, PB 1886; the country's first herbicide tolerant rice cultivars suitable for water saving direct seeded conditions namely PB 1979, PB 1985 and PB 1882; HD 3226 and HI 8759 in wheat; Pusa Mustard 32 and Pusa Double Zero Mustard 32 with low anti-nutritional factors like erucic acid and glucosinolates. Breeder seeds to the tune of 3158 tons and 3504 tons truthfully labelled seeds were produced and supplied.

IARI-bred Pusa Basmati rice varieties namely Pusa Basmati 1121, Pusa Basmati 1718, Pusa Basmati 1509, and Pusa Basmati 6 occupy > 95% of the Basmati rice area in the country. Annual export earnings from IARI developed Basmati rice varieties is about ₹ 30,000 crores. The economic surplus generated by PB 1121 and PB 1509 together is about ₹ 53,800 crores. IARI-bred wheat varieties namely HD 2967, HD 3086 and HD 3226 are cultivated in > 12 mha, thereby contributing 50 mt of grains of wheat to nation's granary. The economic surplus generated by HD 2967 and HD 3086 together is about ₹ 98,425 crores. The mustard varieties developed by IARI contributes to about 35% of the breeder seed indent. The mustard variety, Pusa Mustard 25, generated an annual average total income of ₹ 2919 crores during triennium ending 2018-19 and the producer's surplus is ₹ 1499 crore and consumers surplus is ₹ 1420 crores.

School of Horticultural Science released 55 cultivars of vegetables, fruits and flowers during this period. Some important vegetable cultivars released includes Pusa Parthenocarpic Cucumber 6; gynoecy based bitter gourd Pusa Hybrid 6; self-incompatibility-based cauliflower Hybrid 101; anthocyanin enriched varieties namely, Pusa Purple cauliflower, Pusa Lal Bhindi 1, and Pusa Red Cabbage Hybrid 1. These varieties and hybrids were licensed to 20 seed companies. In fruit crops, export quality mango hybrids, Pusa Lalima, Pusa Deepshikha, Pusa Shreshtha and Pusa Pratibha, and more than 12,500 grafted plants/ scion sticks of mango hybrids were supplied to the farmers, and licensed four private nurseries. In flowers, two marigold varieties, Pusa Bahar and Pusa Deep have been released which is gaining popularity among farmers.

The School of Basic Sciences made significant progress in unravelling the plant processes, pathways and genes for improving resource use efficiency, quality, stress tolerance and yield of crops. A state-of-the art plant phenomics facility has been established to bridge the phenotype-genotype gap. Nocturnal transpiration was identified as significant contributor of total water use in rice and wheat, and for improving WUE minimization of nocturnal transpiration is suggested. CRISPR/Cas9 genome editing was employed to mutate Drought and Salt Tolerance (*DST*) gene in the rice variety, MTU 1010 and SDN1 mutants with enhanced drought and salt tolerance and high yield were developed. IARI has also played a key role in providing inputs for developing policy guidelines for genome editing and Standard Operating Procedures (SOPs) for regulatory review of genome edited plants. Methods to enhance the dough and chapatti quality of gluten reconstituted pearl millet and corn flour, and a wheat gluten based "*Soft Nutri-cereal Atta*" were developed.

The School of Plant Protection focused on diversity analysis, diagnostics and integrated management of nationally important pests and pathogens, and agrochemicals design and discovery. Two new insect genera, one new subgenus and 25 new species were described during 2017-22. Whole genome sequence of 12 species of insect pests and pathogens based on which PCR based diagnostic markers were developed for detection. *Trichoderma harzianum* (Th3) based bioformulation was developed and commercialized for the management of various soil borne diseases. A ready to use powder formulation enriched with *Steinernema thermophilum* for management of termites and white grubs in different field crops. Molecularly imprinted polymers (MIPs) were developed for cleanup and selective extraction of selected pesticides.

The School of Natural Resource Management contributed to diverse areas of restoration and improvement of soil health, precision farming, rainwater harvesting, integrated crop resource management, conservation agriculture, climate change and greenhouse gas assessment, agri-residue, biomass and farmer friendly farm mechanization. Developed "Pusa Decomposer", a microbial consortium of seven fungal species for rapid decomposition of paddy straw within 20-25 days after harvesting. Large scale demonstrations and validation of Pusa Decomposer was carried out in thousands of acres in farmers' fields across India and the technology has been licensed to 22 companies. The Institute developed and further improved Pusa Soil Test and Fertilizer Recommendation (STFR) Meter. This present innovative technology helps in analysis of 14 soil parameters. Four *Jalopchar* technology-based wastewater treatment facilities were designed and developed at different institutes.

The integrated farming system model of a 1.0 ha area has been found to have a potential to generate net returns of ₹ 3.78 lakh $ha^{-1}year^{-1}$. The farm Sun Fridge, an off-grid, battery-less solar refrigerated and evaporative cooled (SREC) structure with 2-ton capacity of fruits and vegetables has been designed for the benefit of smallholder farmers. Farmer friendly farm implements such as Pusa Mini Electric Agri Prime Mover, Pusa Electronic Seed Metering Retrofit Module (ESMM) for cultivators and Direct seeded precision planter. The 32 Global Climate Model analysis on seasonal climate change projections for India indicated that under Representative Concentration Pathway (4.5 RCPs) in 2020s and 2030s, climate change without adaptation, is projected to affect all India productivity of wheat by 6 to -21% and *Kharif* rice by -2 to 12%.

The School of Social Science focused on evaluating innovative extension models and assessment of impact of technologies. The IARI-Post Office Linkage Extension model performed better than traditional extension systems in the five states Uttar Pradesh, Madhya Pradesh, Jammu and Kashmir, Bihar and West Bengal. A multimedia-based extension model named "*Pusa Samachar*" was developed for technology information dissemination and agro-advisory through social media. It was found that 88.67% of farmers regularly watched Pusa Samachar and 81.13% of them shared this content with their colleagues.

The ZTM-BPD unit of ICAR-IARI generated a revenue of ₹ 302 Lakhs through commercialization of 162 technologies to 301 industries across India. Pusa Krishi has developed partnership with 934 firms along with FPO/NGOs. Pusa Krishi, an incubator of IARI, helped the incubated startups to secure external funding. It has incubated 247 startups, of which 121 startups were given a funding of ₹ 17.47 crores. These startups brought 348 products to market, generated employment for 19394 and earned ₹ 255.7 crores, benefitting 36.24 lakh farmers.

The Graduate School of IARI imparts graduate and postgraduate education in 26 disciplines of Agricultural Sciences and related basic disciplines. During the period, 1657 students (991 M.Sc./ M.Tech. and 666 Ph.D.) were awarded degrees including 65 foreign students. At present, the total number of students on roll is 2,131 including 532 M.Sc./ M.Tech., 1,293 Ph.D., 306 UG and 19 international students. Under the ICAR Post-Doctoral Fellowship (ICAR-PDF), 12 PDFs successfully completed their training in 2019-20 and 2020-21. Under the New Education Policy, the first batch of 306 undergraduate students has been admitted at IARI and outreach centres.

Under NAHEP-CAAST project, a Central Common Facility, named Discovery Centre was established at a cost of ₹ 6 crores. Thirty-two different training were conducted and about 2000 students from > 120 different Universities/ Institutes across 24 states and 3 UT of India, and few foreign students were trained in the area of genomics. Thirty-two students and seven faculty members were also trained abroad in international laboratories of repute.

During the last five years, the Institute received ₹ 765.35 crores grant for capital and revenue including administrative expenses from ICAR EFC budget. The scientists received grant amounting ₹ 129.5 crores through external funding. The Institute has published 4,444 articles in internationally reputed journals, of which 1695 articles were published in journals with > 2 international impact factor.

The MHRD National Institutional Ranking Framework (NIRF) ranked IARI at #1 among agricultural Universities in 2017 and 2023. In 2018, University Grants Commission appointed Empowered Expert Committee (EEC) for selecting Institution of Eminence (IoE). EEC recognized IARI as "Special Institution." In the year 2020, IARI was adjudged winner of the Sardar Patel Outstanding ICAR Institute Award.

INTRODUCTION

1

The Indian Council of Agricultural Research (ICAR), New Delhi constituted a Quinquennial Review Team (QRT) on June 5, 2023 to review the research, education and extension achievements of the ICAR-Indian Agricultural Research Institute, New Delhi (ICAR-IARI) during 2027-2022 vide F.No. CS/16/ 08/ 2019-IA-IV (E.No-42673), dated 5th June 2023 (**Annexure I**).

1.	Dr. Mangala Rai, Former Secretary, DARE and DG, ICAR	Chairman
2.	Dr. Suraj Singh Baghel, Former VC, CAU, Imphal & AAU	Member
3.	Dr. S.N. Puri, Former VC, MPKV Rahuri & Former VC, CAU, Imphal	Member
4.	Dr. J.C. Katyal, Former DDG (Edn.), ICAR & Former VC, CCS, HAU, Hisar	Member
5.	Dr. P.K. Joshi, Ex-Director, NCAP and NAARM and Director, South Asia, IFPRI, South Asia Regional Office, New Delhi	Member
6.	Dr. K. K. Narayanan, Founder & Director, Sthayika Seeds Private Limited, Bengaluru.	Member
7.	Dr. Manoj Prasad, Staff Scientist VII & JC Bose National Fellow, NIPGR, New Delhi	Member
8.	Dr. Viswanathan C, Joint Director (Research), ICAR-IARI, New Delhi	Member Secretary

Terms of reference

The ICAR vide F.No. CS/16/ 08/ 2019-IA-IV (E.No-42673), dated 5th June 2023, set the following terms of reference for QRT to review of the work carried out by the IARI during 2017-2022 ar per the ICAR guidelines for Quinquennial Review Team (QRT), 2009.

- Research achievements and their impact
- Research relevance and budget allocation
- Policies, priorities and strategies
- Relationships/ collaborations with SAUs and other stakeholders
- Organization and management
- Constraints
- Looking forward

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THE REVIEW PROCESS

For review of the institute, the QRT conducted several meetings with all the staff and stakeholders of the institute and visited regional stations, sister institutes and farmers' participatory seed production programmes. The details of the meetings are given below.

S. No.	Place of Meeting		Programme
	Date	Location	
1.	3 Jul 2023	IARI, New Delhi	Meeting senior research management*
2.	3 Jul 2023	IARI, New Delhi	Internal meeting on background information
3.	4 Jul 2023	IARI, New Delhi	HoDs & Scientists
4.	3-4 Aug 2023	IARI RS, Indore	HoD, Scientist & farmers
5.	4 Aug 2023	IISR, Indore	Collaborative seed production programme
6.	7-8 Aug 2023	IARI RS, Wellington	HoDs, Scientist & farmers
7.	28-29 Sep 2023	IARI, New Delhi	HoDs & faculty of different Divisions
8.	30 Sep 2023	Urlana, Panipat	Visit to farmer participatory seed production program
9.	30 Sep 2023	IARI RS, Karnal	HoD, Scientist & farmers
10.	30 Sep 2023	IIWBR, Karnal	Collaborative seed production programme
11.	1 Oct 2023	Brass, Haryana	Visit to farmer participatory seed production program
12.	28 Oct 2023	IARI Assam	Director, HoD, scientists and students
13.	30 Oct 2023	IARI RS, Pusa	In-charge, HoD, scientists and staff
14.	31 Oct 2023	IIAB Ranchi	Director, scientists and staff
15.	1 Nov 2023	IARI Jharkhand	Director, In-charge, HoD and scientists
16.	26 Nov 2023	IARI New Delhi	Meeting senior research management
17.	27-28 Nov 2023	IARI New Delhi	QRT Internal meeting
18.	28 Nov 2023	IARI New Delhi	QRT Internal meeting
19.	7 Dec 2023	IARI New Delhi	Briefing with Director & Chairman of BoM & Members
20.	8 Dec 2023	IARI New Delhi	Meeting Secretary, DARE & Director General, ICAR for report submission

* Director, Joint Directors, Project Director, Senior Comptroller & School Coordinators

Quinquennial Review Team

Chairman
Mangala Rai

Member
S. S. Baghel

Member
S. N. Puri

Member
J. C. Katyal

Member
P.K. Joshi

Member
K. K. Narayanan

Member
Manoj Prasad

Member Secretary
Viswanathan C

First QRT Interaction with Director and staff of IARI, New Delhi (July 3-4, 2023)

Board Room
July 03, 2023

QRT interacting at Auditorium (July 04, 2023)

Interacting with Scientists (July 04, 2023)

QRT internal meeting at IARI, New Delhi (Nov 26-28, 2023)

Board Room
(Nov 26, 2023)

Board Room
(Nov 27, 2023)

Board Room
(Nov 28, 2023)

Visit to Divisions and Facilities
IARI, New Delhi (September 28-29, 2023)

Genetics

Maize Experiment Field

Fruit & Hort. Technology

CPCT

Seed Science Technlogy

Mango orchard

Agricultural Physics

Plant Physiology

Plant Pathology

Agricultural Entomology

Agricultural Extension

Nematology

Agricultural Chemicals

Agricultural Engineering

Vegetable Science

Visit to IARI Regional Stations


IARI Regional Station, Indore (Madhya Pradesh)
August 3-4, 2023


IARI Regional Station, Wellington (Tamil Nadu)
August 7-8, 2023


IARI Regional Station, Karnal (Haryana)
September 30, 2023

IARI Regional Station, Pusa (Bihar)
September 30, 2023

Visit to IARI Off campuses
(October 28 – November 1, 2023)

IARI, Assam (Oct 28, 2023)

IARI, Jharkhand (Nov 1, 2023)

Visit to Farmer Participatory Seed Production

Sh. Pritam Singh, Urlana, Panipat, Haryana (Sept 30, 2023)

Sh. Gurcharan Singh, Brass, Haryana (Oct 1, 2023)

Sh. Vikas Chaudhary, Tarawari, Haryana (Oct 1, 2023)

INSTITUTIONAL REPORT

HISTORY AND MANDATE

3

IARI, also known as Pusa Institute, has a rich history spanning over a century. It started its journey as Agricultural Research Institute in 1905 at Pusa, Bihar, later transformed as the Imperial Institute of Agricultural Research in 1911 and the Imperial Agricultural Research Institute in 1919. First academic programme was initiated in 1923. Due to a devastating earthquake in Bihar, the Institute was relocated to Delhi in 1936. With the advent of India's Independence, it was renamed the Indian Agricultural Research Institute (IARI). In 1958, IARI was granted the status of a Deemed-to-be University under the UGC Act of 1956, and in April 1966, its administrative control was transferred to ICAR. The institute played pivotal role in country's green revolution.

The present-day IARI campus is a self-contained, aesthetically designed complex spanning approximately 500 hectares. The campus also includes experimental fields covering an area of around 340 hectares, with about 300 hectares dedicated to irrigated farming research experiments and the remaining used for dryland farming research. Currently, the research activities at IARI are conducted through 19 Divisions, 2 multidisciplinary centers, and 7 service units located in Delhi. It also includes 8 regional stations situated in Amartara Cottage, Shimla (HP); Indore (MP); Kalimpong (WB); Karnal (Haryana); Katrain (HP); Pune (Maharashtra); Pusa (Bihar); and Wellington, the Nilgiris (TN). Additionally, there are two off-season nurseries in Dharwad (Karnataka) and Aduthurai (TN), and a Krishi Vigyan Kendra in Shikohpur, Gurgaon (Haryana). These divisions, centers, regional stations, nurseries, and Kendra function within six schools, namely: i. School of Crop Improvement; ii. School of Horticulture; iii. School of Basic Sciences; iv. School of Crop Protection; v. School of Natural Resources Management and vi. School of Social Sciences. IARI provides training in various aspects such as package of practices, credit, storage, and marketing.

The Institute has a rich and illustrious history as a premier center for higher education and training in various agricultural disciplines. Currently, the institute awards degrees in 23 agricultural disciplines. As a result, the Institute has contributed to the development of highly trained human resources in all major agricultural disciplines, which in turn has played a crucial role in the growth of State Agricultural Universities throughout India. The administrative head of IARI is the Director, who leads the overall management of the Institute. The Board of Management, chaired by the Director, provides the overall direction for management and is supported by four councils: The Research Advisory Council, Academic Council, Extension Council, and Executive Council.

Mandate

The mandate of the Institute are as follows:

- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need-based research, that lead to crop improvement and sustained agricultural productivity in harmony with the environment.
- To serve as a centre for academic excellence in the area of post-graduate education 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 and serve as a national agricultural library and database.

4

PRIORITIES

The major priorities of IARI across the mandates in the areas of research, education and extension are as follows:

Research

Research emphasizes on inter-disciplinary research philosophies, and knowledge generation of concepts, methodologies, materials utilization of global genetic resources to produce efficient, productive crop technologies utilizing new and emerging cutting-edge technologies. In natural resource management and climate research, development and use of systems approach, crop modelling, use precision tools to achieve greater understanding of the production systems to acheive sustainability by reducing the environmental and human health risks including the unfavourable ecosystems are given emphasis. Further, the Institute focuses on fostering excellence in agriculture related to basic and social sciences, develop capabilities in post-harvest technology, agro-processing, product development, value addition and utilization research on agricultural commodities, by-products, agricultural waste and renewable energy resources.

Education

IARI strives to promote excellence, foster high standard, and orient the educational programme towards future needs and opportunities, strengthening all branches of sciences in the curricular and add frontier areas. It provides opportunities for continuing education and development of human resources in new and cutting-edge technology areas through international collaboration not only through formal streams but also in non-formal stream to promote entrepreneurial skills and commercialization of agriculture.

Extension

IARI is focusing on generating innovative models in extension and developmental models through client oriented on-farm research and technology assessment, refinement and disseminate them across the country. It aims to promote institute-village linkage programme through communication research and linkages with rural development programmes and strengthen micro-planning through inter-departmental and participatory approaches.

5

PROGRAMMES AND PROJECTS

A total of 51 research programs (47 mandated programs and 4 flagship programs) organized in school mode were implemented in the Institute during 2017-22. The salient achievements and the impact of research carried out in six different schools under these projects are presented below:

5.1 School of Crop Improvement

The research in School of Crop Improvement consists of two Divisions namely Division of Genetics and Division of Seed Science & Technology, and one service unit called Seed Production Unit at New Delhi, five Regional Stations (RS) namely 1) IARI RS, Shimla, 2) IARI RS, Karnal, 3) IARI RS, Indore, 4) IARI RS, Pusa Bihar and IARI RS, Wellington, and two regional research centres (RRC) namely IARI RRC, Aduthurai and IARI RRC, Dharwad. The research in was carried out to address various issues in crop varietal technology development through 14 different projects and one flagship project, which are listed below:

1. Genetic enhancement of wheat and barley for productivity, disease resistance, resilience, quality and cropping systems.
2. Improving resilience, productivity and quality in rice through genetic and genomic approaches.
3. Genetic improvement of productivity, stress tolerance and nutritional quality of early- to full-season maize hybrids.
4. Development of varietal and hybrid technologies of pearl millet [*Pennisetum glaucum* (L).R.Br.] for higher yield and nutritional improvement.
5. Genetic improvement of chickpea (*Cicer arietinum* L.) for higher productivity under marginal and dry land situations.
6. Genetic improvement of pigeon pea for yield and disease resistance.
7. Enhancement of genetic potential of mung bean and lentil in multi-season and different cropping system adaptations.
8. Breeding climate resilient high yielding rapeseed mustard varieties and hybrids with enhanced quality.
9. Genetic enhancement of soybean for yield, tolerance to abiotic stress, biotic stress and seed quality.
10. Understanding gene functions through genetic and molecular analysis in *Drosophila melanogaster*.

11. Development of technologies/ methodologies for quality seed production, maintenance of seed purity and varietal identification.
12. Seed quality enhancement by processing, packaging and storage options in high volume seed crops.
13. Seed quality enhancement by processing, packaging and storage options in low volume seed crops.
14. Development of protocols, validation and execution for quality seed production through farmers for sustainable truthfully labelled seed production system.
15. **Flagship project:** Development of Basmati rice varieties for domestic and export market.

Achievements

Improved crop cultivars released: A total of 71 improved crop varieties have been released during 2017-22 (**Figure 5.1**).

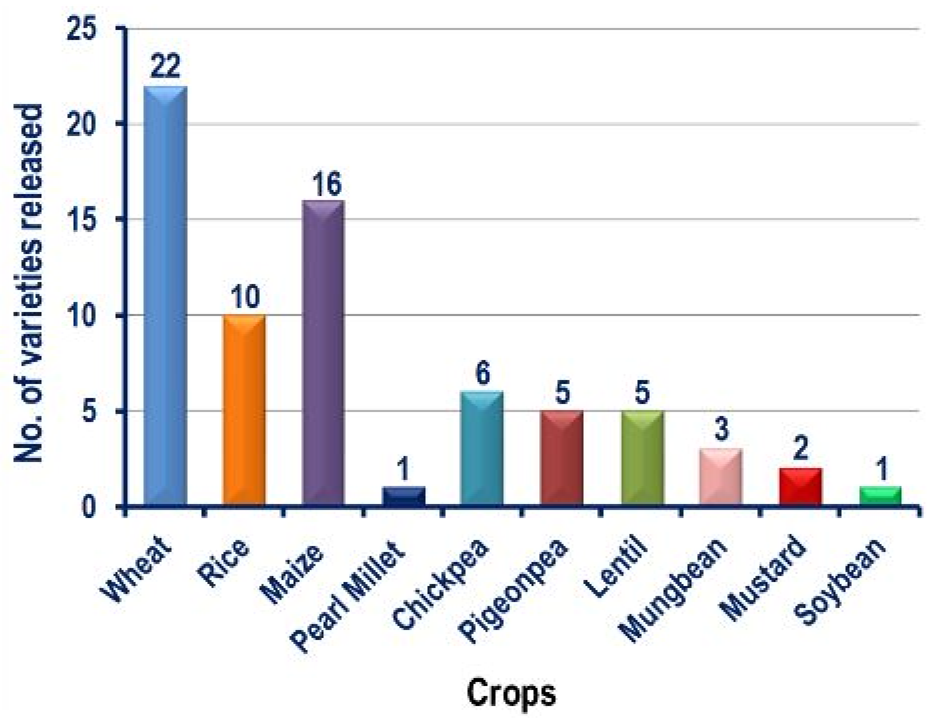


Figure 5.1. Improved crop cultivars in different crops released during 2017-2022

The crop cultivars include 17 hybrids and 54 varieties (**Table 5.1**). Out of these, 25 of them are biofortified cultivars of wheat (11), Maize (11), Lentil (1) and Indian mustard (2), and 23 of them are MAS-derived cultivars of rice (9), maize (11) and chickpea (3).

Table 5.1. Improved crop cultivars (71 No) released and notified during 2017-2022

S. No.	Crop	Varieties
1	Rice (10)	Pusa Basmati 1718, Pusa Samba 1850, Pusa Basmati 1692, Pusa Basmati 1847, Pusa Basmati 1885, Pusa Basmati 1886, Pusa Basmati 1979, Pusa Basmati 1985, Pusa Basmati 1882, Pusa Samba 1853
2	Wheat (22)	HD 3171, HI 1605 (Pusa Ujala), HI 8759 (Pusa Tejas), HW 5207 (COW 3), HI 1612, HI 8777, HD 3226, HD 3237, HI1620, HD 3086 (Pusa Gautami), HI 1628, HI 1621, HI 8805, HI 8802, HD 3249, HD 3271, HD 3298, HD 3293, HI 1633, HI 1634, HI 1636 (Pusa Vakula), HI 8823 (Pusa Prabhat)
3	Maize (16)	Pusa Vivek QPM 9 Improved, Pusa HM 4 Improved, Pusa HM 8 Improved, Pusa HM 9 Improved, Pusa super sweet corn 1, Pusa Jawahar Hybrid Maize 1, Pusa Vivek Hybrid 27 Improved, Pusa HQPM 5 Improved, Pusa HQPM 7 Improved, Pusa super sweet corn 2, Pusa Baby corn Hybrid 1(AH-7043), Pusa HQPM 1 Improved, Pusa Biofortified maize Hybrid 1, Pusa HM4 male sterile baby corn (shishu), Pusa Biofortified maize Hybrid 2, Pusa Biofortified maize Hybrid 3
4	Pearl millet (1)	Pusa 1201
5	Chickpea (6)	BG 3043, BGD 111-1, BG 3062 (Pusa Parvati), Pusa Chickpea 10216, Pusa Chickpea 20211 (Pusa Manav), Pusa Chickpea 4005
6	Pigeon pea (5)	Pusa Arhar 16, Pusa Arhar 151 (Pusa Shreejita), Pusa Arhar 2017-1, Pusa Arhar 2018-2, Pusa Arhar 2018-4
7	Lentil (5)	L4717 (Pusa Ageti masoor), L 4727, L 4729, PDL 1 (Pusa Avantika), PSL 9 (Pusa Yuvraj)
8	Mung bean (3)	Pusa 1371, Pusa 1431, Pusa 1641
9	Indian Mustard (2)	Pusa Mustard 32, Pusa Double Zero Mustard 33
	Soybean (1)	Pusa soybean 6

Genetic Stocks Registered

During 2017-2022, 60 genetic stocks of rice (4), wheat (38), maize (2), lentil (7), *Vigna* sp. (3) and Indian mustard (6) have been registered with the Plant Germplasm Registration Committee, ICAR, New Delhi. These genetic stokcs possess useful traits such as resistance to biotic and abiotic stresses and quality traits.

Quantitative Trait Loci (QTL) mapped

A large number of QTL(s) governing different traits such plant architecture, grain micro-nutrient content, resistance to biotic/ abiotic stresses, etc., have been mapped in different crops. Crop-wise QTLs mapped are mentioned in the parenthesis: rice (48), wheat (22), maize (1), pearl millet (59), lentil (17), mungbean (23) and pigeonpea (11). Some of these QTLs have been validated and are being fine-mapped and used in the breeding programme.

Salient features of some of the important crop varieties and their impact are described below.

RICE

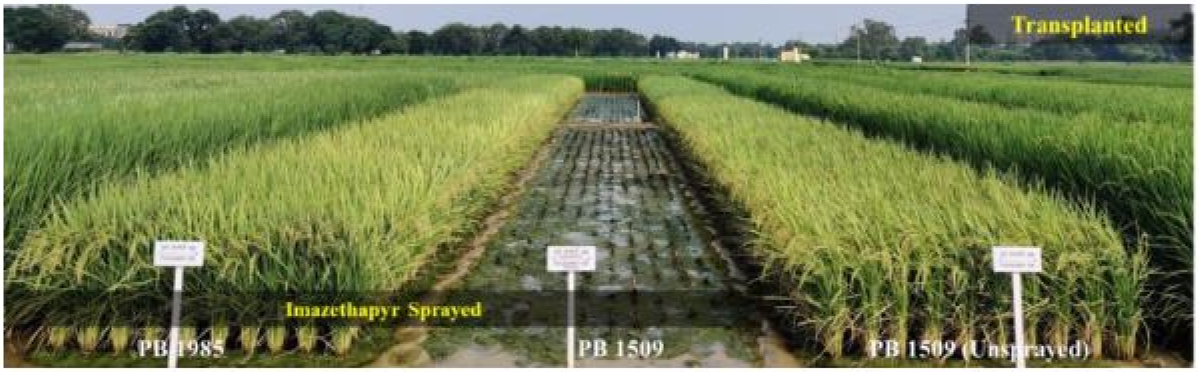
Short duration rice varieties - Pusa Basmati 1692 and Pusa Basmati 1847


Pusa Basmati 1847

Two short duration Basmati varieties, Pusa Basmati 1692 and Pusa Basmati 1847 have been developed and released, which saves 5 to 6 irrigations over other popular Basmati varieties. It also helps in timely harvest of paddy crop in the Basmati growing region, thereby providing sufficient time for after-harvest operations including straw burning. Semi-dwarf plant habit, lower biomass and the decomposition of stubbles is much faster in the field as compared to other Basmati rice varieties. These varieties have brought in much needed crop diversification of rice-wheat to rice-potato-wheat, rice-potato-sunflower, rice-pea-wheat, etc. Pusa Basmati 1847 has inbuilt resistance to both bacterial blight and blast diseases, which helps farmers in effectively managing the disease and saves ₹ 3000/- acre towards management of bacterial blight and blast diseases. These varieties have been licensed to as many as 33 seed companies generating a revenue of ₹ 111.432 Lakhs. Over the last two years, 58.0 quintals of breeder seeds and 1718.5 quintals of truthfully labelled seeds have been produced and distributed.

Herbicide tolerant Basmati rice varieties for direct seeded rice (DSR) condition

Due to labour and water shortage, there is a shift in the rice cultivation from transplanted condition to the DSR cultivation in which weeds are of major concern. During the period, two herbicide tolerant Basmati rice varieties, Pusa Basmati 1985 and Pusa Basmati 1979 has been developed and released, which has tolerance to broad-spectrum herbicide, Imazethapyr. These varieties will help in effective management of weeds under DSR, thus economizing labour and water and also reduce greenhouse gas (GHG) emission.



Field demonstration of imazethapyr tolerance in improved Pusa Basmati 1985

Altering the plant architecture of geographical indication (GI) protected rice varieties, Kalanamak and Chakhao Poireiton (Manipur black rice)

Two improved semi-dwarf high yielding varieties of Kalanamak namely, Pusa Narendra Kalanamak 1 and Pusa Narendra CRD Kalanamak 2 were developed and released for the GI notified districts of eastern UP. Likewise, three promising MAS derived semi-dwarf NILs of *Chakhao Poireiton* have been developed and are being tested GI area of Manipur for their release.

Marker-assisted improvement for biotic and abiotic stresses in rice

Marker assisted breeding including MABB and forward breeding have been adopted to transfer gene(s)/ QTL(s) governing resistance or tolerance to biotic stresses (*xa13, Xa21, Xa33, Xa38* for Bacterial blight; *Pi2, Pi9, Pi54, Pita, Pbl2, qNLB3, Pi1, Pib, Piz* for blast; *qBK1.1, qBK1.2, qBK1.3, qBK3.1* for bakanae; *qSBR11-1* for sheath blight; *Bph31, Bph33, qbph4.3, qbph4.4* for BPH; *AHAS* for herbicide tolerance), abiotic stresses (*Saltol, qSSISFH-8*.1 for salnity; *qDTY1.1, qDTY2.1, qDTY3.1, qDTY9.1, qDTY12.1* for reproductive stage drought stress; *Pup1* for low P stress), grain number (*Gn1a, SPL4*), stem sturdiness (*SCM2*), grain quality (*BADH1, BADH2* for aroma; *qZn1, qZn6* for grain *Zn; qLPA8.1* for low phytate; *lox3-b* for bran quality) into popular Basmati and non-Basmati rice varieties.

WHEAT

Bread wheat Variety, HD3226

HD 3226 was released for irrigated, timely sown conditions of the North Western Plain Zone of India. This variety has a very wider adaptability in changing climatic conditions. It yields 57.5 q/ha and has yield potential of 79.6 q/ha. Owing to its superiority, HD 3226 has reached the top five indented varieties of wheat for breeder seed production within three years.

HD3226

HI 1633 (Pusa Vani)

HI 1633 (Pusa Vani) a bio-fortified variety was released for very late sown, irrigated conditions of the Peninsular Zone. It yields 41.7 q/ha and has a yield potential of 65.8 q/ha, and has high levels of field resistance to stem and leaf rusts. It is good for bread, chapati as well as biscuit making. It has high levels of iron (41.6 ppm) and zinc content (41.1 ppm).

Pusa Vani

Durum Wheat Variety HI 8759 (Pusa Tejas)

HI 8759 (Pusa Tejas) was released for timely sown, irrigated conditions of Central Zone. It has yield potential of >75.5 q/ha with an average yield of 56.9 q/ha. It has good levels of iron (42.1 ppm) and zinc (42.8 ppm); with very high overall acceptability (7.5).

Pusa Tejas

Trait discovery and mapping

Two genes for leaf rust resistance namely, *LrSyn45, LrTm1* in Synthetic 45 and *T. militinae* derived introgression lines (ILs), 44 QTLs for heat stress tolerance from HI1500, a novel QTL (*Qlr.nhv-5D.2*) for leaf rolling under moisture stress. To generate reliable leaf rust differential sets, NILs carrying leaf rust genes *Lr13, Lr18, Lr19* and *Lr26* were developed by backcrossing NP4 line with Thatcher differentials. Mutant lines of HD 3086, non-glaucous lines showed the presence of null allele for the three major genes at *W1* cluster (Ta-DMH, Ta-DMP, Ta-DMC). For the first time population structure of 117 accessions of Indian dwarf wheat (*T. sphaerococcum*) was determined. Speed breeding protocols were standardized for *Triticum aestivum*, *T. durum* and *T. dicoccum* varieties. More than 250 accessions of wild and related species are maintained.

Marker-assisted breeding

MAS-derived lines carrying genes for leaf rust, and yellow rust such as HD3406 (HD2967+*LrTrk*), HD3407 (HD2932+*Lr19*+*Lr24*+*Yr10*), HD3436, HD3437, HD3438, HD3439, HD 3059 (*Yr15*) and HD3440 were developed and are under national testing. Adult plant resistance (APR) genes, *Lr34*, *Lr46*, *Lr67* and *Lr68* were transferred into varieties, HD2733 and HD3059. Celiac disease is emerging as a major problem owing to gluten intolerance in sizeable population worldwide. To address this problem gluten free wheat have been developed by creating knock out lines of major gene, *Glu-D1*.

MAIZE

Biofortified maize

As many as 11 biofortified maize hybrids enriched with Quality protein (lysine and tryptophan) and provitamin A have been developed and released. Pusa Vivek QPM9 Improved, the world's first double biofortified (protein quality and provitamin-A) maize hybrid been released and notified for cultivation in Northern Hill Zone and Peninsular Zone. It is an extra-early maturing hybrid with an average maturity of 95 days in Northern Hill Zone (NHZ) yielding 5588 kg/ha and 85 days yielding 5916 kg/ha in Peninsular Zone (PZ). In partnership with SKUAST (K), this hybrid has been popularized in Kashmir valley on a massive scale. As many as 23 MoUs have been signed with 15 companies for commercialization of maize hybrids.

Breeding for haploid inducer lines

Haploid inducer (HI) lines with *mtl* and *dmp* genes and higher anthocyanin in seeds and plant parts were developed. The improved HI lines possess an 8-10% haploid induction rate (HIR).

Nutritional quality enhancement

Parental lines of white grained hybrids namely, HM5 (HKI1344/HK1348-6-2) and HM12 (HKI1344/HKI1378) were introgressed with *opaque2* and *opaque16* and promising QPM hybrids (*o2o2/o16o16*) with > 0.480% lysine and > 0.120% tryptophan, higher yield and 25-50% opaqueness has been identified. QPM and provitamin-A version of four elite hybrids namely, HQPM1, HQPM4, HQPM5 and HQPM7 were targeted for marker-assisted introgression of favourable allele of *vte4* gene. The α-tocopherol in the reconstituted hybrids showed a 2-fold enhancement in α-tocopherol (16.83 ppm) over original hybrids (8.06 ppm). The MAS-derived hybrids with *lpa1-1* and *lpa2-1* gene possessed ~30-40% less phytate than the traditional hybrids.

Breeding for specialty traits

PSSC 1 and PSSC 2 possessing *su1su1/sh2sh2* with higher brix (~24-25%) over the original hybrids (~17-18% brix) were developed. Hybrids with T-cytoplasm was found to be the most stable for male sterility as compared to C-and S-cytoplasm. Using T-cytoplasm inbreds, two hybrids have been identified/released for commercial cultivation. A major novel QTL, *qProl-SP-8.05*, governing prolificacy in 'Sikkim Primitive' explaining 31.7% phenotypic variation have been mapped which can help in improving baby corn yield.

Breeding for fodder quality traits

The biofortified hybrids, Pusa Vivek QPM9 Improved, Pusa HM9 Improved, PSSC 1 and PSSC 2 hybrids were found to be promising for crude protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), and *in-vitro* dry matter digestibility (IVDMD) traits.

Breeding for resistance to stresses

A set of 10 newly developed inbreds were identified to be resistant to Turcicum leaf blight with productivity of >3.5 t/ha. Five new biofortified inbreds have been identified to show tolerance to fall armyworm. A medium maturity hybrid was found to be moderately tolerant to drought. Two hybrids, 3 parental lines and 33 germplasm accessions were identified to be tolerant to excess moisture stress.

PEARL MILLET

Pusa 1201

A pearl millet hybrid, Pusa 1201 rich in iron (55 ppm), zinc (48 ppm), and Protein 13-14%, with an average grain yield of 28.10 q/ha in 78-90 days has been released for NCT of Delhi. It has a grain yield potential of up to 48 quintals/ha and stover yield is 72 quintals/ha. It is highly resistant to downy mildew and Blast and has stay green trait.

Pusa 1201

Identification of blast resistant lines

Germplasm lines namely IP 11353 and IP 22423 IP 7910 and IP 7941 were identified as resistant to foliar blast.

Prospecting donors and genetic studies on different traits in pearl millet

Inheritance of fertility restoration for the A_1 and cytoplasmic genic male sterility system in pearl millet was found to be governed by two major genes with different types of epistatic interactions. Inheritance of fertility restoration of the A_5 cytoplasm in pearl millet (*Pennisetum glaucum*) was found to be governed by single dominant gene on linkage group 2. The foliar blast resistance in pearl millet was found to be governed by single dominant gene located on LG 4. Twenty-one genotypes possessing high iron and zinc content, and four genotypes with seedling thermo-tolerance under high temperature stress were identified.

CHICKPEA

Pusa 3043, an early maturing high yielding variety

Pusa 3043 yields 20.0 q/ha in 130 days, which is ideal variety for the sustainability of rice-based cropping systems of eastern and North Eastern Indian states comprising the states of Eastern UP, Bihar, Jharkhand, West Bengal, Northern Chhattisgarh, Assam and plains of NE states. It has a 100-seed weight is 21.4 g and grain protein content of 21.1%. It is moderately resistant to *Fusarium* wilt and tolerant to dry root rot, collar rot, stunt, *Ascochyta* blight and Botrytis grey mould.

Pusa 3043

Inheritance of key traits in chickpea

Inheritance of lodging was two dominant non-allelic genes with duplicate gene action-controlled lodging resistance in FLIP 07-183C. Late flowering was found to be dominant, while indeterminate growth was governed by single dominant gene and internode length was governed by a single recessive gene. Molecular characterization and functional role of abscisic acid and stress ripening (ASR) gene established the role of ASR protein (NP_001351739.1) in mediating drought response in chickpea.

As many as seven Chickpea genotypes were identified as donor for early flowering, 18 accessions identified as tolerant for drought and seedling stage salt tolerance and three genotypes, with large number of bigger size root nodules were identified. GWAS identified stable MTAs for higher number of nodules explaining > 15% phenotypic variation.

PIGEON PEA

Pusa Arhar 6, a semi-dwarf short duration variety

Pusa Arhar 6, a semi-erect compact, determinate and semi-dwarf (95-100 cm was released for NCT (Delhi State) with a yield potential of 20 q/ha. It has synchronous and extra early maturity in 120 days. It is suitable for high density sowing with a row to row spacing of 30 cm and mechanized cultivation including Combine harvesting. Its semi-dwarf stature facilitates easy spray of insecticide with Knapsack sprayer. It allows sowing of potato/mustard/wheat after its harvest in October. A large number of elite breeding lines with short duration determinate semi-erect compact plant type with semi-dwarf stature, determinate compact dwarf plant type suitable for mechanized cultivation, semi-dwarf semi-erect compact plant types with bold seed size (9-10 g/ 100 seeds) and early maturity.

Pusa Arhar 16

MUNG BEAN AND LENTIL

Pusa 1431, a short duration mung bean variety

Pusa 1431 is a short duration mung bean variety with an average yield of 13-14 q/ha in 65 days released NCR in spring/ summer cultivation. It is resistant to MYMV, *Cercospora* leaf spot, anthracnose, web blight and urdbean leaf crinckle virus. About 20.69 quintals of breeder seeds have been produced and 204.56 quintals of TL seeds of Pusa 1431 have been produced and distributed to the farmers.

Pusa 1431

L4717, an extra-early biofortified lentil variety

L 4717 is extra-early biofortified lentil variety which matures in 100 days in Central Zone. It has a grain iron concentration of 65 ppm. L 4717 is moderately resistant to wilt and *Ascochyta* blight and resistant to powdery mildew. It is widely grown in NEPZ and suitable for rice fallows in Bihar and West Bengal also due to preferred small seed size and early maturity.

GWAS for mapping 5 MTAs governing grain iron and 7 MTAs for zinc content in lentil; and 3 MTAs for grain iron, 1 MTAs in grain zinc, six genes in the regulation of P uptake and utilization efficiency in mung bean, and 2 MTAs for grain phytic acid content. Mung bean line, PMR 1 was identified with high level of resistance to yellow mosaic disease in field condition at hotspot over years in India. Comparative RNA-Seq analysis identified the role of WRKY, NAC and MYB transcription factor, RLKs, cytochrome P450, JAZ and LOX genes in governing resistance in PMR 1. In *Lens culinaris*, host-pathogen interaction pathways in response to *Rhizoctonia bataticola* infection identified key miRNA targets namely *miR156*, *miR159*, *miR167*, *miR169*, and *miR482*. Based on total dry weight (TDW) under low P, eight donors for P uptake and utilization efficiency in Lentil were identified. Two genotypes, PMF 3 and PMF 4, producing four flowers and a genotype, ILL7663, producing only one to two flowers at multiple flowering nodes were identified in Lentil.

INDIAN MUSTARD

Pusa Double Zero Mustard 31, the first Canola quality Indian mustard variety in India

This is first canola type variety in the India. With an average yield of 23.3 q/ha matures in 142 days, this variety was released for commercial cultivation in Zone II including areas of Jammu, Punjab, Haryana, Delhi and North-Rajasthan. It has 41% oil content in the seeds.

Pusa Mustard 32, high yielding single zero (erucic acid <2% in seed oil) variety

Pusa Mustard 32 is a high yielding single zero (erucic acid <2% in seed oil) variety of Indian mustard with maturity duration of 145 days with an average yield of 27.1 q/ha. It possesses 38% oil content and is low erucic acid. This variety was released for Central zone for commercial cultivation.

Pusa Mustard 32

A new source of resistance to powdery mildew in Indian mustard, RDV 29 (IC589658; INGR20041) have been identified. A total of 49 CMS lines (20 with *mori*, 15 with *eru*, and 14 with *ber* cytoplasms) were developed through continuous backcrossing. Further, 72 fertility restores were also developed and maintained for further use during this period. Isonuclear alloplasmic CMS lines were developed using *mori*, *eru* and *ber* cytoplasm to study the effect of sterile cytoplasm.

To develop low erucic genotypes through marker assisted selection *FAE1.1* and *FAE 1.2*; the gene-based markers for low erucic acid genotypes in Indian mustard has been developed and is being utilized in breeding programme. In order to develop the climate smart and water use efficient genotypes of Indian mustard, the genomic segments imparting the drought tolerance *B. carinata* were introgressed into *B. juncea* through systematic breeding.

SOYBEAN

Pusa 6, a medium duration soybean variety

Pusa 6 is a medium duration soybean variety with an average yield of 21.4 quintals in 124 days. It is resistant to major diseases like MYMV, charcoal rot and pod blight (Ct). Pod blight is emerging disease and it is now reported from all the five zones of AICRP on Soybean It is the only variety which has shown resistance to Pod blight in all the 3 years in multiple locations.

The inheritance of resistance to *Cowpea mild mottle virus* (CPMMV) strain D1 in Indian soybean was found to be governed by a single dominant gene. Molecular mapping identified Uo8405 and Satt635 linked to the gene for resistance to *Cowpea mild mottle virus* (CPMMV) strain D1 located on linkage group H (chromosome 12).

Ten soybean genotypes tolerant to terminal drought stress were identified. Analysis of inheritance showed that the tolerance to seedling stage drought stress tolerance in PK1180 is monogenic. Through single marker analysis has shown that the marker, *Satt277* linked to seedling survival under drought stress located on chromosome 6was identified at a distance of 3.2 cM. Lipoxygenase produced primarily by *Lox2* gene develops off-flavour in soybean seeds. Through marker-assisted backcross breeding approach, null allele (*lox2*) is being transferred to Kunitz trypsin inhibitor (KTI)-free soybean lines. MAS for introgression of herbicide tolerance in seven Indian soybean varieties has been initiated using The S14-9017GT, an American soybean variety, as the donor of herbicide tolerance gene (*EPSPS*).

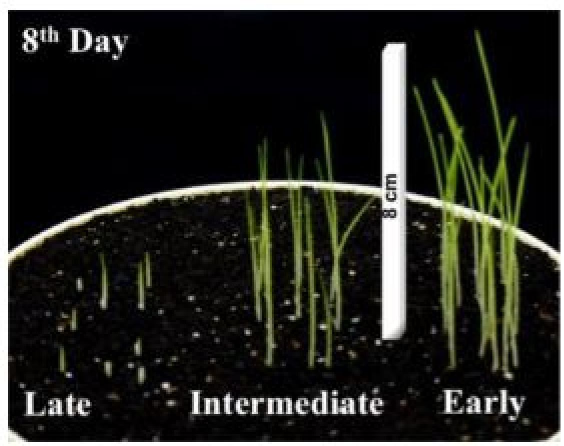
DROSOPHILA

In the 22Kb area of the 2L chromosome corresponding to *DWnt4* position, a total of 342 SNPs were identified from 07 mutant lines through WGRS. The mutation DWnt4^{AL7} has *Met* to *Val* and *Ala* to *Val* substitution at positions 313 and 314 and DWnt4^{RF1} has *Arg* to *Pro* and *Cys* to *Trp* substitution at positions 513 and 512 in 539 aa long protein making them homozygous null alleles of the *DWnt4* gene. *DWnt4*^{AL7} mutations was found to increase the expression of *Wg*, during stage 11, which indicated that *DWnt4* is antagonizing expression of *wg* during patterning of embryonic ectoderm, while it is not doing so using canonical *Wnt* signaling as indicated by no change in expression of *arm* distribution. The germline clones of *DWnt4*^{AL7} were arrested in stage 6 of oogenesis due to accumulation of spectrosomes. Over expression of *DWnt4* causes patterning defects in dorsal epidermis, in the *DWnt4* null mutant alleles we found the loss of dorsal patterning. Absence of was observed, which indicated that 3° cell rows is indicative of functions of *DWnt4* in the *Hh* domain at least for dorsal cuticle patterning.

SEED SCIENCE & TECHNOLOGY

Early seed vigour in rice

The DEGs obtained from the rice microarray data of the matured dry seeds from genotypes with the contrasting phenotype for speed of germination revealed that the seeds of early germinating rice genotypes are well equipped with transcriptional machinery, which facilitates early germination over intermediate and late germinating groups. The early genotypes had a higher GA/ABA ratio which promotes germination. GWAS using 192 divergent genotypes for the time to 50% lemma rupture in rice identified three genes governing early seed vigour on chr 3 (*LOC_Os03g03820*), chr 6 (*LOC_Os06g03570*) and chr 7 (*LOC_Os07g46340*). The *in silco* transcriptome analysis found that *LOC_Os03g03820* was associated with lemma rupture in rice during seed germination.



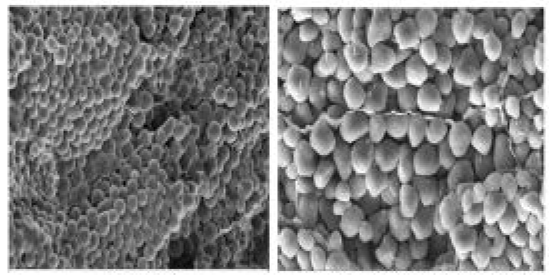
Rice seed morphology and longevity

GWAS identified the most significant and prominent genomic region for seed length and seed width on chr. 3 and chr. 5, respectively. Association analysis for dry elevated partial pressure of oxygen (EPPO) ageing (21 d @ 35°C) for 300 *indica* rice accessions revealed 11 loci. The significant SNP on L7 was located within the *Rc* gene, a bHLH transcription factor regulating pro-anthocyanidin synthesis in seeds, which was validated using isogenic lines possessing contrasting alleles of *Rc* alleles.

Seed storage of speciality maize

Scanning Electron Microscopic (SEM) observations revealed that hard kernelled types (dent and popcorn) had a different starch granule arrangement than soft kernelled maize (QPM, sweet corn and flint corn). Among different groups, sweet corn (sugary and double recessive types) and QPM genotypes showed lowest (up to 6-8 months) germination, while popcorn and waxy types (up to 12 months) showed the highest germination and storability. Seed stored under ambient conditions showed faster deterioration due to the production of more superoxide (O^{2-}), and hydrogen peroxide (H_2O_2) radicals combined with reduced antioxidant activity.

Differences in size, shape, arrangement of starch granules (SEM) of Maize Genotypes



Popcorn | QPM, sweet and flint corn

Seed germination and vigour were found significantly affected by the seed coat colour in *B. juncea* genotypes. The percent lipid used was highest in double zero mustard and found negatively correlated with Seedling Vigour Index-II. Both conventional (95.11%) and single zero (90.7%) genotypes had significantly higher mean germination percentage, than double zero genotypes (81.5%). During storage, ROS accumulation increased and enzymatic antioxidants decreased. Lower NADPH oxidase and superoxide anions were found associated with root growth and seed vigour. Mung bean genotypes for preharvest sprouting resulted in the identification of three tolerant genotypes. Comparative studies of tolerant (D) and susceptible (ND) genotypes at 4 seed stages revealed that germination up to stage 3 (26 DAA) is similar in both D and ND, but later reduced in D due to impermeability of seed coat resulting in hard seededness. The occurrence and variation of hard seededness were studied in 51 mung bean genotypes by growing in the field during summer and *Kharif*. Hard seededness among the genotypes ranged from 2% to 11% in summer and 3% to 46% in *Kharif* season-grown seed lots. The SEM studies also showed that the hard seeds had a compact outer cell layer, closely packed hilum cells, the absence of cracks in the hilum compared to loosely arranged cells, and the presence of cracks in normal seeds.

Seed storability in onion

Fresh seeds of 17 onion varieties were aged at 42 °C, 100% RH for 144 h and seed quality was assessed. The good storers showed the highest area under the curve (1182.25±26.02), indicating their ability for faster, higher and uniform germination compared to medium (1045.64±36.27) and poor storers (850.61±79.29). Further, a significant increase in NADPH oxidase activity, number of free radicals, and decrease in antioxidant enzyme (SOD, CAT, POX and GR) activity was observed in aged seeds of poor storers over medium and good storers.

Seed hard seededness in Kasuri methi

The seeds of Kasuri methi (*Trigonella corniculata* L.) possess hard seededness for nearly six-months. The seeds have maximum germination (70%) at physiological maturity (29 days after anthesis-DAA), followed by a decrease in germination due to increased hard seeds (maximum at 38 DAA). Among dormancy-breaking treatments, freeze (4 days)-thaw (room temperature) method, sand paper scarification (50 grit for 5 min) and sulphuric acid scarification (5 min) were found effective in relieving the seed dormancy.

Seed quality Pigeon pea and soybean

In two pigeon pea varieties (Pusa 991, Pusa 992), the exposure of seed to 40 °C for 24 h was found significantly better for both field emergence (79.8%) and speed of germination (13.5). Similarly, in soybean (Pusa 9752 and JS 335) also significantly higher germination was observed in the seeds exposed at 40°C for 1 h (72.3%) than control (61.1%).

Pearl millet, onion, chickpea and soybean

Silver nanoparticles (AgNP) treatment (50 µg/mL) showed enhanced seed germination and vigour in pearl millet which could be due to the decrease in EC and increase in antioxidant activities. The loss in vigour and viability of aged seed is due to the increased ROS (H_2O_2), membrane permeability (EC) and decreased antioxidants (CAT, POX) activity in the pearl millet seeds. The onion seeds (cv. Pusa Riddhi) when subjected to ZnO nanoparticles (NP) treatments, the 25 µg/mL of NP was found optimum for promoting rapid and uniform germination. In chickpea, the 250 ppm ZnO NPs improved all the seed quality parameters including germination (92%), average shoot length (14.31 cm), average root length (21.19 cm), average normal seedling length (35.5 cm), seedling dry weight (0.513 g), seedling vigour index I (3265), seedling vigour index II (47.16) over untreated control.

Controlled pollination in pigeon pea

The efficacy of pollination control methods using different types of selfing nets/ bags (Nets: 5x 3 x 3m; Bags: 86 x 46 cm, 50x 28 cm, 1x 1m; height 1.65 m) in 04 pigeon pea varieties (Pusa 991, Pusa 992, Pusa 2001, Pusa 2002) was evaluated for seed yield and quality parameters. The larger nets effectively maintained seed yield and quality over control plots, while smaller net bags exhibited poor seed setting and quality.

Hybrid seed production in Cauliflower revealed 3:1 (F:M) row ratio as optimal and *Apis mellifera* was the pre-dominant pollinator. Pod set ranged from 10-58% in CMS and 30-85% in fertile parents in hybrid seed production plots with bee boxes and natural pollinators.

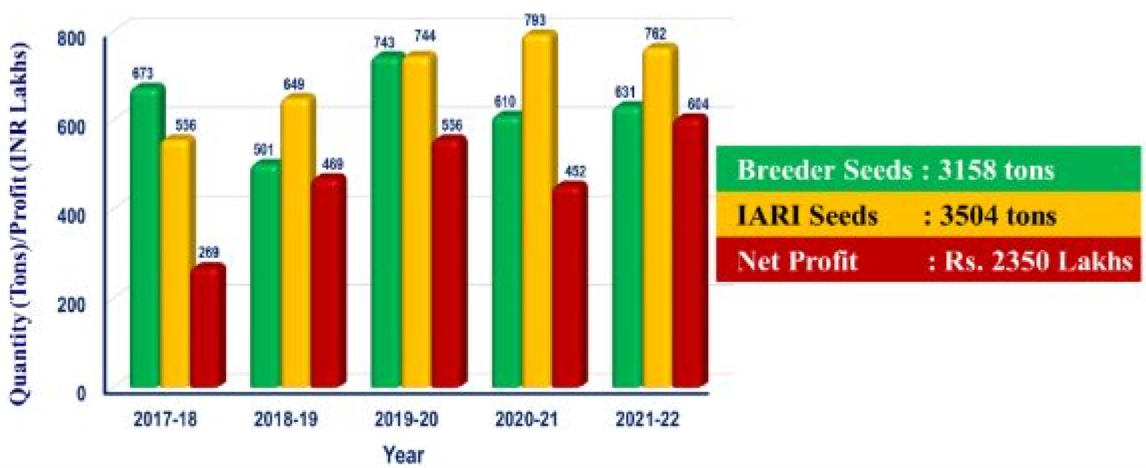
Seed management of paddy sheath rot

Seed treatment with Carbendazim 12% WP + Mancozeb 63% WP@3.0 g/kg seed was found at par with Carboxin 37.5% and Thiram 37.5% WS @2.5g/kg seed. These treatments in combination with a seedling dip in the suspension of *Pseudomonas flourescens* @10g/L followed by one spray of Tebuconazole 50%+ Trifloxystrobin 25% @1.0g/L water at 50 days after transplanting was found most effective in controlling sheath rot of paddy.

Soybean yellow mottle mosaic virus (SYMMV)

Three of 38 soybean samples strongly reacted with SYMMV polyclonal antibodies in DAC-ELISA, and showed 1065 bp amplicon (RT-PCR) with coat protein (CP) specific primers. This was further confirmed through mechanical sap inoculation on French bean followed by testing with polyclonal antibodies and RT-PCR.

Seed Production



IARI Breeder seed production statistics for 2017-2022

Seed production is one of the major activities of IARI, which is being operated through Seed production Unit, New Delhi; Regional Stations at Karnal, Pusa (Bihar), Indore and Katrain (HP). Institute produces three classes of seeds of all mandated field and vegetable crops (Table 6).

Table 5.2. Crop-wise "IARI seed" produced through Farmer Participatory Programme during 2017-22

Crop	Year-wise Production in quintals (q)					Total (q)
	2017-18	2018-19	2019-20	2020-21	2021-22	
Wheat	2149.80	1418.11	1930.48	2344.00	2970.50	10812.89
Paddy	2609.00	3557.75	3993.17	4311.98	3528.66	18000.56
Mustard	81.60	19.23	38.28	35.18	85.77	260.06
Chickpea	0.00	0.00	34.14	9.48	70.41	114.03
Pigeon pea	26.61	2.80	4.06	4.06	0.21	37.74
Mung bean	78.20	126.73	79.29	71.35	175.64	531.21
Lentil	39.28	3.77	20.34	25.57	20.00	108.96
Vegetables	108.04	45.71	39.86	56.52	118.20	368.33
Total	**5092.53**	**5174.10**	**6139.62**	**6901.84**	**6969.39**	**30277.48**

The School of Crop Improvement has developed and released 71 improved crop cultivars. It has made good progress in deciphering genetics and mapping genes/QTLs governing plant traits, stress resistance, and grain nutrient content. Some of these genes/QTLs have been validated and used in marker-assisted breeding. About 3100 tons of breeder seeds and 3500 tons of truthfully labelled seeds have been produced and supplied. Pusa Basmati rice varieties occupies over 90% of the Basmati rice area in India. The wheat varieties HD3086, HD2967, and HD 3226 contribute 50 million tons of wheat grains to the granary. IARI mustard varieties account for over 35% of the breeder seed indent. Annual export earnings from IARI Basmati rice varieties are around ₹ 30,000 crores. The economic surplus from Basmati rice varieties PB 1121 and PB 1509 is about ₹ 53,800 crores; for wheat varieties HD2967 and HD3086, it is approximately ₹ 98,425 crores. Pusa Mustard 25 generates an annual average income of ₹ 2919 crores.

Considering climate change and limited resources, the school needs effective strategies to improve yield through hasten the genetic gain, harness heterosis, improve stress resistance, and meet consumer demand for nutritious crops. There is potential for scaling up seed production to the meet the increasing demand of IARI crop varieties.

5.2 School of Horticultural Science

The research in School of Horticultural Science consists of Division of Vegetable Science, Division of Fruits & Horticultural Technology, Division of Floriculture & Landscaping, Division of Post Harvest Technology and Center for Protected Cultivation Technology (CPCT) at New Delhi, and IARI Regional station at Katrain, Himachal Pradesh. The research work in this school was carried under 9 different projects and one flagship project, which are listed below:

1. Pre-breeding for biotic and abiotic stress resistance and quality in selected vegetable and flower crops.
2. Genetic improvement of selected annual open field vegetable & flower crops.
3. Genetic improvement of selected perennial fruit and ornamental crops.
4. Development of improved technologies for higher yield and quality in selected fruit crops.
5. Development of technologies for higher yield in important flower crops and turf grass management.
6. Development of technologies for realizing production potential of new varieties and hybrids of vegetable crops.
7. Integrated approaches for pre- & post-harvest loss reduction and quality enhancement in fruits and vegetables.
8. Development of nutraceutical & functional food from horticultural produce and cereal & pulse-based convenience food products.
9. Development of Hi-tech cost-effective technologies for protected horticulture.
10. **Flagship project:** Breeding vegetables and flowers for protected environment

Achievements

Improved crop cultivars released

A total of 55 improved horticultural crop varieties have been released during 2017-2022 including vegetables (33), fruits (13), and flowers (9). The crop-wise details are presented below and Table 5.3.

Vegetable crops

Pre-breeding activities were performed in 11 vegetable crops for identification and introgression of gene(s)/QTLs governing important traits. More than 1129 germplasm (including wild species) were screened and identified resistant donor sources for important diseases in different vegetable crops.

Table 5.3. List of varieties and hybrids developed in various horticultural crops during 2017-18 to 2021-22.

S. No.	Crop*	Varieties
Vegetable crops		
1.	Tomato (2)	**Hybrids**: Pusa Rakshit (PC), Pusa Cherry Tomato-1 (PC)
2.	Brinjal (4)	Pusa Hara Baingan 1, Pusa Safed Baingan 1, Pusa Oishiki, Pusa Vaibhav
3.	Onion (2)	Pusa Shobha, Pusa Sona
4.	Okra (2)	Pusa Bhindi 5 **Hybrid**: Pusa Okra Hybrid 1
5.	Cauliflower (2)	**Hybrids**: Pusa Cauliflower Hybrid 3, Pusa Hybrid 301
6	Cabbage (2)	**Hybrids**: Pusa Hybrid 81, Pusa Red Cabbage Hybrid 1
7.	Cucumber (4)	Pusa Long Green, Pusa Seedless Parthenocarpic Cucumber-6 (PC), Pusa Pickling Cucumber-8 (PC) **Hybrids**: Pusa Gynoecious Cucumber Hybrid-18
8.	Musk melon (4)	Pusa Sarda (PC), Pusa Sunehari (PC), Pusa Madhurima, Pusa Kazri
9.	Gourds (2)	Pusa Sponge Gourd 29 (Sponge gourd) **Hybrids**: Pusa Shrestha (sponge gourd)
10.	Bitter gourd (2)	**Hybrids**: Pusa Hybrid 4, Pusa Hybrid 5
11.	Other cucurbits (1)	Pusa Shreyash (Summer squash) (PC)
12.	Legume vegetables (3)	Pusa Dharni (Cowpea), Pusa Sem-5, Pusa Garima (Dolichos bean)
13.	Leafy vegetables (3)	Pusa Vilayati Palak (spinach), Pusa Green (bathua), Central Kale Pusa 64 (Kale)
Fruit Crops		
14.	Mango (6)	Pusa Pratibha, Pusa Shreshth, Pusa Lalima, Pusa Peetamber, Pusa Deepshikha and Pusa Manohari
15.	Sweet Orange (2)	Pusa Round and Pusa Sharad
16.	Acid Lime (2)	Pusa Abhinav and Pusa Udit
17.	Guava (2)	Pusa Pratiksha and Pusa Arushi
18.	Papaya (1)	Pusa Peet
Flower crops		
19.	Marigold (2)	Pusa Bahar and Pusa Deep
20.	Rose (2)	Pusa Mahak and Pusa Alpana
21.	Gladiolus (2)	Pusa Sinduri and Pusa Shanti
22.	Chrysanthemum (3)	Pusa Guldasta, Pusa Shwet and Pusa Sundri

*In parentheses are number of varieties/hybrids; PC-for protected cultivation.

These sources utilized for development of genetic stocks. The progenies have been developed for sourcing resistance to different diseases through interspecific crosses in tomato for ToLCV, okra for YVMV, cauliflower for black rot and Alternaria leaf spot, onion for *Stemphylium* blight and garden pea for *Fusarium* wilt. Introgression of male sterile cytoplasms of *Trachystoma balli* and *Diplotaxis catholica* into cauliflower has been advanced to BC_6 generation. *Erucastrum canarianse* male cytoplasm has been deployed in 11 elite inbred lines of Indian cauliflower which are being used in hybrid development. Four genetic stocks for processing purpose tomato were identified which are being used in breeding varieties with processing quality. Protocols for *in vitro* regeneration, genetic transformation and embryo rescue were standardized for sweet pepper and cauliflower for use in pre-breeding.

Disease resistant varieties of okra

In Okra, Pusa Bhindi 5 was developed and released as a high yielding and field resistance variety. It is suitable for both *Kharif* and spring-summer seasons. The average yield potential is 18.0 t/ha. National Seed Corporation (NSC) has produced greater than 1000 quintals seeds and covering significant area. It is licensed to four private seed companies. Pusa Okra Hybrid 1 is a new high-yielding hybrid with resistance to YVMV and Enation Leaf Curl Virus (ELCV).


Pusa Bhindi 5

High yielding onion varieties

In onion, two varieties namely Pusa Shobha and Pusa Sona were developed and released for cultivation. They produce compact bulbs and have potential for processing. These are suitable for *Rabi* season and contributing to onion production. Two MoU of Pusa Shobha has been done with private seed companies.

Development and use of genetic mechanisms for hybrid development in vegetables

The refined *Ogura*-CMS system is a robust genetic mechanism for hybrid seed production in Cole crops. Indigenous CMS lines were developed and utilizes in breeding hybrids in cauliflower (4) and cabbage (3). Pusa Cauliflower Hybrid-3 (39 t/ha) and Pusa Snowball Hybrid-1 (45 t/ha) are the first CMS based hybrids in Indian public sector in tropical and snowball groups, respectively.

Pusa Cauliflower Hybrid 3

The CMS lines were used in development of Pusa Hybrid-81 and Pusa Hybrid 82 in cabbage. In cucumber, gynoecy was established in tropical backgrounds and utilized in development of Pusa Gynoecious Cucumber Hybrid-18. These endogenous hybrids have been notified and licensed with two seed companies. Their 'IARI Seeds' are available at affordable seed price to benefit the Indian farming community.


Pusa Cauliflower Hybrid 3

Vegetable varieties/hybrids for protected cultivation

Protected cultivation is an emerging option for realizing higher yield and better quality of vegetable crops. However, exorbitant seed price is a big challenge to the growers and to address this, IARI has taken up challenge for breeding indigenous varieties in major polyhouse crops. Total eight varieties have been developed and released for protected cultivation. Pusa Rakshit showed high yield potential of 15.0 q from 100 m^2 in a period of 7–8 months. Pusa Parthenocarpic Cucumber-6 yielded 126.0 t/ha under naturally ventilated polyhouses. These varieties were notified by CVRC and their 'IARI Seed' has been made available for the farmers at affordable prices. Pusa Gynoecious Cucumber Hybrid 1 and Pusa Sarda were licensed with M/s VNR Seeds, Raipur and M/s Sagar Biotech Private Limited, Surat.


Pusa Parthenocarpic Cucumber 6


Pusa Rakshit

Biofortified varieties/lines in vegetable crops

In line of diversifying the Indian food basket, biofortification of cauliflower and cabbage is being undertaken by IARI at Delhi and Katrain centres. Anthocyanin rich cauliflower (Pusa Purple Cauliflower 1; 43.7 mg/100g fw), cabbage (Pusa Red Cabbage Hybrid 1; 7.94 mg/100g) and Dolichos bean (Pusa Sem 5) were developed and released. Their 'IARI Seed' is available at affordable price for commercial cultivation. First sub-tropical anthocyanin rich 'Pusa Purple Broccoli-1' was developed. Introgression of *Or* gene in Indian cauliflower resulted in five fixed lines which are being used to hybrids to contribute in food-based approaches to fight against vitamin-A deficiency. Further, nutrient-rich indigenous varieties namely Pusa Vilayati Palak (Vit. C), Bathua-Pusa Green (iron) and Central Pusa Kale 64 (carotenoids) were developed. These varieties offer diversification for food basket with nutrient-rich vegetables for Indian consumers.

Pusa Purple Cauliflower 1

Pusa Red Cabbage Hybrid 1

Genetic and genomic resources

Total 19 germplasm with unique traits in vegetable crops have been registered with Plant Germplasm Registration Committee, NBPGR, New Delhi. These includes cauliflower (10), tropical carrot (3), cabbage (2), chilli (2), sponge gourd (1) and broccoli (1). These genetic stocks are being used for breeding and licensing.

During the period, 12 QTLs for curding traits in cauliflower, two flanking markers (SSR01148 and SSR 01012) for parthenocarpy (*Parth6.1* and *Parth6.2*) locus in cucumber, linked markers for gynoecious trait in bitter gourd, SSRs linked with downy mildew and black rot resistance as well as *Or* and *Pr* gene in cauliflower have been identified. Pyramiding of downy mildew resistance (*Ppa3*) and black rot resistance (*Xccbo1*) has been done in early cauliflower. The SSRs/SCARs/CAPS markers were developed for background/foreground selection and being used in marker assisted breeding while fine mapping of QTLs is under progress.

Technology development

Significant advancements in vegetable cultivation techniques have been achieved through meticulous studies, particularly in the cultivation of vegetable pea, garden pea, okra, cauliflower, and onion. In the case of vegetable pea, irrigation at 50% of available soil moisture depletion (ASMD) demonstrated significantly higher green pod yields (2.7-22.1% increase) over other schedules. Integrated nutrient management (INM) practices in garden pea showcased that a combination of fertilizer, vermicompost, and zinc sulfate resulted in superior pod yields and increased efficiency metrics. Zero-tilled okra cultivation, under various crop residues and irrigation regimes, displayed comparable yields between recommended and 30% ASMD irrigation, emphasizing water-saving potential. Onion and cauliflower showed significant response of INM for yield, input use efficiency, and economic returns. Water economization strategies in cauliflower, incorporating planting on ridges and furrows, exhibited superior curd yields and substantial water savings. Furthermore, weed management practices in cauliflower and studies on the production potential of cowpea varieties elucidated effective methods for optimizing yields. Phosphorus level optimization in cowpea varieties revealed that 'Pusa Dharni' performed exceptionally well for yield and economic returns.

Fruit Crops

Significant varietal development in mango, citrus, guava, grape and papaya have been achieved with the release and notification of 19 hybrids and cultivars.

Varietal development

In mango, four hybrids Pusa Pratibha, Pusa Shreshth, Pusa Lalima, and Pusa Peetamber were released in 2020 for NCT of Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Rajasthan, Punjab, Rajasthan, West Bengal, Jharkhand and Odisha. Additionally, two mango hybrids Pusa Deepshikha and Pusa Manohari were released in 2021 for commercial cultivation in NCT Delhi. These releases, authorized by the Central and State Seed Sub-Committees, mark a notable advancement in mango varieties. These mango hybrids are available with the institute for non-exclusive licensing. MoUs have been signed with M/s S.L. Orchards, Haryana, M/s Nirmal Nursery, Dehradoon, Uttarakhand, M/s Seven Star Fruit Pvt. Ltd., Nashik, Maharashtra and M/s Shelter Agri-Horti Farm Pvt. Ltd,

Pusa Lalima (Dashehari x Sensation) | Pusa Pratibha (Amrapali x Sensation) | Pusa Shreshth (Amrapali x Sensation) | Pusa Peetamber (Amrapali x Lal Sundari) | Pusa Deepshikha (Amrapali x Sensation) | Pusa Manohari (Amrapali x Lal Sundari)

Kolkata, and a revenue of ₹ 11,75,000/- was generated as license fee. There is a huge demand of these coloured mango hybrids among farmers and 12,500 grafted plants and scion sticks have been supplied to the farmers from different parts of the country.

In citrus, two cultivars Pusa Abhinav (acid lime) and Pusa Round (sweet orange) were released at the national level. Four more citrus cultivars Pusa Udit (acid lime), Pusa Sharad (sweet orange), Pusa Lemon-1 (lemon), and Pusa Arun (pummelo) were released for NCT of Delhi. The diverse range of citrus varieties underscores the progress made in citrus farming.

Grape cultivation also witnessed advancements with the release of two grape hybrids Pusa Urvashi and Pusa Aditi suitable for table purpose and juice making. Additionally, an extra early maturing grape hybrid Pusa Purple Seedless developed through *in-ovulo* embryo rescue technique was released for NCT of Delhi. These varieties are in great demand and IARI has supplied 8,601 saplings to the farmers.

Identification of QTLs for fruit colour in mango

Illustrious work on construction of a high-resolution integrated genetic map based on segregation from female, male, and both parents would serve as a valuable genomic resource in mango. Identification of four QTLs on Chr 3 and two QTLs on Chr 18 for peel color using Amrapali/ Sensation full-sib progenies have significance in improving mango breeding efficiency.

Identification of trait specific hybrids/ germplasm

Low temperature tolerant advance lines of papaya P-9-5 and P-7-9, virus tolerant papaya Pusa Sel. 1 and Pusa Sel. 3, cluster bearing walnut Pusa Khor, dwarfing *Malus* rootstock Pusa Apple Rootstock-1, red pulped and soft-seeded guava hybrid GH-2016-8F (Thai x Punjab Pink) and two citrus canker immune hybrids ACSH-3-2/18 and ACSH-9-13/18 were identified. These valuable genetic resources will be used in future breeding programmes.

Technology development

In mango, genetic studies revealed novel hyper-variable SSRs M15, M73, M109 and P125 for parentage ascertainment in open-pollinated population. The development of 2,151 new SSRs from the Amrapali genome enhanced breeding efficiency. Identification of ripening gene-specific markers, and the validation of differentially expressed genes showcased substantial progress. Identification of SCAR markers KBT5, SDP and PMSM 2 linked to sex-forms in papaya are useful in identification of male and hermaphrodite plants at the nursery stage.

The creation of enriched genomic libraries in guava led to the design of 38 novel genomic SSRs, fostering genetic diversity studies in guava. Breakthroughs in citrus include protocols for haploid production and hybrid seedling recovery, identification of important rootstock genotypes, and standardization of mutagenesis techniques. In pummelo, genetic improvement led the registration of five clones and development of seedless Pusa Arun. Diverse *Vitis* species and wild grapes have been collected to broaden the genetic pool for crop improvement and resilience against stresses. Mutagenesis in papaya resulted in dwarf and precocious lines, offering potential traits for further breeding and cultivation.

Rootstock research led the identification of dwarfing K-2 rootstock in mango for high-density planting, and SCSH 17-12, SCSH 9-19, Billikichli, RLC-4, Yama Mikan, and C35 of citrus for alleviation of abiotic stresses and improving orchard yield efficiency.

Floriculture and landscaping

Pre-breeding

Promising lines of rose were developed through hybridization using powdery mildew resistant and susceptible species. Protocol developed for direct shoot organogenesis from immature achenes of promising hybrids in rose. Phylogenetic relationship among *Rosa* species was established using morphological and molecular markers (SSRs). The DNA barcodes of different rose species have been generated using ITS-16, matK-17, rbcL-23, trnH-psbA-21 and ycf1b-24 markers, and a total of 101 novel nucleotide sequences of genus *Rosa* were submitted to NCBI, USA.

Varietal development

The varieties developed in different flower crops include Pusa Bahar (African type) and Pusa Deep (French type) of marigold, Pusa Mahak and Pusa Alpana of rose, Pusa Shanti and Pusa Sinduri of gladiolus, Pusa Guldasta, Pusa Shwet and Pusa Sundri of chrysanthemum showcased advancements in ornamental plant breeding. The development of early-flowering varieties in marigold, loose flower varieties in rose, high corm and more florets yielding gladiolus and high yielding spray varieties in chrysanthemum aligns with market preferences and contributes to the ornamental plant industry.


Pusa Mahak

Rose varieties Pusa Lakshmi (RH-24-2017) and Pusa Bhargav (RS-01-2016), French marigold varieties Pusa Utsav (Fr./R-51) and Pusa Parv (Fr./R-5-2), gladiolus hybrid Pusa Rajat, chrysanthemum variety Pusa Lohit and bougainvillea mutant Pusa Akansha were identified by IVIC for release.

Technology development

Phytoplasma from rose (*Rosa × hybrida* L.) was characterized using gene specific primers, and alternative host for phytoplasma and its vector was identified. Nucleotide sequences of rose phytoplasma were submitted in GenBank, NCBI, USA. Protocol for *in-vitro* multiplication of promising rose hybrids/varieties has been standardized. Rose varieties have been profiled for volatile compounds using GC-MS and for pigments using HPLC. Screening of chrysanthemum varieties for salt tolerance was carried out under hydroponic system and Little Pink, Lalit, Haldighati and Pusa Aditya were found to be tolerant. Developed *in-vitro* protocol for direct shoot organogenesis/ direct regeneration in African marigold var. Pusa Narangi Gainda and French marigold var. Pusa Deep. Optimized the protocol for *in vitro* maintenance of male sterile lines of marigold. Induction of haploids and doubled haploids (DHs) was carried out in marigold using anthers and ovules. Protocol for *in vitro* mass multiplication of DH line of African marigold var. Local Orange derived through ovule culture was optimized. Protocol was standardized for *in-vitro* mass multiplication of *Eustoma*.

Technological advancements for enhanced yield in flower crops and turf grass management have been achieved through various studies. In LA hybrid *Lilium* cv. Pavia, foliar spray of NPK @ 550 ppm and GA_3 @ 300 ppm demonstrated improved vegetative growth, superior flower and bulb production. Similarly, in LA hybrid *Lilium* cv. MASAI a combination of organic manure (FYM) @ 25 t/ha and inorganic fertilizer ($N:P_2O_5:K_2O$) at 160:120:100 kg/ha outperformed over the control for plant height, leaf length, early flowering, stalk characteristics, bulb, and bulblet production. Evaluation of 17 turf grass species and varieties showed favorable growth under Delhi conditions. Turf species *viz.*, Crow Foot Grass, St. Augustine and Zoysia performed well at a high shade level of 75 per cent. The combinations of sand, cocopeat, and perlite (1:1:1) proved effective for *Bougainvillea* propagation.

In INM of gladiolus varieties namely Pusa Red Valentine and Pusa Jyotsna, application of 75% RDF+ FYM @ 5 t/ha + vermicompost @ 5 t/ha + Azospirillum + PSB proved to be effective for various growth, flowering and corm parameters. In chrysanthemum variety Mayur, foliar spray of $FeSO_4$ + $ZnSO_4$ @ 0.5% each demonstrated better results for various parameters. Cost-effective production technology for ornamental potted plant namely *Syngonium* highlighted the success of treatments such as water-soluble fertilizer @ 2 g/kg soil + VAM @1.5 g/kg soil) with reference to overall growth, development and presentability.

Experiments on alleviating cold stress in marigold varieties showed promising results with Chito oligosaccharides and arbuscular mycorrhiza treatments, especially under protected structures. A sub-project focused on irrigation scheduling and nutrient management in gladiolus demonstrated that 7 irrigations at 15-day intervals after planting, along with specific nutrient applications, resulted in optimal plant height, spike length, and rachis length.

Vacuum drying proved effective for retaining betalains and antioxidant activities in bougainvillea bracts, carotenoids in marigold and anthocyanins in roses. Natural dyes extracted from rose and annual flower crops, including *Linum*, *Coreopsis*, *Godetia*, and *Dahlia*, exhibited optimal fixation when alum was used as a mordant. Among different nano particles, silicon nano particles were found better in enhancing the vase life of gerbera. The study on post-harvest attributes of chrysanthemum cv. Yellow Star revealed that treatment comprising of ascorbic acid and Thidiazuron improved vase life, weight gain, flower diameter, and chlorophyll content. Packaging in HDPE bags enhanced the shelf-life of loose marigold flowers with better moisture and color retention. Dye extraction from rose petals showed stability in acidic pH solutions and vulnerability to high temperatures.

Food Science & Post Harvest Technology

The integrated pre- and post-harvest management studies aimed to retain the fruit and vegetable quality and enhance shelf-life through various techniques. Dashehari showed optimal ripening with <100 ppm ethylene while Chausa and Langra required ≈100 ppm ethylene for 24 hours at 24 ±2 °C and 95% RH. Pre-harvest fruit bagging with polypropylene non-woven bags in litchi cv. Shahi increased fruit weight, TSS, and reduced cracking and fruit borer incidence. Ethylene dose of 110 ppm with 12 hours holding time proved ideal for fruit ripening of sapota variety

Cricket Ball under ripening chamber. For Kinnow mandarin, pre-harvest fruit bagging with polypropylene non-woven bags significantly increased fruit size to 220 g and reduced bruising by 11.1 per cent. Litchi pericarp browning was mitigated by treating fruits with Generally Regarded as Safe (GRAS) sodium hypochlorite and potassium metabisulfite found to be the most effective. Exotic (Surround™) and indigenous (PCS 4™) particle films demonstrated improved colour, fruit quality, and reduced incidence of disease and insect-pests in apple and pomegranate. Pre-storage calcium lactate impregnation (CL @100 mM) extended shelf-life additionally by five days in bitter gourd. Ultrasound-assisted extraction of phenolics from potato peels and the use of *Pseudomonas* as a postharvest fumigant against anthracnose in mango demonstrated innovative approaches for quality preservation and postharvest control of anthracnose. Development of nutraceutical and functional foods, including drinks from black carrots and polyphenolic extraction from citrus peels were standardized. Various innovative products such as gluten-free amaranth pasta, oat cookies with citrus flavonoids, fibre rich muffins, lentil crisps showcased novel ways of incorporating functional ingredients. New products and techniques such as Pusa Pearl Puff, Fiber Pro-antioxidant rich Muffins, Ready-to-eat Aonla Nutra-candy, low-calorie Aonla and Beetroot Crackers, Pusa Nutri Cookies, extraction technology of anthocyanin pigment from black carrots, postharvest ultraviolet-C treatment for better shelf-life and quality of bitter gourd were developed. Patent was granted for the technology of 'heat-stable anthocyanin rich composition and process of its preparation' (Patent No. 321722, dt 27.09.2019). The technology was licensed to three companies, namely, Ozone Biotech Faridabad, Paristha Industries, Hyderabad (Sai Ram) and South Asian Biotechnology Centre, Delhi and a revenue of ₹ 11.0 lakhs was generated.

School of Horticulture is undertaking basic, applied and strategic research in different horticultural crops and has developed and notified 55 varieties / hybrids in different crops *viz*., vegetables (33), fruits (13) and flowers (09) during the period. More than 100.6 q of breeder seeds of vegetable varieties were produced and supplied to NSC/ NHRDF/ KVKs/SAUs for further multiplication and dissemination. Seeds of okra variety Pusa Bhindi-6 was produced at large scale by NSC and marketed more than 1,000 q quality seeds. Similarly, seeds of marigold varieties Pusa Narangi, Pusa Basanti and Pusa Bahar were produced by SPU, IARI and marketed. Besides, 631.0 q of TL seeds were also produced and distributed among farmers. In fruit crops, more than 21,000 grafted plants/ scion sticks of mango, citrus and grapes have been supplied to fruit growers. In order to commercialize horticultural technologies through licensing, 20 MoU were signed in vegetable crops worth of ₹ 40.12 lakhs and 4 MoUs of mango hybrids for ₹ 11.75 lakhs. A patent was granted for the technology of 'heat-stable anthocyanin rich composition and process of its preparation' (Patent No. 321722, dt 27.09.2019), licensed with three companies and a revenue of ₹ 11.0 lakhs were generated. Besides, novel nutraceutical and functional food items *viz.*, Capsicum Salsa, Ready-to-eat Aonla Nutra-candy, Low-calorie Aonla and Beetroot Crackers, Pusa Nutri Cookies, Pusa bitter gourd chips, Pusa Pearl Puff, RTR GLV Powder, Fiber Pro-antioxidant rich Muffins have been commercialized.

Breeding efforts resulted good leads to carry forward the work in the mandate horticultural crops for most of the economic traits such as stress tolerance and quality traits (processing, nutritional value, and export traits). However, slow pace and large breeding materials are affecting precision, and there is dire need to utilize modern breeding and genomic tools for understanding the basics as well as to utilize the tools for ease of breeding processes.

Upscaling of seed production of improved varieties suitable for protected cultivation would certainly help the growers by providing seed of high value crops at cheaper rates which is otherwise imported and has very high cost. Increasing awareness about benefits of consumption of healthy home-grown foods is attracting Indian cities towards urban gardening, however, such movement require customized gardening modules and techniques to support urban gardeners. Rootstock research in mango, citrus, grape and guava has resulted in identification of superior genotypes imparting dwarfing in scion varieties and/or having biotic and abiotic stress tolerance. Further testing of these rootstocks for their compatibility with diverse scion varieties under differential environment would provide opportunity for rootstock selection in optimizing fruit crop performance under problematic soils.

5.3 School of Plant Protection

The School of Plant Protection consists of Division of Plant Pathology, Division of Entomology, Division of Nematology and Division of Agricultural Chemicals at New Delhi, IARI Regional station at Kalimpong, West Bengal, and IARI Regional station at Pune, Maharashtra.The School of Plant Protection carried out eight different projects, which are listed below:

1. Biosystematics of insects, fungi, bacteria and nematodes of economic importance
2. Studies on population dynamics / epidemiology, host-plant relationship, tritrophic interactions, and development of pest management strategies in relation to climate change and contemporary cropping systems

3. Studies on biochemistry, physiology and molecular biology of insects and nematodes of economic importance
4. Development of novel chemicals, toxicological evaluation, structure-activity relationships and formulations for crop protection
5. Assessment and management of contaminants in agricultural produce and in the environment
6. Identification of important plant viruses and virus like pathogens, their characterization, diagnostics and application of emerging technologies for management and host virus interaction
7. Virulence, variability, pathogenomics and diagnostics of major fungal and bacterial plant pathogens
8. Interactions of parasitic and beneficial nematodes with rhizosphere, microbes and insect pests

Achievements

Pest and pathogen identification and characterization

A total of 9752 insect and nematode specimens identified, and 55847 insect specimens collected across India were documented. New insect genera (*Chandra*), subgenus (*Panjal*, a new subgenus of the genus *Crossocerus*), and many species of insect orders like Hymenoptera, Lepidoptera, Hemiptera, Coleoptera and Diptera were identified and documented. First records on some insects from India, and new geographical and locality records within India were also documented for these insect orders. More than 500 species with additional characters were redescribed, 15 checklists along with identification keys for the Indian species were prepared along with identification keys, >700 DNA barcodes were generated and submitted to NCBI, 50,000 insects, 462 type specimens were augmented in National Pusa Insect Collection, and 5000 features of insects were digitized.

Four new nematodes species *viz.*, pin nematode, *Paratylenchus jasmineae* sp. n., predatory nematode *Mylonchulus tuberosei* sp. n. (Nematoda: Mononchida), *Oscheius indicus* n. sp., *Discolaimus pusai* sp. n. (Nematoda: Dorylaimida) were identified. Three nematode species *viz.*, *Hemicriconemoides rosae* in sugarcane from Meerut, Uttar Pradesh, *Heterodera koreana* from bamboo (*Bambusa tulda*), and *Meloidogyne enterolobii* infecting guava in the Coimbatore region of Tamil Nadu were redescribed. The spread route of potato cyst nematodes (PCNs) in India was determined using species-specific microsatellite markers Indian populations of PCNs were genetically identical, and grouped with the B2 cluster from Bolivian PCN populations. Loop-mediated isothermal amplification (LAMP) assay was developed for rapid detection of potato cyst nematodes (PCN) *Globodera rostochiensis,* and entomopathogenic nematodes, *Heterorhabditis* spp. and *Steinernema* spp. from total soil DNA.

A total of 4150 fungal cultures were maintained in Indian Type Culture Collection. More than 50000 disease specimens were preserved in HCIO facility. HCIO checklist of *Cercospora* spp. was documented and published consisting of a compilation of 489 species with 603 of host plants collected between 1894 and 2018. Strategy for mitigating the threat from Ug99 and wheatblast in wheat was formulated. Wheat breeding material from IARI was sent for evaluation through IIWBR, Karnal to Kenya for evaluation that led to lines resistant to Ug99.

Twenty isolates of *Bipolaris oryzae* infecting rice, 77 isolates of *Magnaporthe oryzae* and *M. grisea* infecting rice, pearl millet, finger millets, 105 isolates of *Rhizoctonia solani* infecting rice and other crops, 28 isolates *B. maydis,* 10 isolates of *Fusarium fujikuroi,* 56 isolates of *Ustilaginoidea virens,* 30 isolates of *Fusarium graminearum,* 20 isolates of *Tilletia indica,* 15 isolates of *Xanthomonas vesicatoria* and 70 isolates *of Ralstonia solanacearum* were established. A new species of *Trichoderma* named *T. dumbbelliforme* was identified. Association of *Fusarium falciforme* with guava wilt disease and *Sclerotium hydrophilum* in rice of Northern states were reported. Virulence analysis of various isolates of important fungal and bacterial pathogens *viz., Magnaporthe oryzae, R. solani, Ustilaginoidea virens, Fusarium graminearum, Blumeria graminis tritici, Xanthomonas euvesicatoria, X. euvesicatoria* was studied. Cross infectivity of *Bipolaris sorokiniana* and *B. oryzae* on rice and wheat was confirmed through phenotyping and species-specific markers. Whole proteome of *Rhizoctonia solani* AG1-IA (strain 1802KB Genebank ID: 16395) and AG2-2 (Genebank ID: 2318768) were compared using orthovenn and PHI database.

Virome analysis established presence of tobacco etch virus (*Potyviridae*), barley yellow mottle virus (*Potyviridae*), soybean chlorotic mottle virus (*Caulimoviridae*) and tospovirus resistance protein B in brinjal, and contigs of six viruses were identified in apple. Full genome sequences of new genetic variants of banana streak MY and IM viruses infecting triploid banana hybrids were deciphered. First reports on i. association of carrot thin leaf virus (CTLV) and cherry tomato leaf curl virus, ii. *Candidatus P. aurantifolia* (16Sr II D group) phytoplasma from *Daucus carrota* and iii) seasonal dynamics of viruses in grapevine were published from India. 16SrII-C and 16SrII-D phytoplasma strains associated with phyllody and axillary shoot proliferation in papaya were characterized.

A rapid and efficient loop-mediated isothermal amplification (LAMP) method was developed for the detection of *Fusarium graminearum*, *Tilletia indica* and *Puccinia triticina*. A novel qPCR-based marker was developed for the detection of *Tilletia caries*. PCR, real time PCR and LAMP based assays using NRPS31 gene were developed for the detection of rice bakanae disease. PCR, RT-PCR and RPA based detection assays of *Rhizoctonia solani* of rice were developed using BrD gene. Conventional and real time PCR based marker for the detection of *Bipolaris oryzae* causing brown spot of rice was developed and validated. PCR based multiplex marker to detect *Ralstonia solanacearum* and *Xanthomonas euvesicatoria* from seeds were developed. A virulence gene based specific marker for detection of *avrXccC, avrBs1, avrGf1 genes* of *Xanthomonas campestris* pv. *campestris* causing black rot in cruciferous crops was developed.

Simplified isothermal recombinase polymerase amplification assay was developed for detection of *Candidatus Liberibacter asiaticus*, banana streak MY virus, onion yellow dwarf virus, cucumber mosaic virus, banana bunchy top virus. A lateral flow based LF-RPA assay was developed for *Candidatus* Liberibacter asiaticus. An attenuated total reflection (ATR)-mediated localized surface-plasmon-resonance-based optical platform for the detection of chilli leaf curl virus in chilli leaf samples was developed. A duplex PCR assay for simultaneous detection of chickpea chlorotic dwarf virus and peanut witches' broom phytoplasma in chickpea was developed. A multiplex RT-PCR for simultaneous detection of 4 orchid viruses *viz.*, cymbidium mosaic virus (CymMV), odontoglossum ringspot virus (ORSV), calanthe mild mosaic virus (CalMMV) and ground nut bud necrosis virus (GBNV) was developed. A multiplex PCR system for simultaneous detection of GBNV, WBNV & CaCV in plant and thrips samples was standardized. Monoclonal antibodies were produced for PVX, PVS, PVM, PVY, ToLCNDV, CMV, BBrMV, CyMV, and ORSV and successfully used in ELISA and IC-PCR. Lateral flow device was developed for PVX, ORSV, CyMV, and PVS. Using the invitro expressed coat protein of rice tungro bacilliform virus, polyclonal antibodies were produced, and used in serological detection at a dilution of 1:200. A multiplex PCR was developed and evaluated for simultaneous detection of clostero-, badna- and mandari-viruses along with huanglongbing bacterium in citrus trees.

CYVMV based replicon vector were utilized for knocking out PDS gene in *Nitotiana bentamiana* through CRISPR-Cas9. Antiviral activity of dsRNA derived from the NSs gene of GBNV was validated and used in direct foliar application which prevented virus accumulation and symptom expression. Five dsRNA constructs

(AC1, AC2, AC4, AV2) of ToLCNDV and beta C1 of CYVMV were developed. Comparative transcriptome of tomato during GBNV infection was deciphered. A protocol for begomovirus transmission by single whitefly (*Bemisia tabaci* Asia II 1) was standardized for screening for resistance.

Physiological and molecular studies on insects, nematodes and pathogens

A comprehensive study on spotted stem borer, *Chilo partellus* revealed that insect undergoes hibernation in North and aestivation under South Indian conditions. The diapause in *C. partellus* is governed by overdominance gene effects with deleterious effects on post-diapause development, reproductive physiology, and population build-up. During hibernation, a significant increase in α-Ecdysone and Juvenile hormone and reduction in β-Ecdysone, while during aestivation, no change in α-Ecdysone and increase in β-Ecdysone and Juvenile hormone as compared to nondiapause *C. partellus* was registerd.

Four different biotypes of *C. partellus viz.*, Hisar, Hyderabad, Parbhani and Coimbatore region exist in India, suggesting that sorghum and maize genotypes need to be tested against these populations to identify stable sources of resistance. The Ikemoto & Takai (linear), and Lactin-1 and Lactin-2 (non-linear) models were found efficient for describing temperature-dependent development and predicting seasonal emergence, number of generations and population build-up of *C. partellus*. The first ever whole genome sequencing of *C. partellus* was accomplished, with genome size ≈ 332.2 Mb.

Temporal and spatial dynamics of endosymbionts of *Bemisia tabaci* Asia II-1 revealed significant variation in profile of key facultative endosymbionts. Horizontal transmission of the endosymbionts and endophytes across plant and insect systems in cotton /Tomato- *B. tabaci* system was reported. Oral delivery of dsAgsuc1 in *Aphis gossypii* induced around 50% mortality in nymphs and reduced 39-43% survival in off-springs, thus *Agsuc1* gene could be used for developing transgenic plants for management of the pest.

Sex-based variance in structural and functional diversity of the midgut bacterial community of last instar larvae of pink bollworm studied through metagenomics of 16S rRNA V3-V4 region revealed predominance of *Proteobacteria, Firmicutes*, and *Actinobacteria* in male, suggesting sex-based variation in gut bacteria with vital role in metabolic and physiological activities of pink bollworm. Significantly greater alkaline phosphatase and leucine aminopeptidase N activity in the BG II resistant Guntur population as compared to Delhi (Lab-Sus) population was established. The Cry1Ac resistant (Guntur) and Cry2Ab resistant (Parbhani) populations also showed high activity of alkaline phosphatase than control.

Transcriptomic studies were used to understand host-nematode interactions. Interaction among five esophageal gland genes and cell wall degrading enzymes during infection of *Meloidogyne incognita* was established using RNAi. Host-induced gene silencing strategy was used to generate the transgenic eggplants expressing *msp-18* and *msp-20*, independently. The rice-root-knot nematode, *Meloidogyne graminicola* genome was sequenced. A rice root-knot nematode, RRKN resistant mutant Line-9 showed differential expression of 674 transcripts, and early regulation of genes related to nematode pattern recognition. First transcriptomic comparison of nematode-resistant and susceptible rice plants in the same genetic background was reported for better understanding of mechanisms underlying plant-nematode resistance in rice. The genome sequence of wheat seed-gall nematode *Anguina tritici* (using Illumina MiSeq platform) revealed an estimated size of 164 MB, having 39,965 protein coding genes at 60-fold coverage, and a GC content of 38%.

The role of insect gut receptors in TcaB intoxication process was established, and a cadherin-like gene*GmCAD* was cloned from *G. mellonella*. A candidate toxin gene, PirB was characterized from entomopathogenic bacterium, *Photorhabdusluminescens* subsp. *akhurstii*.

Insecticide resistance in insects

Insecticide resistance studies in Asia II 1 genetic group of *B. tabaci* revealed low to moderate level of resistance against pyrethroids and neonicotinoides, and CYP genes *viz., CYP6CM1, CYP4C64, CYP4CX1* were confirmed imparting resistance to imidacloprid. The phosphine resistance gene *rph 1* was characterized as *"a cytochrome b5 fatty acid desaturase* (*Cyt-b5-r*)" in *T. castanauem, R. dominica, S. oryzae* and *C. ferrugineus*. Insecticide susceptibility studies in rice brown planthopper, *Nilaparvata lugens* revealed high susceptibility to triflumezopyrim and low susceptibility to imidacloprid. Sequential application of Neemazal, Neem oil and Triflumezopyrim was established as most effective for management of planthoppers.

A multiplex PCR protocol was developed for quick diagnosis of phosphine resistance in key stored product insect pests. Another PCR based molecular diagnostics was developed for detection of pyrethroid resistance in *Tribolium castaneum* and *Sitophilus oryzae*.

Insect/ Pathogen-Plant Interactions

Resistant genotypes were found to impart adverse effects on development, survival, progeny production in either of the borer species like *Chilo partellus, Sesamia inferens* and *Spodoptera frugiperda,* regulated through diverse constitutive and induced biochemical mechanisms of resistance. The *Brassica juncia* genotypes viz., RLC 3, IC 355399, Rohini, GP 454, NPJ 50, TS 18-5124 and Kranti were found to have diverse physico-chemical defense mechanisms imparting adverse effects on the reproductive biology and survival of *Lipaphis erysimi,* and thus can be used in *Brassica* improvement program. The low glucosinolate *B. juncea* genotypes were more preferred and had positive impact on the developmental biology of mustard aphid in comparison to medium and high glucosinolate genotypes. A total of 337 genotypes evaluated for resistance against brown plant hopper revealed high level of resistance in RP 2068-18-3-5 with *Bph33 (t)* gene, Babawee with *bph4* gene, Ptb33 with bph2+Bph3+unknown factors and T12 (ACC33964) with *bph7* gene.

Whole genomes of *Magnaporthe oryzae, Tilletia indica, Bipolaris sorokiniana, Fusarium fujikuroi, Ustilaginoidea virens, Magnaporthe grisea, Ralstonia solanacearum, Xanthomonas campestris* pv. *campestris* were sequenced. Role of two uncharacterized and hypothetical pathogenicity genes to oxidative stress and phenolics in *Colletorichum orbiculare* pathogenicity was established. Scytalonedehydratase gene (*Scd* 1) knockout mutant of *Bipolaris sorokiniana* having albino phenotype was developed. For sheath blight monitoring, a blight index was developed corresponding to spatial distribution of the disease. Temperature based index (soil moisture being constant) can be used for early prediction and scheduling application of fungicides. XopF, a T3SS-effector of Xoo (*Xanthomonas oryzae* pv. *oryzae)* was demonstrated to play crucial role during bacterial blight development. Two rice interactors were identified for XopF effector using Y2H system. Predicted the protein structure, its analog and binding site using iTASSER based modelling.

Biological Control and Integrated Pest Management

Native egg-larval parasitoids *Chelonus* nr. *blackburni* and *C. formosanus,* and larval parasitoids *Coccygidium* sp. and *Temelucha* sp. were found from *Spodoptera frugiperda* in Northern India. Aggregated distribution of predators on the wheat crop was observed under mixed aphids and predatory coccinellids population scenario. Endophytic establishment of native *Bacillus thuringiensis* strain VKK-7 in maize effectively controlled *S. frugiperda*. This technology has been licensed to industry.

It was established that, i. control of aphid populations prevents 10.2 to 61.1% yield loss across cultivars and seasons, and ii. alternate use of *Beauveria bassiana* @ 2 g/l, dimethoate 30 EC @ 1 ml/l, imidacloprid 17.8 SL @ 0.25 ml/l, or thiomethoxam 25 WG @ 0.2 g/l water based on the extent of aphid population effectively manages *L. erysimi* in mustard.

Specifications of a forewarning model based on weather and the pest data on BPH developed during 2000-2013 including two outbreak years, were validated. Occurrence of more than 30 rainy days during June to September months entails very high probability of BPH outbreak during October month, was confirmed. The model can be used for BPH forewarning in NCR region, India.

Nematocidal potential of *Trichoderma harzianum* ITCC 6888 against *Meloidogyne incognita* infecting vegetables and *Pseudomonas fluorescens* against *M. graminicola* in direct seeded rice was established. Soil drenching with plant growth-promoting rhizobacteria consortium (*Bacillus subtilis* DTBS 5, *Pantoea agglomerans*, and *Bacillus amyloliquefaciens* DSBA 11) was found highly effective in mitigating *M. incognita* infection.

The *Galleria* cadaver technology for application of entomopathogenic nematodes (EPNs) was licensed to several companies. The genome sequencing of five *Photorhabdus* strains from various geographical regions of India resulted in final assembled genome sizes of 5.3 to 5.6 Mb. The polyphasic taxonomy, the phylogenomic analysis and *in-silico* DNA-DNA hybridization results suggest that the *P. akhurstii* species can further be subdivided into two subspecies, whereas strain BA1 clustering with *P. akhurstii* might represent a new species.

A ready to use powder formulation for direct application enriched with *Steinernema thermophilum*, having a shelf life of minimum 12 months at 25 °C and 5 months at 35 °C, suitable for its application in tropical and sub-tropical countries. This was evaluated against termites and white grubs in different field crops and found at par with the commercial product. Technology was validated by Insecticide India (P) Ltd. and MoU was signed with IARI for licensing.

Development and formulation of agrochemicals

A novel bench scale process for extraction of azadirachtin enriched (~35%) neem oil concentrate was developed. Bench scale processes for i. isolation of Zerumbone (identified as antifungal agent), ii. extraction of essential oil and bioactive phytochemicals from *Pogostemon cablin* leaves and *Zanthoxylumalatum* fruits and iii.

purification of rosmarinic acid-3-O-glucopyranoside using resins from *Trachyspermum ammi* seeds were developed.

Chemo-profiling of wide range of essentials oils, extracts of different plants/ microbes and their bio-efficacy against various fungi, insects and nematodes were carried out. Bioefficacy of essential oils from *Melaleuaca bracteata,* lemongrass, palmarosa and clove and mustard volatile oil against rice root knot nematodes; *Podophylum hexandrum* against *Callosobruchus chinensis, Triboliumm aculatus* and *Sitophillus oryzae,* acetone extract of *Eucalyptus globulus* leaves and lemongrass oil against *Bemicia tabaci* were established; identifying these as key active ingredients for development of biopesticidal formulations.

Over 200 compounds belonging to different chemical series were prepared to develop lead pesticidal chemicals, for example, N-propyl-4-hydroxycinnamamide (LC_{50} 94 ppm against *Nilaprava talugens*), N-propyl-3,5-dichloro-2-hydroxy acetophenonimine against both *R. solani* (ED_{50} 8.02 mg L^{-1}) and *S. rolfsii* (ED_{50} 21.51 mg L^{-1}), N-heptyl-5-fluoro-N-[1-(2-hydroxyphenyl)ethyl]amine against *R. solani* (ED_{50} 24.59 mg L^{-1}) and N-hexadecyl-5-fluoro-N-[1-(2-hydroxyphenyl)ethyl]amine (ED_{50} 20.03 mg L^{-1}) against *Sclerotium rolfsii,*6,8–dichloro–2-(1H-benzimidazol-1-yl)-4H-chromen-4-one (ED_{50} =5.26 ppm) and 6,8-dichloro-2-(1H-pyrazol-1-yl)-4H-chromen-4-one (ED_{50} =5.93 ppm) against *Sclerotium rolfsii*.

A ready to use suspension concentrate formulation of tebuconazole and chlormequat chloride was developed to for lodging resistance in wheat. In multilocation trials, product exhibited significant height reduction (13-42%) in wheat over control. Patent was filed.

Environmental and food safety aspects of agrochemicals

Multiresidue analytical methods for pesticides detection using GC-MS, LC-MS/MS were developed and instrumental parameters were optimized. These methods were utilized for pesticide residue analysis in vegetables, black pepper, honey, stored grains, cereals, pulses, rice, tea and soil/water. Methods for analysis of aflatoxins, mycotoxins analysis were developed/optimized and were used for analysis these toxicants in dry fruits, milk, animal feed, cereals and spices. LC-MS-MS conditions for simultaneous detection of six neonicotinoids *viz.* imidacloprid, acetamiprid, clothianidin, thiacloprid, thiamethoxam and dinotefuran. Validated LC-MS/MS method for estimation of hydrogel monomers/cross-linkers, acrylamide and N,N-methylene-bis-acrylamide, in soil using modified QuEChERS technique. A modified QuEChERS extraction and cleanup method was optimized for trace level quantification of 100 pesticides using UPLC-MS/MS and validated in coriander leaves and curry leaves (representative crops in crop group 027 i.e., Herbs). Performance of the developed method was evaluated in respective member crops (mint leaves, tejpata leaves, respectively).

Molecularly imprinted polymers (MIPs) were developed for cleanup and selective extraction of for chlorpyrifos, fipronil, amoxicillin, tricyclazole and thiamethoxam. Developed polymers were successfully used for analysis of these toxicants in rice, honey, brinjal, water samples etc. Molecularly imprinted polymer MIP-1 showed higher recognition (93.78%) of tricyclazole from water than nonimprinted polymers (NIPs). Microbial degradation of persistent contaminants like bifenthrin, PCBs, fipronil was studied and identified microbes for degradation of these persistent contaminants. Crude oil and poly aromatic hydrocarbon (PAH) degrading microbes were isolated and were evaluated for degradation of these xenobiotics. Consortium of *Pseudomonas sp*. + *B. amyloliquefaciens* and *A. sydowii* was effective in degrading crude oil in a naturally contaminated (25% oil, w/w) loamy soil (Assam). Formulations of identified microbes were prepared and evaluated for their degradation in crude oil/PAH fortified or naturally contaminated soils/medium.

5.4 School of Natural Resource Management

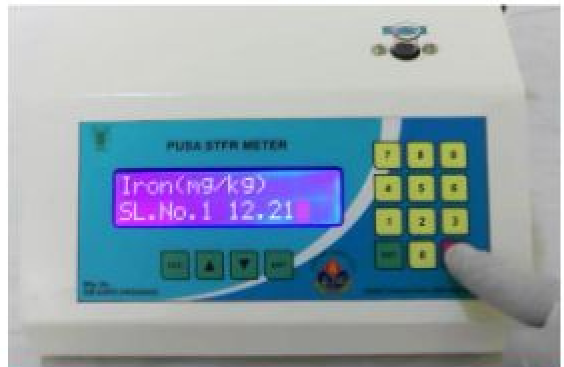
The research in School of Natural Resource Management consists of Division of Agronomy, Division of Agricultural Physics, Division of Soil Science and Agril Chemistry, Division of Environment Science, Division of Microbiology, Division of Agricultural Engineering. Water Technology Center and Agricultural Knowledge Management Unit at New Delhi. The research work in this school was carried under seven different projects and two flagship projects, which are listed below:

1. Restoration and improvement of soil health
2. Safe use of wastewater in agriculture
3. Integrated crop and resource management for enhanced productivity and profitability
4. Risk assessment and management of hydro-climatic hazards on natural resource degradation and agricultural sustainability
5. Assessment and mitigation of greenhouse gas emission and air pollution in agriculture under current and future climatic conditions
6. Agri-residue and bio mass management
7. Development of technologies and strategies for scale neutral farm mechanization

8. **Flagship project:** Precision farming for enhanced input use efficiency
9. **Flagship project:** Diversification of rice-wheat cropping system for enhanced sustainability & profitability

Achievements

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



Pusa STFR Meter

The Institute developed a portable digital soil testing tool, named Pusa Soil Test and Fertilizer Recommendation (STFR) Meter. It is highly useful for the areas where soil testing facility is not available. The present innovative and robust technology would complement the existing Soil Testing Laboratory (STL) network, making soil testing available at farmers' doorstep. It is a low cost, user-friendly, digital embedded system and programmable instrument. Pusa STFR Meter analyzes as many as 14 soil parameters *viz*., pH, EC, organic carbon (OC), available nutrients [N, P, K, S, Zn, B, Fe, Mn, Cu, gypsum requirement and lime requirement. Soil test-based fertilizer recommendation for 100 crops can be made through this instrument with a data storage capacity of 100 samples. It can be connected to PC through a computer-interface and the results can be communicated to the farmers through instant SMS on a pre-registered cell phone. So far, it is licensed to fourteen firms for commercial manufacturing and marketing. Over 1000 units of Pusa STFR meter have been sold so far, which are mainly used for analyzing soil samples from farmers' fields across the country. Total revenue generated through commercialization of this technology is ₹ 105 lakh.

Potassium (K) management protocols specific to conservation agriculture (CA)

Application of 50% recommended K+K solubilizing bacteria (KSB) along with crop residue retention at 4 t ha^{-1} resulted in highest total biomass in maize and wheat (14.46 t ha^{-1} and 14.34 t ha^{-1}, respectively) under CA.

Value addition of waste mica and low-grade rock phosphate

The KSB1 (*Bacillus* sp.) and KSB2 (*Pseudomonas* sp.) along with oxalic acid and citric acid were effective in releasing K from low-grade minerals (waste mica).

Further, pot culture studies revealed this combination enhanced the K uptake and biomass yield of mustard crop. Application of enriched compost (4 t ha^{-1}) developed from low-grade rock phosphate with the intervention of phosphate solubilizing bacteria (5 mL culture kg^{-1} of compost mass) has the potential of curtailing the recommended dose of P application by about 50% without affecting crop yield.

Novel fertilizer products for phosphorus

The P nano-clay polymer composites were synthesized in a calcareous alluvial soil. Experiments indicated that recommended dose of P can be curtailed by 25%, if applied through P nano-clay polymer composites or polymer coated DAP without compromising yield of maize.

Novel fertilizer products for zinc

Nano-clay polymer composites (Zn-NCPC) were synthesized and evaluated for their efficacy in wheat crop. Soil application of 1/5th of recommended Zn through Zinc loaded nano-clay polymer composites (Zn-NCPC) was equally effective as compared to full dose of Zn application through Zinc Sulphate ($ZnSO_4$) in enhancing grain yield of wheat. Product patent filing is in progress.

Threshold limit of organic carbon in soil

The upper and lower threshold limits of the soil organic carbon (SOC) for yield sustainability in Mollisol, Inceptisol, Vertisol and Alfisol were defined through conceptual framework considering the relative yield of 80 and 40%, respectively. The upper and lower threshold limits of SOC stability indices for yield sustainability were 0.60/0.10, 0.6/0.40, 0.30/0.05, 0.40/0.18 in Mollisol, Vertisol, Inceptisol, and Alfisol, respectively.

Biomass and Agri-residue management and its valorization

Microbial consortium for degrading recalcitrant parts of rice stubble was developed, through screening. A microbial consortium of seven fungal species, named as Pusa Decomposer for rapid decomposition of paddy straw (within 20-25 days) was validated. This effective, eco-friendly and economical solution for sustainable rice residue management helps in controlling on-farm burning events. It is available in solid/liquid/capsule forms. 500

Pusa Decomposer

g solid or 5L liquid culture or 4 capsules are sufficient for converting one ton of agro-residues to compost. It accelerates process of paddy straw decomposition and field ready for potato, peas and wheat sowing in 20-25 days following conventional tilling (CT) practices. The technology has been licensed to 22 companies (9 are in production) and along with its sale, generated ₹ 66 lakhs of revenue during 2017-22. Large scale demonstrations and validation of *Pusa Decomposer* technology have been undertaken in several acres of farmers' fields across India, particularly Delhi, Haryana, Uttar Pradesh and Punjab.

In addition, potential of actinobacteria (*Streptomyces thermoviolaceous* S1 and S2), isolated from compost, for active degradation of lignocellulose was identified. Structural and compositional analysis using electron microscope XRD and FTIR provided the evidence for disintegration of lignin- carbohydrate complex and higher lignin removal compared to uninoculated rice straw.

Ethanol production by Simultaneous Saccharification and Fermentation (SSF) was optimized in a lab scale fermenter; Optimized a biological process for delignification and pretreatment for paddy straw, which also led to recovery of value-added lignin.

Plant-microbe interactions and abiotic and biotic stress management

The use of microbial inoculants to alleviate the effect of various abiotic and biotic stress was undertaken across crops- wheat, mustard, pearl millet and soybean, in terms of plant, soil, and soil microbial community profiles. A set of 44 endophytic actinobacterial strains isolated from seeds of six different wheat genotypes collected from five major agro-ecological zones representing three species of wheat *T. aestivum*, *T. dicoccum* and *T. durum*; 90.91% isolates were positive for nitrogen fixation, 77.27 produced ammonia and others exhibited IAA, siderophore and HCN production, phosphate solubilization, as well activity of hydrolytic enzymes. Fourteen isolates displayed antagonistic activity against all the fungal pathogens.

Microbial inoculants for improving soil fertility, crop nutrition and productivity

The BGA based composite liquid formulations were found to maintain a good titre value and is stable up to two years at both 4 and 28 °C. Comparative evaluation of three cyanobacterial formulations (*Anabaena laxa, Calothrix elenkinii, Anabaena torulosa-Trichoderma viride -An-Tr* biofilm) in tomato crop grown in polyhouse and adjacent field illustrated the superior performance of An-Tr biofilm, with an enhancement of 19-20% over control. In addition, inoculation of *Mesorhizobium*, AM fungi and endophyte had positive influence on nodulation, plant growth, and nutrition uptake. *Paenibacillus polymyxa* (HKA-15) and *Bacillus* sp. (W1-2) inoculation significantly increased soybean biomass. Zn and Fe solubilizer with micro nutrient application increaserd nodule dry weight in chickpea.

The effect of direct seeded rice and zero till wheat crop (DSR-ZTW) on soil microbial parameters of an irrigated rice–wheat cropping system was studied. Overall, 36 seed vectored endophytes and 55 from plant parts were purified as predominant morphotypes, and further functional characterization revealed that P/K mobilizers and solubilizers, siderophore producers, besides exhibiting tolerance to abiotic stress

Value addition and Novel products and technologies using microbes

The process parameters to produce polyβ-hydroxybutyrate (PHB) by *Halomonas* sp. LB7 were standardized for batch fermentation in a 7-L bioreactor using optimized growth media having sucrose as C source. A feeding trial was conducted to explore the possibility of using fresh and dried *Azolla* as a feed supplement with prior approval from the institutional animal ethics committee (IAEC) for conducting animal experimentation. Results indicated that replacement of 10% concentrate mixture with *Azolla* was helpful in the improvement of the digestibility of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) in lactating buffaloes. Among the four different growth media *viz.*, MS medium, half MS medium, GB5 medium and M medium analysed for the subculturing of Root Organ Culture (ROC), M-medium was found to possess high effectiveness in terms of % increase in root length. The application of crude starter inoculum (spore + root inoculum) of multiple AM species overperformed monospecies inoculum (*G. margarita)* in colonization of transformed roots *in vitro*.

Microbial genomics and use of omic tools in plant-soil-microbiome analyses

Whole genome sequences of nine important microorganisms, four transcriptomes/ metatranscriptomes, and five plant and soil microbiomes were deciphered and deposited in NCBI databases. Genome–based bioprospecting was carried out of multi-PGP isolate *Lactococcus lactis* strain PHM5-37 (2.4 Mb with GC content of 34.86%), which is being used in biofertilizer programme.

On-Farm Evaluation of Microbial Inoculants in Crops and Agro-Ecosystems

The farmers' participatory on-farm testing (FP-OFT)/ front line demonstrations (FLD) were conducted to evaluate existing carrier based biofertilizers and newly developed liquid formulations (*Azotobacter,* PSB, NPK, Zn, K) by involving 20 Krishi

Vigyan Kendras (KVK) in 11 states (Punjab, Delhi, Bihar, Jharkhand, Gujarat, Rajasthan, Chhattisgarh, Odisha, Madhya Pradesh, Uttar Pradesh and West Bengal). Results showed that application of BGA @1.25 kg/ha and combined inoculation of liquid NPK + liquid Zn replaced 25% of chemical fertilizer and produced additional yield of 2.4 and 1.6 q/ha over farmers' practice and recommended dose of fertilizers, respectively.

Microbial Resources and Biofertilizer production and supply

The Division maintains extensive collections of agriculturally beneficial bacteria, including the National Rhizobium Collection and the Centre for Conservation and Utilization of BGA/Cyanobacteria (CCUBGA). Biofertilizer Unit has upgraded the production and sale of its inoculants from solid carrier based to liquid formulations for major and micro nutrients (Zn and Fe). Additionally, the Unit serves as prototype for prospective entrepreneurs, provides services towards quality monitoring of products, technology packaging, licensing of our products to private industries.

Development of protocol for revival of ponds/water bodies

A protocol was developed to revive the defunct water bodies/ponds/*Jhils* in Mewat, Haryana using Remote Sensing, GIS technologies, water availability quality analysis, functionality, designing, soil characteristics and profile study. Owing to additional 22792 m^3 of storage volume created, the command area increased from 37 to 64 ha thus resulting 2-fold increase in crop yield and cropping intensity from 140 to 201%. Studies on hydrological impacts of rainwater harvesting pond and standing water in paddy field on groundwater recharge and water resource availability in South 24-Parganas district of West Bengal indicated that water stored in the pond had no influence on groundwater recharge but enabled farmers to grow field crops, vegetables and fish.

Development of irrigation water security index for Northern India

An irrigation water security index (IWSI) was developed for NITI Aayog inspirational Bahraich district of Uttar Pradesh taking into account water availability, water productivity, environment and ecology, water-related disasters and water governance using analytical hierarchical process (AHP). Economic water productivity was found to be medium except Chittaur block i.e. poor. Integrated water footprint was the highest for Mahsi block (947 m^3/ton).

Sensor-based automatic surface irrigation system for enhancing application efficiency

A soil moisture sensor-based automatic basin irrigation system was developed which consists of a sensing unit, a communication unit and a control unit. Results revealed that two soil moisture sensors are required to open and close the check gate automatically. This automatic irrigation system achieved irrigation application efficiency > 85%, distribution uniformity > 0.85 and water requirement efficiency of > 95% in wheat crop.

Water Footprint of Rice Wheat Cropping System (RWCS) in the Agroclimatic Region-VI (ACR-VI)

Water footprint of rice-wheat cropping system was estimated in ACR-VI. Combinations of rice cultivar Pusa Basmati 1509 and wheat cultivar HD 2967 under DSR, SRI and puddled methods of rice cultivation resulted in water productivity of 8.5, 7 and 5.2 kg/ha.mm, respectively. Similarly, the water footprint for the entire RWCS was estimated to be lowest with 182, 241 and 311 Mm^3 for DSR, SRI and Puddled method of rice cultivation, respectively.

Development of Composite Drought Index for drought monitoring

Study was carried out to characterize drought in one of the most frequent drought prone areas, *i.e.,* Marathwada region, Maharashtra, through meteorological, hydrological and agricultural drought indices *viz.* Standardized Precipitation Index (SPI), Streamflow Drought Index (SDI) and remote sensing-based indices such as Vegetation Condition Index (VCI) and Water Condition Index (WCI). The developed Composite Drought Index (CDI) was evaluated using foodgrain production for 15 years (2000-2014) during *kharif* season. Overall, the study revealed that among all the drought indices used in this study, CDI had maximum correlation with the foodgrains production.

Performance evaluation of commissioned eco-friendly wastewater treatment

A community scale (75,000 LPD) low-cost wastewater treatment facility at Farah, Mathura was established. Average sewage flow of 23,034 LPD with maximum 64,892 LPD is received by the plant. Results showed that reduction in salt, BOD, turbidity, nitrate, phosphate and sulphate were 20%, 82%, 100%, 64%, 61% and 32%, respectively. 16SrRNA gene based molecular identification of predominant bacterial morphotypes from EMB plates led to identification of six major groups *viz.* *Enterobacter cloacae* (matching with isolates from soil, brackish water, as PGPR and as probiotics from curd), *Escherichia coli* (matching with isolates from healthy human being and their faeces), *Pseudomonas aeruginosa* (matching with isolates from saline soils & hydrocarbon degradation consortium) and *Citrobacter sedlakii* (matching with isolates from soil, mud and fish water).

Development and commercialization of Jalopchar Technology for wastewater treatment

Four *Jalopchar* technology-based wastewater treatment facilities were designed and developed for CCARI (Goa), IIHR (Bengaluru), SKNAU (Jobner) and KVK (Shikhopur) while the fifth one that was developed and commissioned at CAZRI, Jodhpur in 2019 and assessed for its performance efficiency showing a reduction of 83-100% in heavy metal contents in treated wastewater compared to that of untreated wastewater. Apart from this, *Jalopchar* technology was successfully commissioned at ICAR-IISWC (Dehradun), ICAR-NRC on Pig (Guwahati) and ICAR-RC-NEH Region (Umiam).

Heavy metal removal efficiency of vertical subsurface flow constructed wetland

Long-term investigations to remediate wastewater using vertical subsurface flow constructed wetland planted revealed that wetland planted with *Typha, Phragmites, Vacha, Arundo, Vetiver* either as mono cropping or co-cropping had significantly higher heavy metal removal efficiency (Cr 62 to 79%; Ni :70-87%; Pb: 85-89%) compared to unplanted systems (Cr 33-48 %; Ni: 17 to 23%; Pb: 10-17%).

Rice Husk Biochar: A Potent Adsorbent for Nickel Removal from Wastewater

Rice husk biochar (pyrolysed at 400°C, 500°C and 600°C) removed about 65% Ni from waste water in 4 hours through adsorption.

Improving soil physico-chemical properties for enhanced crop productivity

The soil organic carbon mineralization increased with increase in incubation temperature but decreased at 5 to 15 cm depth than that of 0-5 cm depth due to lower microbial activity at lower soil depth. The cumulative CO_2 emissions increased under no-till (NT) and crop residue mulching than that of convention tillage (CT) and no-mulching. NT with crop residue mulching may be followed in maize-wheat system for facilitating carbon sequestration in sandy loam soil of Indo Gangetic Plain region. After eight years of tillage, an increase in Mean Weight Diameter (MWD) was observed under NT and crop residue mulching. With increase in nitrogen, the MWD of soil increased in these depths. Conversion of CT to Zero-till and permanent bed (PBB) with (+R) or without residue resulted in reduction in pores of >60 μm dimension and was mostly contributed by larger size macropores (>110 μm), which resulted in restricted free-drainage under these alternate tillage and land preparations. The improvement in soil physical properties under NT improved the root growth. The Artificial Nural Network with 2 number of hidden layers performed best both for training and testing dataset. MWD of soils from eighteen villages of Nilokheri, Nissang and Assandh block of Karnal district, Haryana was successfully predicted by these machine learning approaches. Based on the gridded daily maximum temperature data (1° x 1°) for six decades (1951-2015), the heat wave magnitude index daily (HWMId) could capture the most-intense heat waves, which have significantly increased over 56% area of the country. Heatwaves also started occuring in nonconventional heat wave regions of southern peninsula and north eastern India in past three decades.

Application of Remote sensing and GIS for natural resource management

A methodology was developed for estimating total organic carbon of soil at farmer's field scale from air borne imaging spectrometer with good accuracy ($R^2 = 0.83$ to 0.89). This was done under very ambitious science campaign on AVIRIS-NG (Airborne Visible Infra-Red Imaging Spectrometer - Next Generation) on air borne platform through collaborative experiment of ISRO and NASA. Real-time satellite derived parameters of rainfall, day and night land surface temperature (LST), and NDVI were generated using IARI satellite data receiving station as a part of Crop Condition Monitoring System for India. Using historical parameter values, weekly anomaly indices of Standardized Precipitation Index (SPI), Temperature Condition Index (TCI) and Crop Condition Index (CCI) were generated for India and maps were hosted on web portal (http://creams.iari.res.in).

New remote sensing derived parameters of Evaporative Stress Index (ESI) were incorporated for identifying water stress areas using ratio of actual to potential evapotranspiration. The ESI maps were generated at weekly interval and at a resolution of 5 km for all India. Satellite remote sensing derived indices such as vegetation health index (VHI) could explain higher variability in wheat yield as compared to the weather indices. The study provides a robust methodology for designing of scientific index-based crop insurance product. Surface soil moisture (SSM, ~5cm) of IARI farm was mapped through digital soil mapping approach. A study was conducted to test novel regional wheat yield forecasting system by assimilating remote sensing derived LAI and weather forecast into crop simulation model (CSM) i.e.InfoCrop-wheat v2.1, using minimum observations as model inputs. The CSM model was calibrated and validated using experiments at research farm of

IARI, as well as the model was validated for 42 farmers' fields and showed good performance of the model at both the scales. An image-based software named "PusaInfoSeed", a Windows-based desktop application, was developed for assessing seed morphometry of seeds of different crops.

A field experiment was conducted at Almora district of Uttarakhand (hotspot area) with the collaboration of ICAR-VPKAS to detect the different levels (0-9 scale of IRRI) of rice blast disease using hyper-spectral remote sensing techniques. The bands at 650 nm (red) and 750-1150 nm (NIR) were found to be useful for this purpose. A robust methodology was developed for distinguishing Happy Seeder and Super seeder sown wheat from the conventional sown wheat at the early stage using Sentinel-2 satellite data.

Realtime monitoring of crop residue burning events

On behalf of ICAR, spatio-temporal monitoring of the active fires due to paddy residue burning was carried out in real- time for all the three states (Punjab, Haryana and UP) from 1-Oct to 30-Nov 2018 on daily basis. Daily bulletin of fire events was prepared and their locations were put on CREAMS Geoportal (http://creams.iari.res.in) for visualization as maps. Total paddy area burnt was also estimated for Punjab and Haryana using Sentinel-2A satellite imageries. The study scope was expanded by undertaking satellite-based monitoring of crop residue burning across India on daily basis and maps were uploaded on ICAR KRISHI Geoportal (https://krishi.icar.gov.in).

Development of Nano-biosensor for nitrate detection

Fabricated biosensor for nitrate detection using nanocomposite of carbon nanotubes and hematitie nanostructures. The fabrication of nanosensor was accomplished using prepared nanocomposite (CNT-α-Fe_2O_3) and nitrate reductase for specific detection of nitrate in soil extract. The comparative studies with the colorimetric method were also conducted. The high correlation ($r^2 = 0.99$) with the colorimetric method implies futuristic scope of practical utility of the fabricated nanosensor for fast, accurate, and on-situ detection of nitrate content in soils during crop cultivation.

Enhancing cropping system productivity and profitability under irrigated conditions

Zero-tillage flat beds with residue retention showed a 4.3% increase in wheat grain yield compared to conventional tillage bed planting. Likewise, the conventional-tilled furrow irrigated raised beds and conventional tilled-flat beds resulted in 8-12% improved grain yield of soybean over zero-tilled flat beds. The raised bed crop had higher water productivity of maize and wheat (0.88- 0.89 g/lit) and accounting ~ 40-50 % enhancement over conventional tilled plots. The integrated farming system (IFS) model of a 1.0 ha area involving crops, dairy, fishery, duckery, biogas plant, fruit trees, and agro-forestry system was developed. The system has potential to generates net returns ~ ₹ 3,78,784/ha/year with an employment of 628 man-days. The grain yield (4.03 t/ha), harvest index, NPK and Zn concentrations, and B: C ratio of rice were significantly higher in the CA-based Integrated Crop Management (ICM) module [{zero tillage (ZT)–summer mung bean residue retention (SMB–RR) + ZT–direct seeded rice (DSR) + wheat residue @ 3 t /ha} + {75% RDF (N–ZCU)} + {glyphosate as PP @ 1 kg/ha + pretilachlor–PE) @ 0.75 kg/ha followed by bispyribac–sodium @ 25 g/ha as POE + need-based irrigations and IDM/IPM].

Enhancing cropping system productivity and profitability under rainfed conditions and limited irrigation

Integration of phalsa with mung bean-potato recorded the highest system productivity (25.9 t/ha). However, Karonda -mung bean -potato system resulted in maximum net return (₹ 282320/ha), and water use efficiency (33.0 kg/ha-mm). Similarly, the phalsa-mung bean-potato system had the highest C sustainability index (27.6), carbon sequestration potential (0.6-0.67 Mg/ha/year), and water use efficiency (33.0 kg/ha-mm). An IFS model (1 acre area) comprises polyhouse cultivation of vegetables (600 m^2 area for cultivation of tomato, capsicum, and cucumbers), mushroom production (50 m^2 area), agri-horti system (1200 m^2 area), apiculture and open filed cultivation of vegetables, flowers, cereals, oilseeds and pulses on 2200 m^2 area was developed. The IFS model is economically efficient and environmentally robust and has the potential to generate a net income of ₹ 175,650 per year.

The integrated crop management system recorded higher system productivity (12621 kg /ha), net energy (471632 MJ/ha), and economic returns (₹ 166320/ha). However, the integrated organic management system resulted in the highest energy productivity (0.83 kg/MJ), eco-efficiency (₹ 15/MJ/ha), and the lowest greenhouse gas intensity (0.06 kg grain kg per CO_2 eq).

Developing efficient strategies for managing emerging weeds in different cropping systems

Pre-emergence application of pendimethalin 1.0 kg/ha + one hand weeding at 30 DAS in pigeon pea and pinoxaden 50 g/ha + metsulfuron 5 g/ha (Tank mix) at 30

DAS in wheat is recommended. Pendimethalin 1.5 kg/ha (pre-em) + bispyribac-Na 25 g/ha at 25 DAS + hand weeding (HW) at 45 DAS, and pendimethalin 1.5 kg/ha (pre-em) + bispyribac-Na 25 g/ha at 25 DAS is recommended for direct seeded rice cultivation. The Brown manure (BM) option comprising *Sesbania* + *Crotalaria* (12.5+12.5 kg/ha) mixture with 2,4-D 0.5 kg/ha applied at 25 DAS gave the highest maize-wheat system productivity and system net returns and was most superior.

Precision nutrient and water management

The maximum system productivity (12.5 kg/ha) and system net gain (₹ 38318 /ha) under the maize-wheat system were accrued under 7 and 5 t/ha targeted maize and wheat yield, respectively coupled with GS-based N fertilizer application. The higher agronomic efficiency of N in maize (31.61 kg/kg N applied) was observed with the application of basal N based on nutrient expert recommendation over state recommendation. The maximum grain yield of conservation agriculture led maize (7.81 t/ha) and wheat was registered with the application of 90 kg N as basal and Green Seeker guided N along with irrigation at 25% ASMD. The supply of 75% recommended N with conventional fertilizer along with nano-urea spray (N75PK + nano-urea) reduced the energy requirement by ~8-11% and increased energy use efficiency by ~6-9% over 100% nitrogen through conventional fertilizer.

Organic and zero-budget natural farming

The grain yield of basmati rice increased significantly due to the use of FYM or vermicompost or their combined use with crop residues and biofertilizers. Liquid formulations (Azotobacter, PSB, Zn SB, KSB, NPK) of biofertilizers were user-friendly, effective, and potential sources of partial crop nutrition in rice and other crops under organic farming. The Zero budget natural farming (ZBNF) practice was the least productive in maize-wheat system. Consequently, the grain yields of maize and wheat were obtained higher under an integrated system followed by inorganic, organic, and ZBNF.

Farm Sun Fridge and technologies for post-harvest management and value addition

The farm Sun Fridge- an off-grid, battery-less solar refrigerated and evaporative cooled (SREC) structure has been designed and can be self-built by smallholder farmers. Several innovative features have been incorporated including a "water battery" (a thermal reservoir) to provide nighttime cooling, a dual-use refrigeration coil to cool the thermal reservoir and interior air simultaneously, and a solar adaptive controller to regulate power demand by refrigeration compressor based on available solar energy. This structure is of 2 tons capacity of fruits and vegetables.

For post-harvest management and value addition of agricultural produce the technologies like Pusa Rotatable Tray Infrared Dryer/Processor, Pusa Infrared Drum Dryer – Processor, Process Protocol for Dehydration of Apple Slices, Pusa Battery Operated Turmeric/Ginger Washer, Phase change material (PCM) based Hybrid dryer for Herbs and spices and Pusa Portable Hybrid Dryer were developed.

Pusa Mini Electric Agri Prime Mover with attachments

Developed 450W mini electric prime mover is a versatile unit for agricultural operations like secondary tillage, planking, ridge/furrow making, interculture and slit breaker. The effective field capacity of prime mover with sweep type tool and three tyne cultivators for weeding-cum-interculture in sugarcane crop were 376 and 408 $m^2.h^{-1}$ at 0.48 and 0.44 $m.s^{-1}$, respectively at 50 to 70 mm depth.

Direct seeded precision planter

A precision planter was developed for direct seeding of paddy crop to save seed, labour, fertilizer and water. The electronic metering of precision planter was based on speed synchronization with proximity sensor and PWM based microcontroller The developed seeder precisely plants long grain basmati paddy seeds in rows saving of 12 % in seed was observed.

Direct seeded precision planter

Seeder cum inoculum applicator

An integrated seeder cum microbial inoculum applicator was developed for in-situ residue management. The machine carries an inoculum tank of capacity 400 L (Front mounted for balancing). The field capacity of the machine is 0.34 ha. per hour.

Eco-friendly and Profitable Crop Residue Management (EPCRM)

The EPCRM Centre was established at Krishi Vigyan Kendra, Tepla, Ambala to demonstrate solutions to the problem of paddy straw burning.

Variable rate fertilizer applicator

Variable rate fertilizer applicator was developed to monitor and regulate the amount of fertilizer applied to the field based on the net deficit quantity (NDQ). The key features of the development are automatic grid detection, analysis of fertilizer deficiency and application of fertilizer to manage the NDQ.

Technologies for small farm mechanization

For small farm mechanization, different technologies like Electronic Safety Alarm and brake Device for Chaff Cutter, Energy-Based Custom Hiring Monitoring Meter for Tractor, walk behind rotary cereal crop harvester, Harness for manual load carrying, Pusa Mini Electric Agri Prime Mover with attachments, Walking-type battery-operated boom sprayer, Multi-crop Ridger planter were developed.

Technologies for resource conservation and precision agriculture

For resource conservation and precision agriculture number of technologies like Cumin Harvester, Planter for System of Wheat Intensification (SWI), Precision Swinging lance sprayer, tractor-drawn raised-bed pulse planter for precision sowing, Robotic Precision Planter, Device for real time disease severity estimation of Groundnut Bud Necrosis Virus in Tomato, Control volume sprayer for grape clusters, LiDAR based Check Row Planter, Tractor guidance system for precision planting, Remote Control System for Smaller Tractors

Climate scenarios for agricultural seasons

Thirty-two Global Climate Model analysis on seasonal climate change projections for India indicated that minimum temperature to rise more than rise in maximum temperature. Rise in temperatures to be more during rabi than during kharif and also more in north parts of India than in southern region. Rainfall to increase more in rabi than during kharif with increased variability in rainfall and temperatures. In future climates, the Kharif season mean minimum and maximum temperatures are projected to increase in the range of 0.946 - 1.061 °C and 0.741 – 0.847 °C, respectively by 2039 as compared to the mean seasonal values of year 1976-2005. Similarly, Rabi season mean minimum and maximum temperatures are projected to increase in the range of 1.096-1.207 °C and 0.882-0.947 °C by 2039. Temperatures are projected rise up to 4.6 °C by the end of the century. The projected increase in Kharif rainfall is 2.3-3.3% by 2039 while that of Rabi rainfall is 12%.

Climate change impacts on crops and adaptation gains

Without adaptation, climate change is projected to affect the wheat productivity by about -3.2 to -5.3% in 2020 (2010-2039); -8.4 to -19.3% in 2050 (2040-

2069); and -18.9 to -41% in 2080 (2070-2099) under different representative concentration pathways (RCPs 2.6, 4.5, 6.0 and 8.5). Adaptation will improve the yield at state level in the range of 10 to 40% in major wheat growing states. Developing short-duration heat tolerant varieties is important for sustaining wheat yield in central India. Rainfed rice productivity is projected to change in the range of 7 to -28% in 2020; 2 to -20% in 2050 and -10 to -47% in 2080 climate scenarios in different RCPs with significant spatial variation. However, adaptation can significantly increase productivity up to 40%. Many of the climate resilient technologies were demonstrated in farmers' fields in over 22 villages in 5 states (UP, MP, Haryana, Bihar and WB) and significant adaptation gains were to the tune of 35% in various crops was recorded. In addition, the GHG emissions were reduced and farmers resilience is increased. Similarly, climate change is projected impact the yields of other crops such as maize (up to-18%), mustard (up to 12%) and potato. The result showed the CH_4 emission and GWP of CH_4 (Kg CO_2 eq. ha^{-1}) from rice crop (Pusa Basmati 1121) was higher in organic farming as compared to the conventional farming system. Several low GHG emitting technologies such as Direct Seeded Rice, Neem Oil Coated Urea, alternate wetting and drying of rice field were identified with a potential to reduce GHG emissions by 70%, 9% and 20%, respectively.

The interactive effects of CO_2, temperature and ozone were quantified (in T-FACE and O_3-FACE rings) on several crops such as rice, wheat, soybean, mustard and found that yield loss in elevated ozone and temperature is partially offset by elevated CO_2. The effect of liquid nano urea (LNU) application on maize growth PJHM 1 maize variety and yield under elevated CO_2 and temperature interaction was studied in T-FACE facility. The grain yield of maize was observed to be lower in all the nano-urea applied plots under the different treatments.

Crop simulation modelling

The InfoCrop v2.1-generic model was updated with green gram crop module. The InfoCrop-green gram model was calibrated and validated for simulating the growth and yield of green gram. The model performance in simulating the crop varieties such as Pusa 9531, Pusa Vishal and Pusa 0672 under rainfed and assured irrigated conditions and different sowing dates was with a r^2 of 0.89. Similarly, simulation models for cauliflower, spinach and tomato were developed and applied for the copyright. Copy rights were obtained for InfoCrop v2.1, coconut model (CocoSim) green gram model (VignaradSim). The geo-spatial InfoCrop model and cropping system models are being developed.

Environmental pollution and remediation

Studies indicated that leaching of nitrate to the water bodies can be prevented by the application of algae manure as compared to chemical fertilizer. In a field experiment with wheat, the N use efficiency was maximum with resin coated urea (22 kg grain yield increase/ kg of N applied) followed by phosphogypsum coated urea (19.6 kg grain yield increase/ kg of N applied) and Neem oil coated urea (18.7 kg grain yield increase/ kg of N applied) treatments.

Lead removal capacity by *Brevibacillus laterosporus* was assessed through using ca-Alginate based immobilization technique. At a combination of bacterial Ca-Alginate: 3.5 %, Initial lead concentration: 67 ppm and Incubation temperature: 50 °C, model generated maximum predicted removal was 86.87%. This was validated in laboratory condition, and removal of 84.29% was recorded. Experiments were conducted with two types of microplastics i.e., polyvinyl chloride (PVC) and poly propylene (PP) and leaf compost (LC) and vermicompost (VC) from two sources i.e., packaged (commercial) vs in-house (non-commercial). The results clearly showed a higher sensitivity of durum than bread wheat towards presence of microplastics irrespective of their type and source.

Air pollution effects on crops

To assess the impact of SPM pollution load on wheat crop, a field experiment was carried out at IARI with 21 wheat varieties as well as in nearby villages of two NTPC Auriya (22 villages). A positive correlation was observed between SPM deposition rate and leaf area. Analysis of dominant particulate matter in air parcel revealed the presence of carbonaceous particles, mineral dust, clay particles and trace amount of heavy metals such as Hg, Pb and Ti in SPM. A substantial proportion of PM10 and PM2.5 particles comprises of bioaerosols e.g. bacteria, and fungi, that affect the structure of aerosol particles. Air sample collection from low to high polluted area showed that 70% of bacteria in the polluted samples are pigmented. The crop yield was affected due to air pollution.

Agricultural Knowledge Management

Krishikosh, an exceptional repository in agriculture and allied sciences (https://krishikosh.egranth.ac.in/), serves as a unique knowledge hub housing theses, valuable books, institutional publications, technical bulletins, project reports, lectures, preprints, reprints, and various documents scattered across Research Institutions and State Agricultural Universities (SAUs) in India. Functioning as a tailored digital repository platform for NARES Institutions, *Krishikosh* allows users to upload and manage their content, aligning with the open-access policy of ICAR. With over 2,40,000 items, including 175,000 theses from NARES Institutions, the repository has garnered 23.07 million hits on its website from April 2017 to March 2022, with visitors spanning 175 countries, including India, the United States, China, and others. The platform played a pivotal role in reviving the IARI Website and stands out for its comprehensive digital collection. Notably, *Krishikosh* contributed to the development of a weather-based forewarning model for *Helicoverpa armigera*, a pest affecting crops at different growth stages. This model, validated at ICRISAT, Patancheru, offers web interactive forewarning, predicting infestation stages and suggesting suitable control options. The research falls under the DST-ICRISAT project, "Center of Excellence on Climate change research for plant protection: Pest and disease management for climate change adaptation."

Further advancements include GIS-based forewarning systems for mustard aphids, a collaborative effort with the team at SAC, Ahmedabad (https://vedas.sac.gov.in/vedas_special/vedas_mustard_pest.html). *Krishikosh* stands as a dynamic platform fostering agricultural knowledge exchange, research, and technological innovations.

The School of Natural Resource Management has developed several technologies such as Pusa STFR Meter, novel fertilizer formulations for improving soil health and enhancing nutrient use efficiency, microbe based biomass and agri-residue management and its valorisation, microbial inoculants for improving soil fertility, crop nutrition and productivity, value addition, microbial genomics and use of omic tools in plant-soil-microbiome analyses, development of protocol for revival of ponds/water bodies, sensor-based automatic surface irrigation system, eco-friendly wastewater treatment technology (*Jalopchar* Technology), remediation technologies for heavy metal contamination, precision water and nutrient management, and weed management, organic and natural farming technologies, farm implements for farm operations, particularly for small-farms and Farm Sun Fridge and technologies for post-harvest management and value addition and precision agriculture, crop simulation models, climate resilient technologies and GHG mitigation.

The School has contributed significantly to the scientific knowledge on soil health management, crop management, remote sensing and GIS based natural resource management, crop residue management, real-time monitoring of crop residue buring events, enhancing cropping system productivity and profitability under irrigated and rainfed conditions, simulation modelling, climate change impacts, adaptation, climate smart agriculture, GHG emissions, environmental pollution and remediation, air pollution effects on crops and agricultural knowledge management. Many of these studies have contributed to the formulation of agricultural policies, India's communications to International Agencies such as IPCC and UNFCC and as inputs for central and state Governments. Many of the technologies have been licenced for commercialization, obtained copyrights, demonstrated in farmers' fields and popularized.

Based on the recent research development and emerging challenges, the School of NRM envisages the following plan of work for next five years

Improvement of applied nitrogen use efficiency and development of environmentally friendly novel fertilizers and novel methods of application of fertilizers for sustainability, Net-Zero Carbon emission approaches for Net-Zero targets through Food System Integrated modelling for climate and ecosystem services and climate change and extreme event impacts, carbon markets and for development of climate-resilient agriculture need to be prioritized. Future course of research will concentrate on new and innovative agronomic management practices for precision farming for sustainable agriculture, sensor-based technologies for crop, nutrient and irrigation management and use of robotic, drone and AI technologies in agriculture. Further, the focus will be made on microbiome, and rhizosphere research, development of microbial biofertilizers for enhanced crop and soil health and integrated studies on conservation agriculture including weed management, energy efficiency, organic farming and design and development of smart machinery for precision agriculture, robotics and automations as well as equipment for small-farm. Similarly, research efforts on water management technologies at various scales including micro water resource development, canal automation, water disaster management and wastewater treatment will be strengthened. In order to accomplish these targets, funds for upgradation of labs, field infrastructure, additional man power and training in advanced areas of research needs to be provisioned.

5.5 School of Basic Sciences

Inauguration and dedication of plant phenomics facility

To bridge the phenotype-genotype gap, the "Nanaji Deshmukh Plant Phenomics Centre (NDPPC)" was constructed, inaugurated and dedicated to the Nation by the Hon'ble Prime Minister of India, Shri Narendra Modi on 11th October 2017.

Honourable Prime Minister dedicating the Phenomics Centre to the nation

Phenomics of transpiration and WUE in rice and wheat

Rice germplasm (150) was studied for diurnal and nocturnal transpiration. Both types of transpiration were significantly lower in BAM819, BAM1689, IR83388-B-B108-3 and Vanaprava as compared with drought tolerant check Nagina 22. Through GWAS, four significant SNP markers associated with water use efficiency (WUE) were identified. For QTL mapping of transpiration and WUE, 170 RILs (BVD109 × IR20) of rice were phenotyped at NDPPC and genotyped using 50K SNP genotyping Chip. Under irrigated conditions, three QTLs related to day-time and night-time WUE was mapped successfully in chromosome 6 and 8. Under drought, two QTLs related to whole day transpiration rate was mapped in chromosome 6 with high PVE.

In wheat, 184 RILs (HD2967, high yielding × C 306, drought tolerant) were phenotyped for WUE and drought tolerance. Under drought stress conditions, C306 used about 869 L of water kg^{-1} of grain produced, while the best RIL used 571 L of water kg^{-1} of grain produced.

Phenomics of nitrogen use efficiency (NUE) in rice precision phenotyping

300 diverse rice germplasm was phenotyped in NDPPC to identify donors and QTLs for high NUE and N deficiency tolerance. Big data (2.88 TB phenome image) was acquired using RGB, IR & NIR sensor. Four rice genotypes (BAM3690, CAUVERY, Suweon and Eypo) were identified as elite NUE donors based on multi-

trait index based on factor analysis and genotype-ideotype distance (MGIDI). GWAS with 150 rice genotypes identified two major QTLs associated with N uptake efficiency and utilization efficiency.

Root phenotyping and QTL identification in rice

A novel, easy, robust, and cheaper method to measure root angle in rice (29) and wheat (56) under natural field conditions was reported. GWAS using 50K rice SNP chip identified 36 most significant QTLs for constitutive and stress inductive root traits. Out of this, 10 were novel QTLs which can be utilized for developing varieties suited to both irrigated and stress environments.

Development of high throughput phenotyping protocols

Through collaborative work to develop Computer Vision methods for plant Phenotyping, a machine learning based approach, *SpikeSegNet*, was developed for automated spike detection and counting from RGB images in wheat. "SENESCENCICA" software developed to quantify the senescence rate and classify wheat leaves based on leaf colour into categories of green and senescence portion.

Sink activity and grain quality of rice genotypes under high night temperature

The pattern of starch synthesis and catabolic enzymes in developing rice grain were analyzed under high night temperature (HNT) stress during grain filling in Vandana (HNT susceptible) and Nagina 22 (HNT tolerant). Poor availability of non-structural carbohydrates for seed filling in Vandana occurred due to increased flag leaf respiration rates leading to the loss in grain weight. The granule bound starch synthase (GBSS) activity increased in Vandana at 20 days after anthesis (DAA) suggesting the compensation for amylose accumulation in later stages of grain growth. Alpha amylase activity increased in Nagina 22 under HNT. Grain amylose content decreased in Vandana but was maintained in Nagina 22. These results suggest that GBSS regulates change in amylose content in rice cultivar under high night temperature.

Stem reserve mobilization (SRM) in wheat under combined heat and drought stress

SRM contributes to grain weight and grain yield, especially under drought conditions. SRM was analysed in late sown wheat for tolerance to high night temperature (HNT, +3°C above mean ambient night temperature of 21°C) during grain filling period. HI 1563 and HD 2932 were identified as HNT tolerant genotypes. Genotypes maturing in 120-130 days showed higher translocation efficiency from penultimate and lower internodes as compared to long duration genotypes (130-140 days) under HNT. Increase in translocation efficiency from penultimate internode minimized yield loss under HNT in wheat. Both SRM and stem reserve efficiency (SRE) are significantly highly correlated with stem specific weight under irrigated, drought, heat as well as combined heat and drought field conditions in wheat.

Photo-protective role of photosynthetic pigments for heat stress tolerance in wheat

Heat tolerant (HD 2329) wheat genotype maintained photosynthetic pigments in general and carotenoids (zeaxanthin & lutein) due to increased non-photochemical quenching (NPQ) under heat stress. Better membrane stability and lower level of lipid peroxidation was observed in HD2329 than that of sensitive genotype (HD 3086). The xanthophyll cycle activators namely, Ascorbic acid (ASC) (10 mM), BA (40 μM), $Ca(NO_3)_2$ (CaN) (60 mM), putrescine (Put) (10 mM) dithiothreitol (DTT) (3 mM) (xanthophyll cycle inhibitor) modulated xanthophyll cycle activity and improved heat stress tolerance in wheat.

Improving high temperature and drought stress tolerance in rice by Polyamines and in wheat by silicon application

Rice genotypes exposed to high temperature (HT) (38-41°C) and drought stress at anthesis stage were sprayed with putrescine (2.5 mM) and spermidine (1.5 mM). Spermidine application improved spikelet fertility and panicle grain yield in PRH 10 and PB1121 under drought stress suggesting polyamines may improve high temperature and drought stress tolerance in selected rice genotypes.

In wheat, silicon (Si) application induced the expression of heat-responsive transcription factors (TF) and heat-shock proteins (HSPs). The maximum expression of HSF, *A6e*, was observed in response to Si2.5 under heat stress during pollination stage in HD3086 (thermotolerant) while *HD97* TF was induced during grain-filling in BT-Schomburgk (susceptible). However, Si negatively affected the activity of catabolic enzymes like amylase but heat stress enhanced its activity.

Role of awn length on various physiological traits in wheat in relation to thermo-tolerance

The awn length in wheat variety HD 3086 and its 6 mutant lines (M2 generation) was studied under heat stress and normal conditions. The mutant lines possessed reduced awn length in comparison to wild type. Shorter awns (in mutants) resulted in higher ear (spikelet) temperature at anthesis and thereby negatively impacting the harvest index of main ear. Grain yield per plant for mutants was negatively associated with ear and awn temperature at anthesis.

Role of epicuticular wax (ECW) and phloem immobile mineral nutrients in stress tolerance of wheat

Dynamics of ECW and phloem immobile mineral nutrients (Si, B, and Mn) were analysed in wheat genotypes under heat and drought stresses. Under drought, main ear grain yield was linked positively to ECW content of flag leaf and husk of ear at anthesis stage, and Si, B and Mn content in the husk of the ear at harvest suggesting ECW and minerals can play an important role on heat and drought stress tolerance in wheat.

Evaluation of biotic elicitor induced accumulation of ABA concentration in the root and shoot of contrasting rice genotypes under drought stress

Seed-priming with bio-elicitors like methyl jasmonate (MJ), paclobutrazole (PBZ), and salicylic acid (SA) revealed increased ABA accumulation in both shoot and root of drought tolerant (N-22) and drought sensitive (Pusa Sugandh 5) rice genotypes. Among the bio-elicitors, MJ priming showed maximum increase in ABA level in both genotypes under drought stress however, the increase was higher in N-22 than PS-5.

Seed-priming with 100 μM PBZ and MJ resulted in increased NADPH oxidase (NOX) activity in N-22 in both root and shoot tissue. The related genes, *OsNox1* and *OsNox5*, were upregulated in all three bio-elicitor primed samples irrespective of the control or drought conditions. Molecular cloning, sequencing and conserved domain identification of NADPH oxidases revealed the presence of NADPH oxidase superfamily domain such as respiratory burst NADPH oxidase proteins that produces ROS as a defence mechanism.

Ear contribution towards the grain yield in different wheat genotypes

A study was conducted to determine the contribution of the main ear (by ear shading technique) towards its yield in 18 different wheat genotypes grown in field under normal and heat stress (late sown) conditions. The contribution of ear to its yield in these genotypes varied from 2.4 to 47.0% under non-stress conditions. Shading of main ear under heat stress caused minimum and maximum reduction in yield in DBW 14 and PBW 343, respectively and thus contribution of ear to its yield varied from 0.2 to 45.5% under heat stress conditions.

Evaluation of rice cultivar Nagina 22 mutants for higher photosynthetic efficiency

Growth analysis and photosynthesis studies were carried out with 240 rice Nagina 22 mutants at 65-75 days after sowing. The photosynthesis in these mutants showed higher rate in M-245-1A, 16-AKS-2, 2208-A, 108-2, and SM67-1 as compared to wild type (25.3 μmol m^{-2} s^{-1}). This was associated with the leaf thickness related traits such as higher specific leaf weight and higher leaf soluble protein content but not the rate of Rubisco carboxylation per unit leaf protein.

The leaf vein density (LVD) may provide an avenue for improving photosynthesis. A mobile phone-based platform was developed for rapid leaf imaging for venation and 430 mutants of N 22 were phenotyped. A positive association between leaf photosynthetic capacity and leaf venation was observed as in mutant SM67-1 with higher photosynthesis possessing LVD of 6.0 compared to 4.3 veins mm^{-1} in WT while the mutant M57 with lower photosynthesis showed LVD of 3.7 veins mm^{-1}.

Physiological analysis of nitrogen use efficiency in rice

A contrasting set of 24 rice genotypes selected out of 300 based on relative biomass accumulation (RBM) and chlorophyll retention (CR) under low N stress were evaluated for root system architecture, N accumulation, activity of N assimilating enzymes in hydroponics and NUE parameters, rate of photosynthesis and yield in field. Under field condition, NUE varied from 3.7 to 69.0 at low N and 17.3 to 65 g grain g^{-1} N uptake in control. Genotypes with higher tolerance to seedling stage N deficiency (high RBM and CR) also recorded high NUE in field under N stress. Thus, phenotyping for seedling stage N deficiency tolerance in hydroponics can be a potential surrogate to identify rice genotypes for high NUE under field conditions.

Nitrogen remobilization efficiency and identification of wheat with positive grain protein deviation

Genetic variability for N accumulation, partitioning, and remobilization in wheat was studied using a nested association mapping (NAM) panel consisting of 195 lines. Pre- and post-anthesis biomass accumulation were correlated with grain yield, while NRE was positively correlated with above-ground N accumulation at anthesis (AGNA) and grain yield. AGNA and above-ground N at post-anthesis (AGNPA) were positively associated with grain protein deviation (GPD). A few lines exhibited positive GPD combined with higher grain yield and grain protein concentration (GPC), making them potential genetic resources for improving grain yield and GPC under limited N conditions.

Genome-wide analysis of NIN-LIKE PROTEIN (NLP) transcription factor family genes in rice

The NLP family were identified as nitrate-responsive *cis*-element (NRE)-binding proteins, which function as transcriptional activators of nitrate-regulated genes. Based on physiological analysis of rice germplasm under N sufficient and deficient conditions, genotypes with high NUE under sufficient N (APO), high NUE at low N (IR-3-1-1 and NL-42), and N responsive and low NUE (Pusa Basmati 1) were identified. *In silico* analysis revealed 6 NLP genes (including alternative splice forms 11 NLPs) from rice genome. Expression of NLPs was enhanced by nitrate supply as well as under N deficiency (NLP1, NLP4, NLP5). The high NUE genotype IR3-1-1 showed a general upregulation of NLP expression which correlated with high N assimilation and uptake and transcript abundance, indicating that NLPs could be a potential target to improve NUE.

Nitrogen deficiency stress regulated miRNAs and their potential targets in wheat

41 wheat genotypes including bread wheat, synthetic hexaploid, Indian dwarf wheat and Emmer wheat were screened for NUE in the field. Out of which, 8 contrasting genotypes were grown in hydroponics for 30 days to assess NUE and N deficiency related traits. miRNA-seq analysis based on NUE, anthocyanin content, and root traits in three genotypes (BT-Schomburgk, *T. dicoccum*, and *T. sphaerococcum*) revealed ~100 miRNAs that were differentially regulated in response to N deficiency. Target genes of N deficiency regulated miRNAs were predicted belonging to different classes suggesting reprogramming of whole cell metabolism.

Signalling cross talk between osmotic and nitrogen deficiency stresses in wheat

In drought prone areas, N availability is less, and thus imposing dual stress on the crop. Regulation of genes for N responses under N starvation, osmotic (OS), and dual stress conditions in HD2967 seedlings and drought tolerant check C306 was studied. N deficiency led to accumulation of ABA in wheat seedlings. Relative expression analysis of candidate genes involved in nitrate signalling, nitrate transporters, and nitrate and ammonium assimilation were upregulated by OS. *TabZIP1* and *TaPIMP1* TF were identified as new players in low N response in wheat.

Evaluation of bread wheat and triticale genotypes in soil and hydroponics for identification of traits and 'donors' under low phosphorus stress

Diverse bread wheat (89) and triticale (×*Triticosecale* Wittmack, 15) genotypes were evaluated in soil and hydroponics with low and sufficient P. Out of 22 (soil) and

38 (hydroponics) P efficient wheat genotypes, nine were overlapping in both screens while in P inefficient cluster, out of 23 (soil) and 5 (hydroponics), three were common. A few P efficient genotypes identified were DL784-3, DBW 16 and GW 322 and triticale TREAT, whereas P inefficient were C306 and ABACUS PVR (triticale). Thus, selections in hydroponics are likely to be relevant in the field as demonstrated by overlapping of genotypes in both the mediums.

Identification of donor for dual-nutrient (N and P) efficiency in wheat

Seventy bread wheat genotypes were phenotyped for tolerance to low N and P stresses for root parameters, nitrate assimilating enzymes, acid phosphatase activity in root exudate, leaf area and biomass to identify the contrasting genotypes. Based on these responses, HD2781 (tolerant/efficient) and C306 (sensitive/inefficient) were selected to evaluate the relative expression of candidate genes involved in transport of N and P in roots, genes involved in N assimilation and P remobilization. Results showed that HD2781 is genetically efficient and responsive genotype, and can be used as 'donor' for developing varieties for N and P use efficiency.

Regulation of phosphorous remobilization by abscisic acid (ABA) in wheat

Under P deficiency, one of the adaptive mechanisms in plants is the scavenging and remobilization of P from cell walls. Role of ABA, ethylene and nitric oxide was studied in remobilization of P from root cell wall under dual-nutrient deficiency stress (DNDS) in wheat genotypes, HD2781 (DNDS-tolerant) and C306 (DNDS-sensitive). Activity of pectin methyl esterase (PME) and pectin hydrolysis was higher in HD-2781 as compared to C306 across the treatments. Reduction in cell wall P content in HD-2781 in root tissue under nutrient stress indicated better P remobilization towards shoot as there was less P retention in cell wall. Endogenous ABA inhibits the activity of PME, thus inhibiting the cell wall P remobilization. The ABA content was significantly lower in HD-2781 as compared to C-306. The pathway of P remobilization from root cell wall was affected by ABA but it was found to be independent of both NO and ethylene in HD-2781, but no clear relationship was found in C-306.

GWAS for identification of genes for phosphorus related indices in diverse bread wheat genotypes

GWAS on 82 diverse bread wheat accessions phenotyped under low and sufficient P was carried out using 35K Wheat Breeder's Affymetrix array. GWAS revealed 78 marker-trait associations but only 35 of them passed Bonferroni correction and a total of 294 candidate genes. These genomic regions could be utilized for improving bread wheat to tolerate low P stress through marker-assisted selection.

Epigenomics of phosphorus use-efficiency in rice

The deficiency of P in plants was found to trigger differential DNA methylation patterns, with CG methylation accounting for the majority of changes. Upstream regions had the highest proportion of differentially methylated cytosines (DmCs), followed by gene bodies and downstream regions. In the NIL-23 genotype, increased CG methylation occurred in leaves, while Pusa-44 showed decreased methylation in all contexts. Epigenetic changes influenced the expression of a small percentage of differentially expressed genes (DEGs) in both genotypes. Under P starvation conditions, specific genes were regulated differently due to methylation changes, with down-regulation in Pusa-44 and up-regulation in NIL-23. These findings highlighted the role of DNA methylation in response to P deficiency in plants.

Interactive effects of elevated [CO_2] and nitrogen fertilization on wheat

The rising CO_2 levels influenced the mechanism of N assimilation, nitrate uptake, nitrate and nitric oxide signalling, plant growth and yield in contrasting wheat genotypes, BT Schomburgk and Gluyas Early, differing in N assimilation was studied. The enhanced NO production under EC and high N levels negatively regulated the nitrate reductase and HATS at both transcriptional and post translational levels. Expression of ammonia assimilation and nitrate signaling genes was down-regulated by EC under high N availability, accompanied by increased nitrosothiol accumulation. Nitrate uptake rates and components of low affinity transport system (LATS) was reduced in plants grown under EC. Excess N application increases reactive N species (RNS) and reactive oxygen species (ROS), suggesting that excessive N does not alleviate the grain protein under EC.

Influence of elevated CO_2 × temperature on phosphorus nutrition in rice seedlings

The study investigated combined effects of elevated CO_2 (eCO_2), temperature (eT), and low P on growth, antioxidant system, and P starvation signalling in two rice varieties (IR 64 and IR 64-Pup1). The treatments included low and sufficient P levels, ambient and elevated temperatures, and ambient and elevated CO_2 concentrations. Elevated CO_2 and temperature (eCO_2 × T) promoted biomass and P uptake but reduction in total leaf area in low-P plants. Lipid peroxidation increased significantly under low-P conditions and elevated temperature, leading to higher membrane injury under low P × eT. The expression of *OsmiR399a* and *OsmiR399b* was up-regulated by low P × CO_2 × T, while their target gene *OsPHO2* was down-regulated. The expression of *miR827* and its target NLA-SPX was lower under $eCO_2 \times T$, but eCO_2 enhanced their expression. The expression of the low P-induced gene OsPHR1 was strongly enhanced by eCO_2 and $CO_2 \times T$. The interaction of elevated CO_2 and temperature enhanced the activity of P starvation signalling components, leading to increased P uptake.

Interactive effects of phosphorus nutrition and drought stress in mungbean and 'donor' identification

Water availability and P are crucial factors for crop production. Cross tolerance to drought and low P stress was studied in contrasting mung bean accessions. Combined stress resulted in reduced gas exchange traits and P uptake compared to individual stresses. Tolerant accessions showed increased root growth, leaf area, biomass, nutrient uptake, and symbiotic N2-fixation under combined stress. They also exhibited higher osmolyte concentration, antioxidative compounds, and antioxidant enzyme activity. Transcript abundance of candidate genes varied between accessions, with IC333090 showing higher expression of drought-related genes. Physiological markers like membrane stability index, relative water content, organic acid exudation, and grain yield can be used for evaluating agronomic performance.

Genome-wide analysis of protein tyrosine kinases and protein tyrosine phosphatase in osmotic stress response of rice

Study revealed 27 and 9 *PTK* and *PTP* genes, respectively from rice genome. Osmotic and drought stresses differentially regulated majority of *PTKs* (77%) and PTPs (67%). Since *PTK24* showed expression specifically in panicle/anther, the critical tissue sensitive to abiotic stresses, *PTK24* was cloned and a gene construct (*pCAMBIA1300-P$_{AtRD29A}$::OsPTK24::T$_{nos}$*) was developed for functional validation.

Genome-wide identification of matrix metalloproteinases (MMPs) in rice

During its entire lifecycle, plants encounter several abiotic- and biotic- stresses which they often address by undergoing phenotypic alterations involving significant modification of extracellular matrix (ECM). The existence of MMPs in rice was explored and identified three candidates which conform to the literature-defined criteria to be qualified as MMPs. *In silico* expression analysis of MMP candidates (OsMMPs) revealed differential expression pattern under different abiotic stresses and tissue-type.

Cloning of stress inducible root specific promoter from rice

To validate the root-specific drought, osmotic, and salt stress inducible *OsMYB TF* gene promoter, GUS reporter transgenic line was developed. The *OsMYB* promoter::*GUS* reporter transgenics confirmed that the cloned promoter is inducible by multiple stresses and hormones specifically in roots.

Cloning of nocturnal promoter

Arabidopsis homologs of *Din1*, *Din4* and *Din6* promoters were cloned based on qRT-PCR expression analysis of these genes under diurnal and nocturnal conditions. Promoter::GUS reporter gene constructs for *Din1*, *Din4* and *Din6* were developed and transformed Arabidopsis plants for functional analysis.

Genetic Engineering of photosynthetic efficiency in rice

For enhancing the Calvin cycle efficiency, heat tolerant Rubisco activase (RCA) and Sedoheptulose-1,7-Bisphosphatase (SBPase) were used for transforming rice cv. MTU 1010. The transgenics overexpressing SBPase (4 events) and RCA were confirmed by molecular analysis. Enhanced photosynthesis in overexpressed SBPase and RCA was noted in transgenics. For nocturnal CO_2 fixation (CAM like rice), a gene construct expressing maize PEPCase under the nocturnal promoter *AtELF3* was developed and transgenic rice plants were confirmed by molecular analysis.

Genetic engineering of WUE in rice

Black rice cv. *Chakhao amubi* was genetically engineered with Arabidopsis *ERECTA* under stress-inducible *RD29A* promoter in rice, five events (T0) were obtained and were confirmed by molecular analysis.

Cap binding protein 20 (CBP20) regulates miRNA biogenesis in rice

For functional validation of *OsCBP20* in micro-RNA biogenesis pathway, rice transgenics constitutively overexpressing *CBP20* were developed. Three different overexpression lines were analysed by transcriptome sequencing and differentially expressed genes (DEGs) were confirmed by qRT-PCR. Results showed five upregulated (Chlorophyll A-B binding protein, FAD dependent oxidoreductase, expressed protein, protochlorophyllide reductase A and DUF26 kinases) and highly downregulated (SCP-like protein, pathogenesis-related Bet v I family protein, dehydrogenase, cytochrome P450 and AMP-binding protein) DEGs. As compared with target miRNAs, these miRNAs showed negatively correlated expression pattern in CBP20 overexpression lines indicating the role of CBP20 in biogenesis of these miRNAs in rice.

Characterizing the differentially methylated regions (DMRs) identified in wheat under heat stress

Wheat cvs. Raj 3765 (thermotolerant) and HD 2329 (thermo susceptible) were exposed to HS (38ºC, 1 h) and subjected to whole genome bisulphite sequencing. About 1469 differentially methylated regions (DMR) in Raj 3765 with 865 hyper methylated DMR and 604 hypo methylated DMR were observed. Similarly, in HD2329, a total of 1179 DMR with 647 hyper methylated DMR and 532 hypo methylated DMR were found.

Tissue specific proteome analysis for the identification of SAAPs in wheat under heat stress

Samples collected from HD2967 under control (22±3ºC) and terminal HS (38±3ºC) were subjected to 2D PAGE analysis revealed 120 DEPs; 160 upregulated and 60 downregulated under heat stress.

Identification of superior genotype for eating and cooking quality (ECQ), resistant starch and nutraceutical properties in rice

The physicochemical tests rely on rice chemical composition, cooking quality, gelatinization temperature and physical properties of cooked rice. Out of 50 rice genotypes, PB1509, PNR-381, IR77384-12-35-3-6-7-2-B and CT-1006-7-2M-5-1P3-M were found superior in ECQ traits.

Pullulanase enzyme activity assay and estimation of resistant starch (RS) were carried out in rice varieties at various grain filling stages revealed that maximum RS content and pullulanse activity were observed in the mature stage with a positive correlation between RS and pullulanase activity.

Phenolic profiling of differentially pigmented Indian varieties - black (Chakhao) and red (Njavara) revealed a variation of 70.2 to 82.5 mg/g in pro-anthocyanidin content, which is negligible in white rice (PB1509). The possible role of these two bio-actives in anti-hyperglycemic activity was further validated using streptozotocin (STZ)-induced diabetic mice model which revealed black rice and red rice contributed significant reduction in plasma glucose with concomitant decrease in the destruction of pancreatic acinar tissue.

Enhancing the nutritional, functional and sensory quality of soymilk using probiotic fermentation approach

Fermented soymilk using single and mixed cultures of *Lactobacillus* and *Weissella* strains enhanced nutraceutical potential, flavour quality, and textural properties. Probiotic fermentation with mixed cultures increased total antioxidant activity, reduced phytic acid levels, increased free mineral content, and converted isoflavone glycosides into more bioavailable forms.

Carotenoids profiling of differently pre-treated processed orange carrot products

Highest β-carotene retention was in citrate buffer-probiotic fermented samples while α-carotene content was higher in 1.5% sorbitol dip and citrate buffer-probiotic fermented samples. Fermentation protects provitamin-A carotenoids during processing and storage. Sorbitol-treated and citrate buffer-probiotic fermented slices maintained β-carotene stability.

Genetic modification of soybean for improved nutritional/flavour quality

A 1545 bp cDNA sequence encoding Isoflavone-conjugate specific β-glucosidase was cloned and characterized from germinating soybean seedlings and confirmed as Glycosyl Hydrolase family by identification of signature elements using bioinformatic tools.

The role of five miRNAs was studied in two contrasting soybean genotypes (NRC 37-an isoflavone-rich genotype and NRC7- an isoflavone-deplete genotype). Amongst all the miRNA-target pairs, *Gma-miRNA26*, *Gma-miRNA28*, and their corresponding targets showed perfect negative correlation across all the stages and genotypes.

Validation of γ-TMT3 promoter from two contrasting genotypes - Bragg and DS74

Functional validation of γ-TMT3 promoter from Bragg and DS2706 was carried out. Arabidopsis plants were stably transformed by γ-TMT3 promoter fused with β-glucuronidase (GUS) gene confirmed by GUS assay.

Development of an efficient transient transformation method in soybean – AGRODATE (Agrobacterium mediated Disc Assay for Transient Expression)

Using leaf discs, a transient transformation in soybean was developed that involved syringe agro-infiltration under vacuum using an optimized infiltration buffer. The buffer contained specific components, including DTT and Tween 20 thus improving transformation efficiency by 15%.

Improving shelf-life in pearl millet flour by understanding the mechanism of rancidity and technology development

Screened 60 diverse genotypes of pearl millet for acid value, peroxide value and enzymes involved in off odour development such as lipase, lipoxygenase, peroxidase and polyphenol oxidase at different time interval. A rancidity matrix has been developed to rate the pearl millet genotypes into low, medium and high rancid type. Hydrothermal treatment reduce rancidity in pearl millet flour by decreasing acid value and peroxide value, indicating reduced rancidity.

Optimization of onset of gelatinization to enhance the dough and chapatti quality of gluten reconstituted pearl millet and corn flour

Both the dough systems viz. gluten reconstituted pearl millet (PM-g) and maize (MZ-g) at 8 and 5% respectively showed a dominance of elastic behaviour (G′) over the viscous one, a typical behaviour of flour dough. Compared to MZ-g dough at 5%, higher G′ was observed in PM-g dough which was due to higher swelling power of starch at prevalent gelatinization temperature during dough making process.

Development of Wheat Gluten based "Soft Nutri-cereal Atta"

To address poor dough and chapatti making quality of pearl millet and maize flour and its utilization in bakery industry, a technology of vital wheat gluten (VWG) reconstitution in bajra and makka flour was developed with products namely **"Hallur: 'Soft Bajra Atta"** and **Makai: Soft Makka Atta"**. Similarly, different percentage of VWG were optimized and further tested for dough quality parameters in makka flour to make it as superior as wheat flour. Both "Hallur: 'Soft Bajra Atta" and Makai: Soft Makka Atta" were commercialized through a private company.

Microgreens: A Nutraceutical food for better health and wellness

Six crops (Brassica, Mungbean, Lentil, Pearl millet, Red radish, and Red cabbage) were evaluated for microgreen production and nutritional content. Microgreens exhibited significantly higher antioxidant potential, vitamin (4-6 times), and mineral (2-3 times) content compared to their mature counterparts. Based on this research, a NutriGreens kit called 'TinyFields' was developed, containing seeds of various Brassica family members.

Physico-chemical analysis of aged rice for improved quality traits

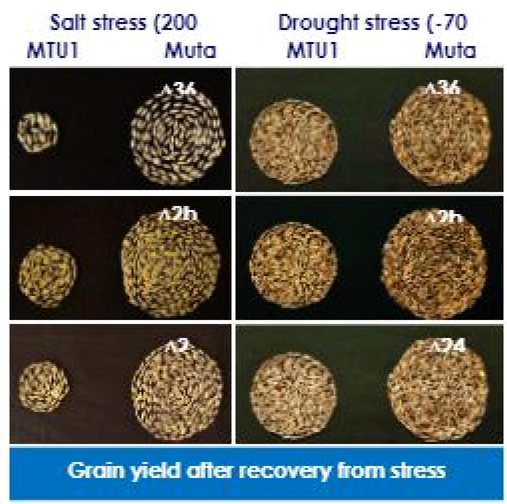
Viscosity profiling, texture analysis and matrix interaction analysis of freshly harvested Basmati (PB-1121 & PB-1509) and Non-basmati (BPT-5204 & Swarna) rice varieties were compared with one-year aged (6 & 12 months stored) rice grain. The confocal laser scanning microscopy images of cooked rice slurry revealed that matrix component interaction was more in 6- and 12-month aged samples of all varieties as compared to freshly harvested rice. Protein and lipid interact with starch by being embedded within the internal starch matrix.

Profiling of seed protein quality in chickpea and pigeon pea genotypes

Desi chickpea genotypes displayed lower Amino Acid Score (AAS) for lysine, while Kabuli genotypes had lower AAS for threonine. The Protein Digestibility Corrected Amino Acid Score (PDCAAS) in chickpea was lowest in BGD 112 while highest in Pusa 256. Likewise, in pigeonpea genotypes, the PDCAAS was lowest in BSMR 736 and highest in ICP 87.

CRISPR/Cas9 genome editing in rice

Genome editing in rice is carried out to create mutants of *DROUGHT AND SALT TOLERANCE (DST)* gene. Four alleles of DST mutants were developed in rice cv. MTU1010. All mutant alleles showed higher tolerance than that of WT plants to both salt and drought stresses under pot culture conditions, and showed reduced whole plant transpiration and drought tolerance in the field condition. These mutants also showed > 25% increase in grain yield under normal condition in field.



Grain yield after recovery from stress

Summary

During the period 2017 to 22, a fully functional state-of the-art Nanaji Deshmukh Plant Phenomics Center was established. This facility is being used to generate big data non-destructively to assess the rice and wheat germplasms and RILs to identify donors and QTLs for water and nitrogen use efficiencies in collaborations with breeders. High-throughput phenotyping protocols are developed based on machine learning approach which is being used widely by researchers. Basic physiological mechanisms were deciphered in rice and wheat crops in response to abiotic stresses such as high-night temperature, terminal heat stress (in wheat), drought, and nutrient (N and P) stress. Effect of various bio-elicitors like plant growth regulators and other compounds were studied to ameliorate the adverse effects of high temperature and drought on plants. For nutrient stress, several candidate genes and microRNAs regulating N and P stress were identified through genome-wide studies and transcriptomics, respectively as well as epigenetic changes in rice under P stress. A few physiological traits and donors for low N and P in rice and wheat were

also identified. Interactive effects of climatic factors (CO_2, high temperature and drought) with N and P nutrition revealed physiological and molecular basis of resilience in wheat, rice and mungbean. In the area of genomics, several genes and promoters are identified, cloned and some of them are ready for functional validation in rice or model plants which might impart tolerance to abiotic stresses. With respect to the nutritional quality, shelf life and nutraceuticals, superior rice genotypes are identified and improved the functional and sensory quality of soymilk using probiotic fermentation approach. Development of wheat gluten-based maize and bajra flour are developed and micro-greens were evaluated for nutritional content, both these products are commercialized. In the Flagship project, *DST* mutants were developed in rice MTU1010 which are to be tested in field conditions.

To maintain the phenomics facility in running condition, sufficient funds are needed to meet the maintenance and electricity cost as well as to meet out the AMC of the software by LemnaTec. Several phenotyping experiments in field (~4 acres), pot-culture and glasshouse are being conducted using hand-held devices, so to maintain such experiments, skilled and semi-skilled manpower are required. The genes and promoters have been identified and cloned to functionally validate them against several abiotic stresses, however, there is lack of dedicated growth chambers with 24 h power backup to carry out such studies. In the next five years (2022-27), efforts will be made to register the identified germplasm with special traits, develop the mapping population with the help of breeders, functionally validate the genes and promoters, and identify some genes/TF which can be utilized for genome editing to improve the growth, yield and quality in targeted crops.

5.6 School of Social Science

1. Enhancing smallholder's productivity and agricultural growth through technology, sustainable intensification and ecosystem services
2. Inclusiveness and effectiveness of agricultural markets and trade reforms and development of agro-industries
3. Commercialization and impact of improved agricultural technology
4. Development of innovative agricultural extension models
5. Enhancing nutritional security and gender empowerment
6. Maximizing farm profitability through entrepreneurship development and farmer led innovations
7. Out scaling agricultural innovations for enhancing farm income and employment

Achievements

Division of Agricultural Economics

The divisional research focused on topics of national importance, particularly agricultural productivity and growth, sustainable intensification, valuation of ecosystem services, nutrition-sensitive agriculture, market reforms, and the impact of agri-technologies, policies & institutional innovations.

Transformation of agricultural production system for nutritional security & sustainability

The value of ecosystem services provided by paddy landraces in Wayanad, Kerala, and the Eastern Yamuna Canal (EYC) irrigation system in western Uttar Pradesh were estimated. The Wayanad paddy ecosystem generates ₹ 6,26,919 per ha worth of ecosystem services annually, of which 77 percent is non-marketed. The study estimated farmers' willingness to accept a mean compensation of ₹ 7,933 per ha as an incentive to cultivate traditional paddy varieties, which is low compared to the annual value of ecosystem services. The average value of ecosystem services delivered by the Eastern Yamuna Canal (EYC) irrigation system was estimated to be ₹ 1123 million, relatively higher than the working expenses (₹ 757million) of this canal irrigation system. Both studies indicate the significance of accounting for the value of ecosystem services in any eco-compensation framework.

A study on the effects of fertilizer use on crop response and environmental sustainability revealed that the policies like the Retention Price Scheme and the DBT pilot scheme have significantly affected fertilizer consumption. A wide variation in yield response to fertilizer use existed among the states, and responses were lower in states where the share of farmers overusing nitrogen was higher. Further, the trend in the Nitrogen budget indicated increasing Nitrogen surplus and decreasing Nitrogen use efficiency. Through meta-analysis, an average yield improvement of 0.05 tonnes per hectare was found due to biofertilizer application. The adoption of biofertilizers by sample farmers of Gangetic Plain was found only 14 percent. Farmers preferred liquid-form biofertilizers having higher shelf life from reliable (preferably government) sources, as indicated by the choice experiments in the region.

Spatial analysis showed Bihar, Meghalaya, and Jharkhand as the hot spots for childhood stunting; while age, gender, birth order, maternal BMI, education, sanitation facility, wealth index, and region were the significant predictors of stunting. In this context, biofortification is a promising technique that can enrich staple food products with micronutrients. The meta-analysis suggested that consuming iron biofortified crops will increase the iron content by an average of 0.09 g/dl, and serum retinol and plasma zinc levels by an average of 0.66 μg/dl.

The estimation of the demand-supply gap showed that there may be a net surplus of around 4 million tonnes in the case of bajra and 0.1 to 0.2 million tonnes of small millets by 2033. But in the case of jowar and ragi, there may be a net deficit upto 1.14 to1.45 million tonnes and 0.2 to 0.36 million tonnes, respectively. Hence measures may be taken to ensure assured supply and diversify cropping systems by incorporating millets.

Innovations in Agricultural Marketing and institutions for enhancing farmers' income

Farmers' access to markets was analyzed for Paddy farmers in India using unit level NSSO 77th round data. Most of the paddy farmers (46 per cent) preferred selling to local traders even though the satisfaction levels with the sale outcome were lower. The results of the multinomial logit model suggest that small and marginal farmers and farmers belonging to the disadvantaged section of society, like SC/ST farmers, prefer local traders over APMCs. MSP awareness is a critical factor that encourages farmers to sell to APMCs. Further, the farmers selling to APMC realize 27 percent more sale value than those selling to local traders.

The overall farmers' coverage under e-NAM was estimated to be only 13 percent of total cultivators in the country so far. Tthe highest percentage coverage was in Haryana (94%), followed by Telangana (58%). An analysis based on the primary data from Karnataka, Haryana, and Punjab indicated that increased automation of the auction process helped in increasing the transparency (88%), competition (85%), reduced scope for collusion and cartels, and quick payment of sale proceeds (85%). Marked improvements are required in the components, like the participation of traders from different APMC markets (23%), grading system (46%), and online payment system (42%), which may help farmers realize better prices for their produce. The study pointed out that a unified license is a prerequisite for inter-market trading. Hence, accelerating the pace of issuing of licenses should be a priority.

Estimates of the potential of Food Processing Industries to generate employment in the country was also worked out. The results indicated that a one percent increase in output would increase employment by 0.27 percent.

Outscaling & Impact assessment of IARI technology, policy & institutional innovations

Ex-post impact assessment of prominent crop varieties using the economic surplus model was done for the following NARS varieties: Basmati rice- PB 1121, PB 1509; Chick pea- JG11, JAKI 9218, JG 16; Soybean- JS 335, JS 95-60. In terms of total economic surplus, PB 1121 has generated ₹ 39250 crores (at 2019-20 prices), PB1509 has generated ₹ 2941crores (at 2019-20 prices) in the case of rice; and JG 11 has generated ₹ 397 crores (at 2020-21 prices), JAKI9218 has generated ₹978 crores (at 2020-21 prices) and JG 16 has generated ₹ 78 crores (at 2020-21 prices) in the case of chickpea. The total economic surplus generated from the soybean variety JS335 was ₹ 50111 crores, and that from JS95-60 was ₹ 6749 crores.

The PM-KISAN beneficiaries were found to adopt production technologies better in the case of groundnut farmers. The gross returns (₹ 39880/-) and B-C ratio (2.16) were higher for beneficiaries of PM-KISAN due to the utilization of cash transfers to purchase high-quality inputs in time. However, using the doubly robust Inverse Probability Weighted Regression and Propensity Score Matching methods, we found no empirical evidence to suggest that loan waivers enable farmers to improve productivity in farming in Uttar Pradesh. Interestingly, the Kisan Credit Card (KCC) holding households have ₹ 7058 more farm income per hectare than the non-KCC holders. It was also found that access to KCC reduces farmers' dependency on money lenders for borrowing credits by 25 percent. Another study on farmers' perception and usage of soil health cards in Andhra Pradesh showed that 58% of farmers were benefitted by using the SHC, and 60% agreed that SHC has reduced extra expenditure.

Division of Agricultural Extension

The major focus was laid upon testing of various extension models covering the emerging advantages of ICTs and partnerships for addressing the issues of yield gaps, climate change adaptation; nutritional security, and entrepreneurship development. Socio-economic assessment of govt schemes was also carried out.

Development of Innovative Agricultural Extension Models

The IARI-Post Office Linkage Extension model performed more effective than traditional extension systems in the five states Uttar Pradesh, Madhya Pradesh, Bihar, J&K and West Bengal. A Multimedia-based Extension Model named "Pusa Samachar" was developed for technology information dissemination and agro-advisory through social media It was found that 88.67% of farmers regularly watched Pusa Samachar and 81.13% of them shared this content with their colleagues. A Multimedia- based Extension Model named Pusa Samachar was developed for technology information dissemination and agro-advisory through social media. The first episode of "Pusa Samachar" was uploaded in IARI official YouTube channel on 22 August 2020, and every Saturday at 7 PM new episode is uploaded and till now, 149 episodes have been broadcasted from the official channel of IARI. About 100 episodes in regional languages (Tamil, Telugu, Kannada, Bangla and Odiya) have been produced and uploaded on IARI YouTube Channel. In every episode time specific crop management practices, successful farmer stories, and weather broadcasts are given. Pusa WhatsApp Salah (9560297502) has been created for redressal of farmers' queries.There are about 32000 subscribers.

Convergence-based extension and social learning-based extension models were tested to disseminate climate resilient technologies. The convergence-led extension model implemented in Gaya district of Bihar helped in creation of three ponds and 4 check dams by the Department of soil and water conservation and FIGs with 90:10 contribution. It facilitated irrigation in 15 acres of land, besides raising income through fish cultivation in ponds. There was significant difference in the yield of wheat among the experimental groups before and after the ICT mediated social learning. Due to adoption of technical know-how and do-how with social learning; the farmers in experimental groups obtained 48.57 per cent increase in yield. Based upon community -based interventions, climate-smart villages have been developed in Haryana, Bihar and West Bengal, where the farmers have adopted climate- resilient technologies.

Effectiveness and performance of the PM-KISAN scheme

The study showed a mean effectiveness index score of 15.17 with standard deviation of 0.732 in Uttar Pradesh followed by 14.95 with a standard deviation of 0.994 in Bihar. The study also found that in Uttar Pradesh 21.67 percent of farmer respondents perceived the scheme as highly effective, followed by 63.33 percent as medium and 15 percent as low for livelihood development. In Bihar, the respective figures were 25, 50, and 25 percent. The doubly robust Inverse Probability Weighted Regression Adjustment (IPWRA) showed that the PM-KISAN scheme increased the beneficiaries' livelihood index by 2.5 percent.

Socio-economics impact assessment of the existing Government schemes on climate change adaption

Socio–economic assessment of "Pradhan Mantri Krishi Sinchai Yojana (PMKSY)" conducted in Haryana revealed higher yield (12-17%) as well as savings on irrigation water (34-40%) and labour cost (50-66%) in sprinkler-based irrigation systems in comparison to flooding method of irrigation followed in pearl millet, wheat, mustard, cauliflower, onion and spinach. Also, the micro-irrigation system changed the cropping system from Pearl millet–Wheat based cropping pattern to Vegetable-Wheat and Vegetable–Mustard, Vegetable-Vegetable based effective alternative cropping system for climate change adaptation and livelihood security. Socio-economic assessment of "Farm Pond on Demand" (*Magel Tyala Shet Tal),* a scheme launched by the State Agriculture Department in Maharashtra, was carried out in Vidharbha and Marathawada regions with a sample size of 320 framers. It was found that the cultivated land utilization index of major crops increased from 0.22 to 0.67 after the adoption of farm ponds. The benefit- cost-effectiveness increased from 17.27 to 48.83 percent.

Enhancing Nutritional Security and Gender Empowerment (01.04.2014 to 31.03.2021)

Two hundred demonstrations on nutrition kitchen garden and twenty demonstrations on bio-fortified varieties of ICAR institutes (var. DBW-303 & DBW-187 of wheat and PM 30 & PM 31of Mustard) were conducted. The farmers' sensitization programmes on bio-fortified varieties such as Field Days (2) on Mustard PM 30 and pearl millet (var. Pusa Composite 443 &701) were organized, in which 110 farmers were benefitted. The health camps (04) sensitized 200 rural women about iron deficiency. Networking was done with local institutions like *Anganwadis,* ICDS, Gram Panchayats, Self Help Group (SHG) members and KVKs. Capacity building interventions with 15 trainings, mainly in value added nutri-foods preparation, engaging 500 beneficiaries were organized through Community Agri-nutri Security Centres (CANSCs).

The impact study on kitchen garden interventions revealed that out of 35 families, 21 families lowered their maximum monthly expenditure on purchase of vegetables (Rs.400-500/), and 9 families lowered it to 50 per cent (Rs.250-Rs.350/-). Out of 35 women, 29 members expressed that it helped their families improve the consumption of fresh vegetables in their diet and improved social relationships with their neighbors by sharing the surplus produce from their homestead gardens.

The interventions undertaken through CANSCs has impacted the dietary diversity as well as economic and social status of the targeted women in Lahchoda and Mukari villages of Baghpat district (U.P.) but did not show any impact on the anthropometric (BMI) of the participants.

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

The varieties with low erucic acid Mustard (PM 30&31) (4 qtl.), bio-fortified wheat varieties (DBW-303&187 (high iron content (43.1ppm) (6 qtl.) and nutri kitchen garden (400) were demonstrated in project villages. A total number of 4 trainings of three days each were conducted. The impact of nutri-sensitive agricultural (NSA) interventions on household nutrition security was studied using a sample of 350 rural households from Baghpat and Sonipat districts. The difference in HFCS between treated households and control households was 70.77 and 56.96 for nearest neighbour matching methods and it was statistically significant at 5 percent level.

Maximising Farm Profitability through Entrepreneurship development and Farmer-Led Innovations (2014-2021), which is extended as Converging Agripreneurship, Farmers' Innovations and Modern Technologies (2021-2026)

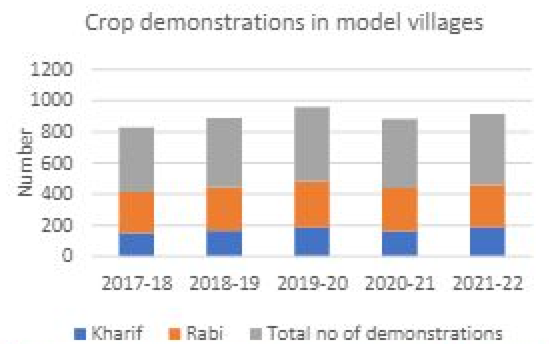
The objective was to develop a business model for small farm holders to make farming remunerative. 190 case studies of Farmer-Led Innovations across 17 states of India were conducted to draw lessons for developing agripreneurship among other farmers in the region with similar situations as part of out-scaling FLIs. Based on learnings derived from case studies of innovator farmers, a model of Farm Entrepreneurship Development was devised and validated in project villages. Farm Entrepreneurship Development process was found to be dynamic interplay of entrepreneurial competencies and entrepreneurial climate resulting in success of their agrienterprises. Significant entrepreneurial competencies were identified as opportunity recognition, drive for excellence, quality concern, risk taking behaviour, innovativeness and business orientation. Among the key factors of entrepreneurial climate listed were available technical guidance, availability of credit, special government schemes, effective networking, infrastructural ease of transport, and marketing avenues.

Two Farmer Producer Companies (FPCs) were established with 100 members each and four women SHGs were formed in project villages in collaboration with NABARD. One farmer already linked with IARI for commercial seed production through participatory seed production programme has been facilitated to continue the programme. 25 wheat farmers of 6 villages from Dewas, Indore and Dhar districts were developed as wheat seed entrepreneurs during 2021-22. The farm income was enhanced to ₹ 36,000/- to ₹ 1,32, 000/- .

Centre for Agricultural Technology Assessment and Transfer (CATAT)

Out-scaling Agricultural Innovations for enhancing farm income and employment

An approach of Integrated Development of Village was taken up to transform the adopted villages through agricultural technology application to serve as model villages for the neighbouring villlages. With the baseline survey, bio-resource mapping, and agro-ecosystem analysis the major problems were identified in the selected villages in NCR. Interventions were made for popularization of high yielding varieties of different crops for enhancing profitability and nutritional status of the selected households. A total of 2237 number of demonstrations were conducted. The approach also laid emphasis on promotion of seed production, mobilization of farmers for group action for value addition and marketing; use of appropriate weedicides, application of resource conservation technologies like Laser leveler, Drip irrigation in vegetable crops, Raised -bed planting and mulching. Various capacity development programmes were organized in the project locations. Linkages with different stakeholders such as KVK, ATMA, line departments, marketing agencies, financial institutions, and input agencies were strengthened through their participation in the field interventions.



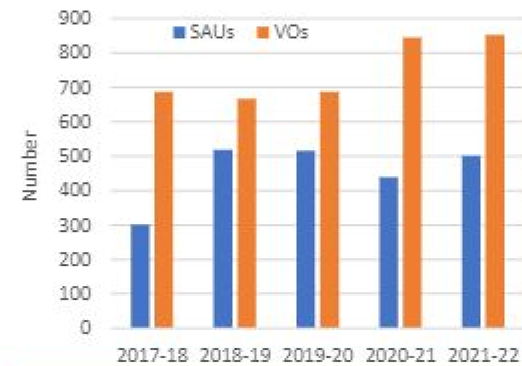
Number of demonstrations conducted in the model villages

Out scaling of IARI technologies for enhancing farm income (Project Started on (01.04.2021)

The concerted interventions have resulted in out-scaling of the two varieties in the project village and its surroundings. The limited seed input provided for demonstration yearly from 2015 to 2020, has led to their multiplication and spread in terms of increased acreage and production in the region. Within the span of 6 years, PB 1121 and PB 1509 have estimated to spread in an area of 5577.82 ha and 3440.49 ha respectively. The farmers could get 10-15% higher income from PB 1509. Additionally the cost of production was also reduced upto 5%.The change in cropping pattern and crop diversification after IARI interventions revealed that majority (76.66%) of the respondents shifted from using traditional varieties to improved HYVs, from using long duration varieties to short duration varieties (70%), from sugarcane-wheat-sugarcane to rice-mustard-sugarcane (61.66%) and from broadcasting to line sowing (30%). A majority (63.33%) of the respondents observed change in use of high yielding varieties of crops especially wheat, paddy and mustard (60%), IPM practices (56.66%), soil testing (58.34%), seed treatment in paddy and wheat (53.33%), and use of biofertilizers (48.33%).

Strengthening Extension Education Programme of Developing Innovative Models and Techniques for Higher Productivity and Profitability in Agriculture.

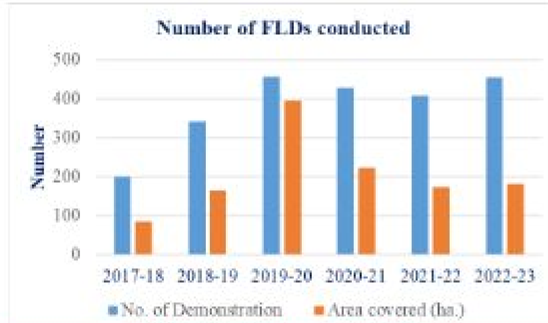
An innovative partnership-based extension model was conceptualized on the principle of 'sharing of strength' for technology dissemination through 'partnership' involving the public institutions (ICAR institutes and SAUs) as well as Voluntary Organizations (VOs). The partnership model is emerging as a potential solution to the problems of effective transfer of technology to the ultimate users as the heavily burdened public extension is majorly supply driven rather than demand driven. Interventions were made to address the productivity problems of disadvantaged areas/areas like water scarcity areas, hill agro-eco system, and new / non-conventional areas. A total of 2278 and 3741 demonstrations were conducted with SAUs and Voluntary Organizations, respectively. Through interventions of the project, several newly introduced crops have become popular in non-conventional areas. Palak (spinach) variety Pusa Bharti has been well accepted in Karnataka because of its good market price, broader leaves, rapid growth and multicut traits as compared to the local varieties. Moong variety Pusa Vishal was found suitable in Hazaribagh district of Jharkhand for better return as 80% pod mature at same time. As a result, farmers could take early vegetables in the same field, thus maximizing their income. Pigeon Pea Varieties Pusa 2002 and Pusa 992 were preferred by farmers for higher yield (9 q/ha and 10.5 q/ha, respectively) and good taste in Uttarakhand hills. In Bilaspur, Himachal Pradesh, farmers have started growing seasonal vegetables like okra, capsicum and early cauliflower which were found remunerative. The earnings improved their livelihood.



Number of demonstrations conducted under National Extension Program

KVK Gurugram

The Institute's Krishi Vigyan Kendra at Shikohpur, Gurugram, plays a critical role in improving farmers' awareness and farm productivity as well as empowering rural youth for self-employment. Field problem based on farm testing; Front Line Demonstrations (FLDs) on oilseeds, pulses & cereals; Training for different target groups; Empowerment of women in agriculture; and Agricultural extension activities & farm advisory services were conducted. As many as 2287 FLDs on major crops were conducted in an area of 1217.6 ha.



Demonstrations in FLD

During the period 291 training programmes were organized for farmers, on weed management, seed production, INM and plant protection measures of rabi crops, drudgery reduction technologies, income generation activities for women empowerment, minimization of nutrient loss in processing, benefitting 7265 farmers and farm women in different villages of Gurgram district.

Table 5.4 Vocational Trainings organized for rural youth by KVK Gurugram

Enterprise	Training conducted (no.)	Youth trained (no)	Unit Sustaining (No.)	Average income per/ year/ person (Rs.)
Mushroom	06	109	07	91,000/- to 2,38,000/-
Protected cultivation	07	114	32	1,15,000/- to 12,57,000/-
Value addition	05	126	12 units	1,26,000/- to 12,00,000/-
Goatry	01	10	06	84000/- to 126000

On-farm testing (OFT) is mainly focused to test the developed technologies that might be helpful to solve the most important and widely spread problems of the groups of farmers. OFTs were conducted on Integrated Nutrient Management (INM) and Integrated Weed Management (IWM) in wheat, Management of Diamond back moth (DBM) in cauliflower, Management of Fusarium wilt in Summer Squash, Use of revolving stool to reduce drudgery in women during milking operation, Management of Nematode in Summer Squash (Chappan Kaddu), Efficiency of the mineral mixture & vitamin AD3E on reproduction performance in buffaloes

Awareness Camps, Field days, Kisan Gosthies, Farmers-Scientists Interactions, Exposure visits, mobile based farm advisory and celebration of important events like *Poshan vatika MahaAbhiyan,* International Women's Day, World Bee Day, World Environment Day etc were also organized for the benefit of the farmers.

Outreach Projects

Farmer FIRST Programme (Participatory Technology Application and Multi-Stakeholder Convergence for Market led Agripreneurship and Sustainable Rural Livelihood)

The project interventions were carried out in Palwal district of Haryana with crop, horticulture, and livestock modules. Under Crop based Module, 2938 farmers were benefitted covering an area of 1175 hectares. Under Horticulture-based Module, 3077 farmers were benefitted covering an area 1230 hectares. Under the Livestock based Module, Mineral Mixture were provided to 383 households. Under Enterprise-based Module, 25 farmers were engaged in seed production, who produced 754 quintals seeds of paddy and wheat. An income of ₹ 87713.90 was earned from the sale of seeds as compared to only ₹ 54610.99 from grains per acre. The farmers are being mobilised in collaboration with *Garmin Shiksha Evam Association Mitraon*, Najafagarh block Delhi for formation of seed and vegetable growers' association, which may be converted as farmer producer organization (FPOs) later.

The Integrated Farming Systems module was introduced in farms of 5 farmers in 5 ha area. A total income from the IFS module of one hectare was about Rs. 2, 57,784.51, securing an increase in net income of 65.63%. About 23 training programmes were conducted for 1298 beneficiary farmers on different technologies of crop production, value addition, and seed production. 165 Farmers-Scientists interface meetings were organized to popularize the improved varieties and technologies.

Tribal Sub-Plan Approach (TSP)

The Tribal Sub-Plan is a plan or a strategy that was introduced by the government to ensure the socio-economic development of the tribal people of India. It is a part of the annual plan of a state or UT (Union Territory).

Five awareness cum workshops were organized on doubling the farmers' income with the tribal farmers of Jalpaiguri, Alipurduar and Kalimpong districts of West

Bengal. Critical inputs like improved varieties of paddy, fish tank, tomato hybrid seed, chilli hybrid seed, micronutrients, vermicompost units and bio-fertilizer were provided for demonstrations. A total of 27 demonstrations of 5 varieties were conducted in 11.40 hectares in 4 tribal villages of Dhar district and 22 demonstrations of eight varieties in 11.80 ha area of Jhabua district were conducted in M.P. Overall average increase in yield was up to 18 q/ha (46%) in these demonstrations. Introduction of durum wheat as a health food was done for the first time. Mobile Feed block machine (1 number), Feed and fodder crusher (1 No.), Feed and fodder mixer (1 No.), Pusa Basmati thresher (4 No.), Manual Chaff cutter (5 No.) and Pre-germinated paddy seeder (60 No.) were provided to the tribal farmers of Madhya Pradesh under TSP Scheme.

NEH Programme

Engaging different KVKs of NEH region 3450 quintals of potato seed (Varieties: Kufri Jyoti, K. Pukhraj, K. Himalini) and 2599 kg of vegetable seed (marigold, carrot, radish and vegetable kits) were provided to the farmers of NEH region for enhancing yield and income as well as nutritional security. A total of 2150 farm families were benefitted from this and 1500 hectares of area was covered under the different demonstration programmes organized. Under this programme, 2720 units of wheel hand hoe, 586 units of pedal operated paddy thresher and 316 units of pre-germinated paddy seeder developed by Division of Agricultural Engineering, ICAR-IARI, were disseminated in different areas of NEH region for demonstration purpose. Beneficiary farmers were also provided hands on training on operationalization of these small farm equipment.

DBT Project: Establishment of Biotech-KISAN Hub

A micro-processing unit was created at KVK Chitrakoot under DBT Biotech KISAN Hub Project. Equipment like hydraulic press, pulper, flour mill, spice mill, mixer cum grinder and other accessories have been provided in the hub from the project for use by the local farmers for processing at community level. A total of 2829 farmers covering 906 SC/ST farmers and 901 female farmers were benefitted through different interventions. There was yield advantage in range of about 8 to 31 per cent by improved varieties as compared to the local check in different crops under demonstrations. HD 2967 variety of wheat secured about 46 per cent higher yield than the local variety and the farmers secured additional income of ₹ 24840 per ha, while HI-1605 variety provided 24 per cent higher yield and additional income of Rs 12960 per ha. The yield advantage with the improved varieties of chickpea was in range of

20-32 per cent. Pusa 547 variety of chickpea secured the highest yield gain of 32 per cent and additional income of ₹ 21600.

Expanding the activities of Biotech-KISAN hub in aspirational districts

The technological as well as capacity building interventions were made in 7 aspirational districts (Dholpur, Karauli and Baran in Rajasthan; Mewat in Haryana; and Shrawasti, Balrampur, and Bahraich in Uttar Pradesh). A total of 6209 demonstrations of improved varieties of paddy, wheat, moong, pigeon pea, mustard and vegetables crops; bio- fertilizers (PSB, VAM, azotobacter, Trichoderma, Pusa Sampoorn, crop residue management and agro-techniques were laid out and 167 trainings were organized benefitting more than 3000 farmers.

Scheduled Caste Sub Plan (SCSP)

The ICAR-IARI implemented the Scheduled Caste Sub Plan (SCSP) programme for the upliftment of scheduled caste farmers in thirty districts of Uttar Pradesh, Haryana and Delhi to enhance their income through improved seeds of crops and vegetables, critical inputs like fertilizer, plant protection chemicals and agricultural machinery, and capacity building initiatives through farmers-scientist's interfaces.

During 2020-21, The ICAR-IARI organized a total of 10,412 demonstrations of its improved varieties of paddy, wheat, mustard, lentil, chickpea and vegetables were organized and a total of 5, 724 SC farmers were benefited in seven districts of two states of Uttar Pradesh and Haryana. During the financial year 2021-2022 and 2022-2023, demonstrations of Kharif and Rabi season IARI improved varieties of paddy, mungbean, pigeon pea and wheat, mustard, lentil, chickpea, and Vegetables were conducted and 67,570 SC farmers were covered in 30 districts of Uttar Pradesh and Haryana states.

***Mera Gaon Mera Gaurav* (MGMG)**

The *Mera Gaon Mera Gaurav* (MGMG) program is aimed to increase the farmer-scientist interface, to reduce the lag in delivery of information to the target group of farmers. It is being implemented in 120 clusters comprising of over 600 villages by the multi-disciplinary team scientists.

Pusa Krishi Vigyan Mela

IARI has been organizing Pusa Krishi Vigyan Mela annually on a salient theme since 1972, where-in the latest varieties and technologies developed by the institute are demonstrated live in demonstrations as well as experimental plots, showcased through audio-visuals and communicated to the end users through technical sessions and interactions. IARI also honours the farmers for their own innovations by felicitating them as IARI-Fellow Farmers and IARI-Innovative Farmers. During the last five years the themes of the mela were Krishi Unnati; Agricultural Development: Innovative Technologies; IARI Technologies for achieving sustainable development goals; Self -reliant farmer; Self -reliant farmer through technological knowledge; Nutrition, food and environmental security through millets. The mela witnesses the footfalls of about 1 lakh farmers from the various part of the country.

Pusa Krishi Vigyan Mela

The research in Social Science covered the salient areas of estimation of ecosystem services, innovations in marketing, climate change adaptation, nutritional security, entrepreneurship development, development and validation of various extension models engaging partnerships of public and private institutions. Ecosystem valuation estimated that the Wayanad paddy ecosystem generated ₹ 6,26,919 per ha worth of ecosystem services annually, of which 77 percent is non-marketed. The average value of ecosystem services delivered by the Eastern Yamuna Canal (EYC) irrigation system was estimated to be ₹ 1123 million, relatively higher than the working expenses (₹ 757million) of this canal irrigation system. Assessment of IARI varieties in terms of total economic surplus showed that PB 1121 has generated ₹ 39250 crores (at 2019-20 prices), PB1509 has generated ₹ 2941crores (at 2019-20 prices) in the case of rice; and JG 11 has generated ₹ 397 crores (at 2020-21 prices), JAKI9218 has generated ₹ 978 crores (at 2020-21 prices) and JG 16 has generated ₹ 78 crores (at 2020-21 prices) in the case of chickpea. More than 30,000 farmers could get salient video-based advisories through multimedia extension model *Pusa Samachar*, the IARI varieties could be tested and promoted in 16 states covering the major agro-ecosystem through public-private partnership-based extension model. Basmati varieties PB 1121 and PB 1509 have been estimated to spread in an area of 5577.82 ha and 3440.49 ha, respectively due to extension interventions. IARI varieties have become popular in non-conventional areas, eg. Palak (spinach) variety Pusa Bharti in Karnataka, Moong variety Pusa Vishal in Hazaribagh district of Jharkhand, Pigeon Pea Varieties P 2002 and P 992 in Uttarakhand hills. Convergence-based extension engaging private and public institutions resulted in promotion of climate resilient technologies in IGP regions and creation of water ponds and structures to address the problems of water scarcity. Fifteen Farmer Producer Companies (FPCs) have been established to strengthen farmers' linkage to markets. Vocational training of KVKs have led to establishment of enterprises of mushroom, protected cultivation, value addition, and goatery and securing income in range of 0.80 to 12 lakh per annum. More than 90 thousand farmers of disadvantaged communities (SC&ST) have been benefited in capacity enhancement for livelihoods through support of knowledge, skills and critical inputs.

5.7 The Graduate School

Since its inception in 1905, ICAR-IARI has flourished as a Centre of Excellence for Post Graduate education. The teaching programme at IARI started way back in 1923, with a two-year diploma course in all major fields of agricultural sciences leading to Associateship of IARI. The institute was accorded the status of a Deemed University in 1958 under the Section 3 of the University Grants Commission Act of 1956.

The Post Graduate School of IARI awards post-graduate degrees under Masters and PhD programmes in 26 disciplines of Agricultural Sciences and related basic disciplines in collaboration with its sister institutes, namely, IASRI, NBPGR and NIPB located within premises of IARI, New Delhi campus, five outreach academic collaborative programmes at CIAE, Bhopal, IIHR, Bengaluru, NIBSM, Raipur, NIASM, Baramati and IIAB, Ranchi, IARI, Assam and IARI, Jharkhand. Students are admitted through all India level entrance examination conducted by the NTA/ICAR. Annually, foreign students are also admitted through DARE against 30 seats approved by academic council, IARI under M.Sc., M.Tech. and Ph.D. degree programmes. During 2017-22, 1657 students (991 M.Sc./M.Tech. and 666 Ph.D.) were awarded degrees including 65 Foreign students.

The Accreditation Board of ICAR granted accreditation to Master and Doctorate degrees of all the teaching disciplines of IARI in 2021. In 2017, IARI got accreditation from the National Assessment and Accreditation Council (NAAC), UGC with A+ grading and received 23rd NIRF ranking among overall Institutions of country from MHRD, GoI.

Management

The Academic Council (AC) is the apex body of the institute in the matter of academic activities of the Institute at the PG School. It is supported by the Board of Studies in 26 disciplines and four Standing Committees namely, i) Courses, Curricula and Academic Affairs, ii) Faculty and Discipline, ii) Scholarships, Financial Assistance and Academic Progress, and iv) Students' Problems and Discipline, Welfare Board and Residences. Based on the recommendations of AC, IARI management implemented many new initiatives during 2017-2022, highlighted below:

Curriculum design and development

Introduction of New Courses/Changes made in the existing Courses

Two new courses in the Fruit Science discipline (Advances in Growth and Development of Fruit crops; FSC 621, 3L+1P and Hi-Tech Fruit production; FSC 603, 3L+1P) and one Non-Credit Compulsory e-Course "Introduction of Disaster Management" in the discipline of Agricultural Extension were approved by Academic Council in its 407th meeting.

Keeping in view, the latest innovations and changing global scenario, the AC in its 411th meeting approved two new courses for PG students, namely, Science and Society (PGS 508) and Non-coding RNAs (BI 644). Existing nomenclature of two disciplines was Modified as: (i) Floriculture and Landscaping Architecture" as "Floriculture and Landscaping" (ii) 'Agricultural Extension' as 'Agricultural Extension Education.

The Academic Council approved initiation of Diploma and PG Diploma courses at IARI, in some of the areas like (i) Organic Farming; and (ii) Good Agriculture Practices for Basmati Rice Cultivation.

Implementation of Semester System

To comply with BSMA guidelines, semester system was implemented from academic session 2020-21.

Revision of Course Syllabi

Courses/Syllabi for all the teaching disciplines of IARI were revised as per the BSMA recommendations and the same were approved by Academic Council, IARI in 2020.

Introduction of new programme

The ICAR Post-Doctoral Fellowship (ICAR-PDF) programme was initiated in 2019 under '*Strengthening and Development of Higher Agricultural Education in India'* Scheme of ICAR with an objective to support the bright and talented researchers to build capacity in frontier areas in agriculture and allied sciences. Two researchers in 2019-20 and ten in 2020-21 successfully completed the programme.

Teaching learning and evaluation

Internal quality assurance measure(s) undertaken

To improve the quality and visibility of PG student research work, the council decided to enhance the NAAS rating requirement >6.0 out of 10.0 for meeting the requirement of PhD thesis submission from 2019-20 with exception to few disciplines (Agricultural Engineering, Agricultural Extension, Agricultural Economics, Agricultural Statistics and Computer Application).

Shifting academic activities from offline to online mode during Covid 19 period

The COVID 19 pandemic situation posed unprecedented challenges in all spheres of life, and education was no exception. However, IARI faculty embraced these challenges as an opportunity for acquiring new competencies needed to make a seamless shift from class room teaching to online teaching. They exhibited unparalleled resolve, resiliency and tenacity to overcome all the hurdles. The Academic Council, IARI in its 413th meeting in 2020 ratified following PG School online activities implemented during Covid 19 lockdown and also permitted to continue till return of the normalcy:

1) Online registration and fee payment; 2) Webinar series on topical interests; 3) Upgradation of PGS Online management system; 4) Online mode for conducting classes, exams, credit seminars, ORW presentations, thesis seminars, pre-qualifying & qualifying exams, thesis submission & evaluation, final thesis, *Viva Voce* exam etc. 5) Online meeting of standing committees, Academic Council, professors' meetings, and Board of Studies.

New awards introduced for Faculty and Students

Faculty Awards

The following four new awards were instituted from 2021-22

i. The "Best Extension Scientist Award" for outstanding contribution in the field of Agricultural Extension

ii. "Best Women Scientist Award" for outstanding female scientist (as envisaged in GATI) in the field of agricultural sciences. The biennial award carries a sum of Rs.50,000/-.

iii. "Dr. H.K. Jain Memorial Young Scientist Award", in the field of Agricultural Sciences covering the disciplines related to basic and applied sciences. The annual award carries a sum of Rs. 50,000/-.

iv. "NABARD Researcher of the Year Award", in the field of outstanding work on the issues related to rural credit. The annual award carries a sum of ₹ 50,000/-.

Student Awards

i. Institute took initiative to introduce "NABARD-Professor VL Chopra Gold Medal Award" for 01 MSc/MTech and 01 Ph.D. student, sponsored by NABARD. The annual award carries cash prize of ₹ 25,000/- each.

ii. Divisional Gold Medal was instituted in the Division of Soil Science and Agricultural Chemistry in the memory of the SSAC alumnus Dr. K. N. Synghal. The annual award carries cash prize of ₹ 10,000/- each.

Initiatives towards implementation of NEP 2020

Academic Council, IARI in its 417th meeting approved initiation of the following new programmes: i. UG Programme; ii. diploma/certificate Courses; iii. joint/dual/Sandwich Ph.D. degree programmes in collaboration with foreign universities; (iv) Induction of international faculty; Self-finance scheme for Indian, foreign nationals, and Non-Resident Indian students.

UG programmes have been initiated from 2022-23 academic session.

Students' Support and Progression

Students graduating from IARI have greatly contributed to India's growth in the field of agricultural research and education. Many of our students joined as ARS scientists in various ICAR institutes and as assistant Professors in SAUs and CAUs. Other notable organizations, where our students joined, include NABARD, Nationalized Banks and State services. During the period under review, 57.89 % progressed to higher education while 29.14 % got jobs in public and private organizations.

International Linkages

Under the approved MoU executed between ICAR and Western Sydney University (WSU), Australia, a partnership agreement was signed in 2019 for award of dual degrees and student exchange programmes between Western Sydney University (WSU), Australia and IARI. Five students were selected for this programme.

Human Resource Development

The Institute plays an important role in human resource development by organizing several national and international training programmes (regular, *ad-hoc* and individual) and refresher courses in specialized areas for the scientists of NAREES under the programmes like 'Niche Area of Excellence', 'Centres of Advanced Faculty Training' (CAFTs) and NAHEP-CAAST being run in the institute. Three Niche Area of Excellence Schemes for capacity building were granted to the institute, by Education Division ICAR in the disciplines of Biochemistry, Soil Science & Agricultural Chemistry and Agricultural Chemicals. A total of 374 training programmes/ workshops were organized for capacity building of trainees from across NAREES.

Infrastructure development

Two New hostels (One Boys' Hostel and One Girls' Hostel; 500 bed each) with world class facilities and amenities were constructed for students. Discovery centre, NAE Formulation and Analysis centre were established to strengthen HRD ecosystem in IARI.

Library and Learning Resources

Prof. M.S. Swaminathan National Agricultural Science Library, established in 1905 is the largest 6 agro-biological library in the South-East Asia housing more than 4 lakh publications and having more than 1900 registered members The library functions as the repository of FAO, and CGIAR institutes' publications and provides services as the lead centre to all ICAR sister institutes/SAUs and international institutes. The library is equipped with CCTV surveillance System, RFID (Radio Frequency Identification) Technology, and Library Management Software, KOHA.

NAHEP-CAAST-IARI

Centre for Advanced Agricultural Science & Technology (CAAST) on "Genomic assisted crop improvement and management" is the student centric sub-component of World Bank sponsored National Agricultural Higher Education Project (NAHEP) granted to IARI. This provided a platform for strengthening educational and research activities of post graduate and doctoral students. A Central Common facility, consisting of molecular biology laboratory and big data analytical lab, was established. A total of 282 students were trained under the scheme. Nine students and two faculty were provided support for international trainings.

Awards/ Special Lectures/ Celebration of Important Days

IARI faculty received several prestigious awards and Fellowships. The prominent ones won include ICAR Rafi Ahmed Kidwai Award Bharat Ratna Dr. C. Subramanium, Dr BP Pal award (02), Dr Sukumar Basu Memorial award (01), ICAR

Best teacher award, Hari Krishna Shastri Memorial award (04), AB Joshi Memorial Award (02), Best Agricultural extension Scientist Award (02), NAAS/NASI Fellowship and Associateships etc.

Students received various outstanding awards including: ICAR Jawahar Lal Nehru Award for best Ph.D. thesis, PM fellowship, Indo-UK fellowship and Full Bright Nehru fellowship, IRRI fellowship, Nehru Memorial Gold Medal, DJ Raski Gold Medal. A large number of our students were awarded DST-CII PM fellowship award, Rajiv Gandhi National Fellowships, CSIR, UGC and DST Inspire Fellowships.

Many special lectures namely Lal Bahadur Shastri Memorial Lecture, Dr. B.P. Pal Memorial Lecture, Teachers' Day Lecture etc. were organized and important days such as International Women's Day, International Yoga Day, National Girl Child Day, 'Bharatiya Bhasha Utsav', Health Awareness Day, Constitution Day were celebrated.

The annual convocations of IARI hosted Union Agriculture Minister (four times), Hon'ble President of India and Hon'ble vice President of India during 2017-22.

Linkages with Industries

PhD Students of IARI won six Prime Minister Fellowship schemes for Doctoral Research, which is a public private partnership (PPP) scheme jointly funded by Science & Engineering Research Board (SERB) and Confederation of Indian Industry (CII). As a part of this fellowship, the students pursue their research on industry relevant problem, and are jointly mentored by IARI and industry.

Institution Building in Other Countries

The excellence of IARI is recognized internationally. IARI played key role in establishing

i) Afghanistan National Agricultural Sciences and Technology University (ANASTU), Afghanistan

ii) Advanced Centre for Agricultural Research and Education (ACARE), Yezin Agricultural University, Myanmar.

Under ANASTU programme, the first three batches of M.Sc. Agronomy were completed under joint degree programme. To facilitate online teaching for 4th batch, a tele-education facility was established at the ICAR-IARI. In 2019, three new M.Sc. courses in Horticulture, Plant Protection, and Animal Husbandry were also introduced.

Hon'ble President of India Shri Ram Nath Kovind Ji dedicated Advanced Centre for Agricultural Research and Education (ACARE)'to the people of Myanmar on December 12, 2018. **Under ACARE programme,** Post Graduate courses of Yezin Agricultural University (YAU) were revised. Three new programmes (Agricultural Extension Education, Molecular Biology & Biotechnology and Food Engineering and Technology) were initiated, for which faculty from IARI was deputed for teaching. Equipment & furniture of approx. US$10,99,365/- procured for ACARE.

Other important achievements

1. The ICAR-IARI campus at Dirpai Chapori, Gogamukh, Assam was inaugurated on September 25, 2020 by Hon'ble Union Agriculture Minister.
2. Based on the EOI application, IARI was selected for participating in the Gender Advancement for Transforming Institutions (GATI)- which aims to bring about institutional reforms to attract, recruit, retain and promote women into scientific laboratories and institutions of higher education.

5.8 Technology Commercialization, Publication, recognition and patents

ZTM-BPD unit of ICAR-IARI through its Corporate Connect endeavour, Pusa Krishi helped the incubated startups to secure external funding, get paid pilot opportunities, and connect with a wider market. The program functions in a phased manner. Out of theentire cohort, the relevant startups are shortlisted by the team with respect to their relevance for the industry partner in consideration. Then their Technology Briefs are shared with the partner organization's representative, who further shortlists and shares their selection with Pusa Krishi. Based on this, several rounds of one-on-one conversations are scheduled and moderated by a Program Manager from Pusa Krishi. Further to this, the partner organizations conduct their internal due diligence and then decide upon the engagement manner.

No. of Technologies Commercialized	Number of Industrial Partners	Total Revenue generated (₹ in Lakhs)	Membership withcorporate firms	Membership with FPO/ NGO
162	301	302	934	153

A number of publications that came out in National and International journals in different disciplines and papers presented in symposia and conferences are given in Table above. A total of 4348 publications in National and International journals with a NAAS rating > 6 have been published. The scientists of the Institute have been awarded for their significant contributions in the field of research, teaching and extension work. These include-Rafi Ahmed Kidwai Award, Hari Krishan Shastri Awrad, Ramnath Singh Award, Outstanding Teacher Award, Outstanding Women Scientist Award, Gram Sanskriti Agri-Technology Award, Dr. R.T. Doshi Award, Jawarharlal Nehru Award, NAAS Award, etc. A total of 57 awards were received by scientists namely NAAS Fellow, NAAS Associate, NAAS Young scientist, NASI Fellow, NASI Young Scientist and INSA Fellow. The IARI was awarded Sardar Patel Outstanding ICAR Institute Award in the year 2020. In the year 2023 the institute was conferred First position in NIRF 2023 among the Agriculture and Allied Sectors. The IARI was rated A+ by NAAC accreditation.

From 2017-22, IARI has filed 11 Patent applications and 38 patents has been granted. Four copyright applications were filed and all are registered/granted during the period. Additionally, 24 Trademark applications have been filed and 19 have been registered during the period. ZTM & BPD also filed 7 copyright applications to protect the technology/ knowhow. 27 Plant Variety applications have been filed and registered. ZTM & BPD Unit has organized ITMC meetings to evaluate research outcomes, management of IPR portfolios, make decisions on inventions that need to be protected by patents and to formulate the terms and conditions of offers for commercialization of IPR enabled as well as know-how based IARI technologies from 2017-22.

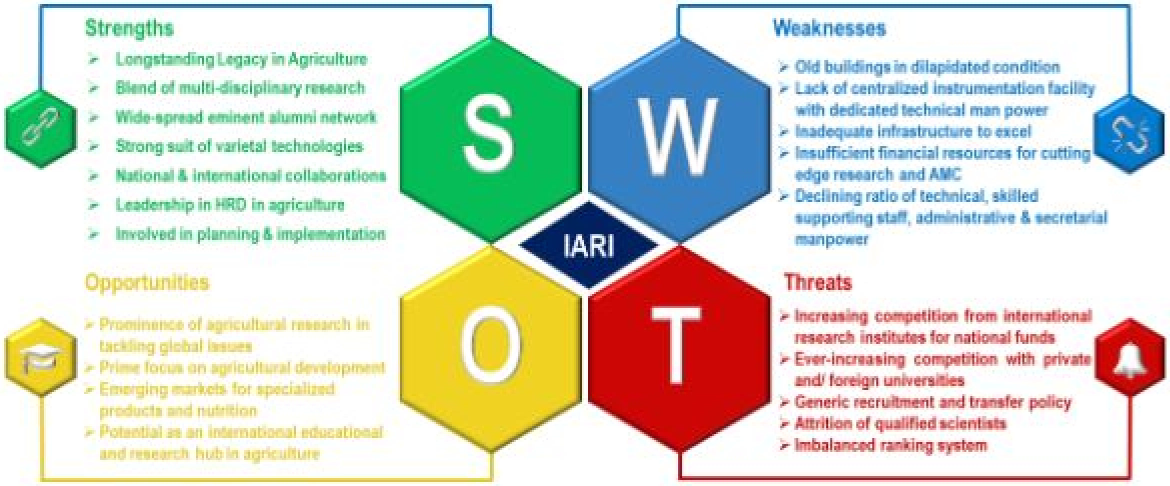
Table 5.5. Patent Granted

S. No.	Patent No.	Title	Year of Grant
1	283378	Urea Molasses Mineral Block Machine	2017
2	281543	Improvement in/or relating to synthesis of O-alkyl derivatives of Oxime ethers of piperonal as potential fungicides	2017
3	279536	Process for the preparation of 5 substituted 1-3,4 oxiadiazole – 2 thiols as new urease and nitrification inhibitors	2017
4	282129	Improved neem Larvicidal Composition	2017
5	282133	Mosquito Larvicidal Compositions	2017
6	284264	A novel bio-pesticidal formulation with improved shelf-life and the method for its preparation	2017
7	282047	Pusa Chickpea thresher	2017
8	290155	Development of slow-release nano formulations of bioactive molecules and method of preparation thereof	2017

S. No.	Patent No.	Title	Year of Grant
9	290363	A product and process for the decontamination of pesticide residues from vegetables by using safe reagent	2017
10	290085	Anti-oxidant and anti-bacterial di-aryl-indazol-3-ols and their method of preparation thereof	2017
11	295150	Development of polymeric formulations of bioactive molecules and method of preparation thereof	2018
12	300102	Amphiphilic polymers based slow-release nano formulations of β-carotene and method of preparation thereof	2018
13	299749	Production of cocktail polyclonal antibodies for broad spectrum ELISA based diagnosis of potyviruses and cucumoviruses using fusion construct derived from coat protein gene sequences from Papaya ringspot and Cucumber mosaic virus	2018
14	294416	Nanocopper"-a copper-based formulation to combat bacterial blight of pomegranate, rice and bean	2018
15	301187	Beneficiation of Phosphate Rock for the segregation of phosphorus containing heavy metal free minerals	2018
16	292080	Nanoencapsulated Hexaconazole: A novel fungicide and the process for making the same	2018
17	302775	Powered Animal Feed Mixer	2018
18	299908	Animal Feed Crusher	2018
19	291334	Light Heat and water-resistant neem meliacin concentrate and product with controlled release	2018
20	293925	Improvements in/or relating to the preparation of liquid pesticidal concentrates of neem meliacin(s)	2018
21	296712	Composition for early, profuse sporulation under solid state of the improvised isolate of *Trichoderma harzianum* and a process thereof	2018
22	292555	Pusa 5SD- a bio-formulation of *Trichoderma harzianum* (IARI P-4) for seed treatment	2018
23	294901	Development of SCAR Marker for identification of *Chaetomium globosum* -A potential biocontrol	2018

S. No.	Patent No.	Title	Year of Grant
		agent	
24	292524	A novel formulation of Plant Growth promoting Rhizobacteria with enhanced shelf-life and the method of its preparation	2018
25	321722	Heat Stable Anthocyanin Rich Composition and process of its preparation	2019
26	316692	Nanofabrication of phosphorus on kaolin mineral receptacles	2019
27	313550	Pigeon pea Pod Stripper	2019
28	349105	Novel naphthyridine based hydrazines as potent agrochemicals	2020
29	338098	Liquid Bioinoculant of *Azotobacter chroococcum* and the process thereof	2020
30	340541	Insecticidal Formulation of Novel Strain of *Bacillus thuringensis* AK 47	2020
31	341699	Plant transformation vector for suppressing MIPS gene expression and method for culturing low phytate soybean	2020
32	330282	Digital Soil Test Fertilizer Recommendation (STFR) Meter	2020
33	343546	A cross flow flexible membrane filtration assembly for small processing volume	2020
34	346124	Pusa Basmati Rice Thresher	2020
35	354498	Zinc in clay-mineral receptacles in nanoforms for their use as a advance materials novel fertilizer	2020
36	372346	Nanofabrication process involving clay minerals as receptacles for manufacturing advanced nanomaterials including novel fertilizers	2021
37	361582	Rapid Detection of Large Cardamom Chrike Virus	2021
38	355313	A Microbial Consortium of Nitrogen, Phosphorus and Potassium (NPK) Providing Bacteria	2021

5.9 SWOT Analysis of ICAR-IARI



Strengths

IARI has a rich legacy and extensive knowledge in agriculture science and research. It has 19 divisions, 8 regional stations, and various units covering diverse agro-ecosystems in India. The institution fosters multi-disciplinary research and disseminates proven technologies to the farming community. IARI has produced talented human resource who hold prominent positions in research, academia, and management, globally. It possesses competent human resources across 26 disciplines and has a strong alumni network in leadership roles, worldwide. The institute has developed popular crop varieties, such as Basmati rice, contributing significantly to the agricultural sector.

Weaknesses

The buildings at IARI, New Delhi are very old and in deteriorating. The institute has no central instrumentation facility with dedicated trained technical man power. The infrastructure is also inadequate and there are insufficient financial resources hinder cutting-edge research and equipment maintenance. Inadequate grants affect faculty and student skill development in international laboratories, abroad. The current scientist to technical ratio is 1:0.4 as against prescribed norm of 1:1.5. Like-wise, there is significant decline in the number of skilled supporting staff (SSS), administrative and secretarial manpower.

Opportunities

The global focus of agricultural research to address issues such as climate change, food and nutrition security, environmental challenges present excellent opportunities for IARI. Agricultural development is the prime focus of government, policy makers and planners. The aspirations of the Indian population are changing leading to growing market for specialized products and processed foods, including organic and biofortified options. IARI can become a major hub for agriculture education in collaboration with ICAR institutes and foreign Universities/ Institutions.

Threats

IARI faces competition from international research institutes for grants from national/state funding agencies. General, private, and foreign universities also pose competition in agriculture research, education, and extension. The recruitment and transfer policy undermines faculty competency for training quality human resources. Attrition of experienced scientists and faculty to higher positions is a concern. University rankings focus more on general universities, disregarding the societal impact of agricultural universities.

STRUCTURE AND ORGANIZATION

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The Institute is a constituent unit of the Indian Council of Agricultural Research (ICAR), which is a Society registered under the Societies Registration Act XXI of 1960. The Director is the Principal Executive Officer of the Institute. The Institute has five main bodies, which are responsible for broad policy matters and decision making in the field of research, education and training, extension and administration. These are:

i) Board of Management
ii) Executive Council
iii) Academic Council
iv) Institute Research Council
v) Extension Council

The Board of Management serves as the highest policy-making body of the Institute. The Director, who is the executive and academic head of the Institute, chairs the Board of Management, Executive Council, Institute Research Council, Academic Council, and Extension Council, as the *ex-officio* Chairman. The Board of Management and the Academic Council are the apex bodies that make decisions on administrative, financial, and academic matters. The Academic Council, Executive Council, Institute Research Council, Extension Council, and various Standing Committees provide recommendations and suggestions to assist the Board of Management in making appropriate decisions.

The research activities of the Institute are coordinated by the Joint Director (Research). The Dean and the Joint Director (Education) coordinate the academic activities of the Institute. The Joint Director (Extension) handles matters related to extension education. The Joint Director (Administration) provides support to the Director in making decisions regarding service matters for both faculty and staff. The Comptroller is responsible for managing financial aspects of the Institute. All the divisions, units, regional stations and regional research stations are organized into six different schools namely, (i) Crop Improvement, (ii) Natural Resource Management, (iii) Crop Protection, (iv) Basic Sciences, and (vi) Horticultural Sciences (vi) Social Science, which are coordinated by the School Coordinator, who is the senior most head of the Division in that School.

Institute Research Council

The Institute Research Council (IRC) is responsible for the formulation of research projects, monitoring their progress and application. The prioritization, monitoring, and evaluation (PME) cell coordinate these meetings. Two IRC meetings are organized every year namely, IRC I and IRC II. In IRC I, individual scientists from each division present their work. These presentations are then evaluated by expert members from within the institute and the Joint Director of Research or the Director. The focus of these evaluations is to assess the objectives and achievements of both in-house and externally funded projects. Midterm corrections and adjustments may be undertaken based on the feedback received during these meetings. In IRC II, the principal investigators of the projects present the overall work done by all scientists associated with the project. The expert members and the Joint Director of Research or the Director evaluate the presentations. These meetings serve as a platform for interdisciplinary research discussions and provide an opportunity to review the accomplishments of various projects. Overall, the IRC plays a vital role in monitoring and evaluating the research activities of the Institute. It ensures that research programs and projects are progressing as planned, and any necessary adjustments are made to achieve the desired objectives. The IRC meetings also foster interdisciplinary collaboration and provide a forum for reviewing and recognizing research accomplishments within the Institute.

Research Advisory Committee

The Research Advisory Committee (RAC) evaluates the achievements of the Institute, and recommends the necessary steps to be taken to meet the mandate. The function of RAC is to give directions and suggestions on the research programmes of the Institute and review the research achievements of the Institute and to see that these are consistent with the mandate of the Institute. The School Coordinators present the overall work done in different projects of the divisions of the school to a panel of experts from outside the institute, who evaluate and provide suggestions for improvement of the project outcomes.

Academic Council

The Academic Council holds the highest authority in matters pertaining to academic activities at the Graduate School of the Institute. It is responsible for making decisions related to graduate and postgraduate education and training. The Academic Council is supported by the Board of Studies in each discipline and four Standing Committees, namely, (a) Courses, Curricula, and Academic Affairs Committee, (b)

Faculty and Discipline Committee, (c) Scholarships, Financial Assistance, and Academic Progress Committee, and (d) Students' Problems and Discipline, Welfare Board, and Residences Committee. These committees address specific issues related to academic programmes. The Academic Council possesses the authority to make decisions on all academic matters and ensure their implementation. It translates these decisions into action to promote effective academic functioning within the Institute. During the period from 2017 to 2022, the Academic Council made several significant decisions. The Academic Council's role is crucial in maintaining the quality and standards of academic activities at the Institute's Post Graduate School, ensuring a conducive learning environment for students and promoting academic excellence.

Extension Council

The Extension Council (EC) of the Institute is responsible for monitoring and promoting the extension activities of the institute, as well as fostering collaboration with external agencies and institutions. During the reported period, fifteen meetings were held by the Extension Council. The feedback mechanism helps in strengthening the linkages between the Institute and the Development Department of the Delhi Government for the implementation of extension programs. The Extension Council also worked on planning and implementing a comprehensive plan for extension activities and Training of Trainers (TOT) programs. These activities aimed to foster collaboration between the Institute and external organizations. The Extension Council provides a platform to present the research activities of the Centre for Advanced Agricultural Technology (CATAT) and the Division of Agricultural Extension. Policy matters related to extension activities were also addressed by the Extension Council. Plans were made to reorganize the council with the aim of deciding relevant technologies for extension activities and dealing with issues, policies, models, and mechanisms of technology transfer. The council was also responsible for approving recommendations from Standing Committees. Overall, the Extension Council plays a vital role in monitoring, coordinating, and promoting extension activities of the Institute. It facilitates collaborations, develops plans for technology transfer, and oversees the implementation of various programs and initiatives aimed at agricultural development.

Institute Joint Staff Council (IJSC)

The Institute's Joint Staff Council (IJSC) is an elected body consisting of representatives from the administrative, technical, and skilled supporting staff of the institute. Every three years, four members are elected from each of these three categories. Once elected, the members choose a Secretary and three additional members to form the Joint Staff Council. The role of the IJSC typically involves representing the interests and concerns of the administrative, technical, and skilled supporting staff. The IJSC serves as a platform for communication and collaboration between the staff and the institute's management. It plays a crucial role in advocating for the staff's rights and facilitating a conducive and supportive work environment within the institute.

Institute Grievance Committee

The Institute Grievance Committee (IGC) is a grievance redressal mechanism established within the institute to address and resolve individual grievances of the staff members. Its primary purpose is to provide a platform for employees to express their personal grievances, ensure a prompt review of the complaints, and make decisions regarding their resolution. The committee serves as a communication channel between the staff members and the management of the institute, facilitating effective communication and dialogue. By addressing individual grievances, it helps in resolving conflicts, improving working conditions, and fostering a positive work environment. The Chairman of the committee is the Joint Director (Extension), who presides over the meetings and leads the discussions. Alongside the official members, there are also members elected by the staff, ensuring representation from the employees themselves. The committee holds regular meetings to discuss and deliberate on the matters brought forward. During these meetings, the grievances are reviewed, discussed, and decisions are recorded. The decisions made by the committee may include actions to address the grievance, provide necessary support, or any other appropriate measures to resolve the issue. Overall, this committee plays a crucial role in ensuring the timely and fair redressal of individual grievances within the institute.

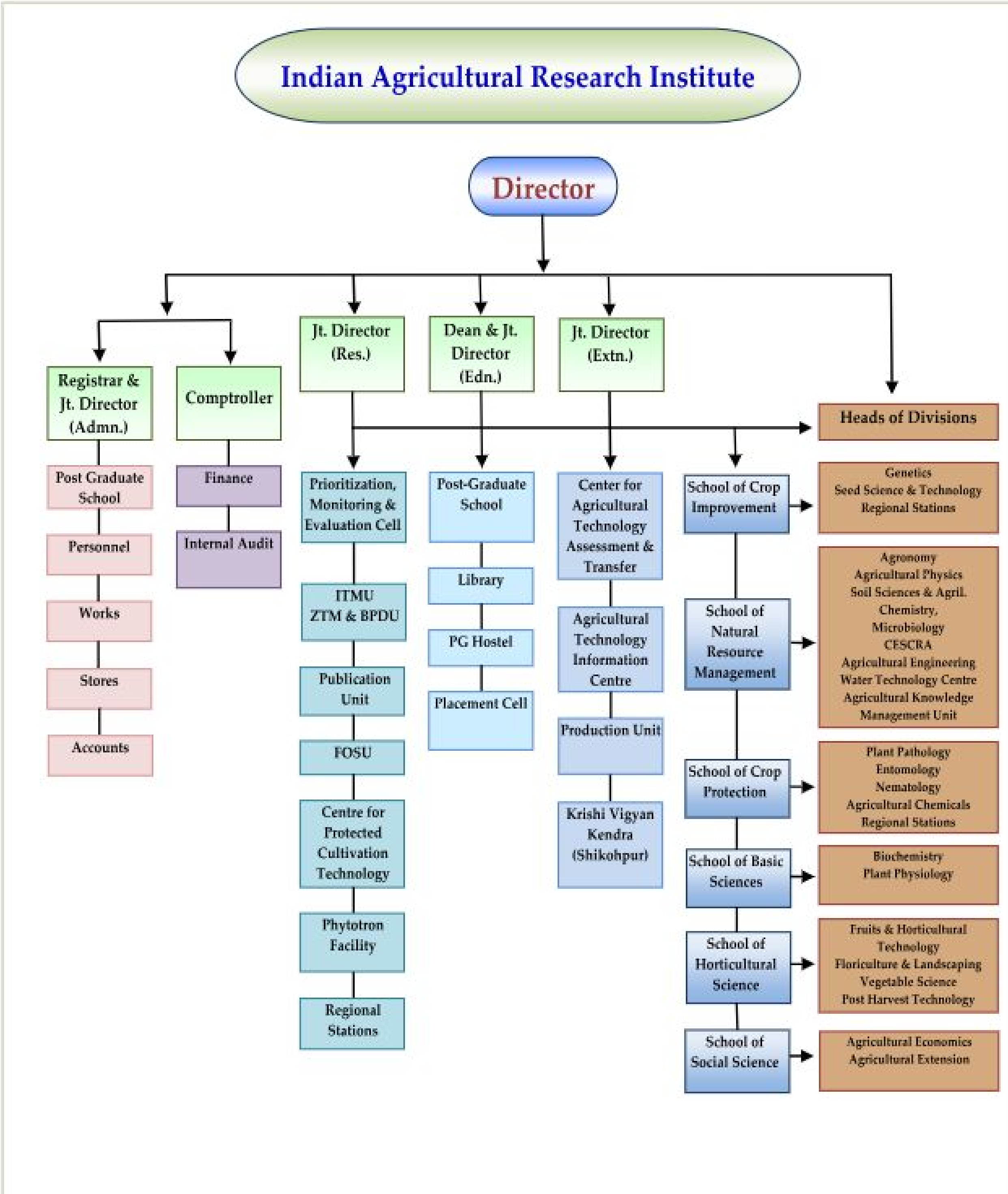

Fig 6.1 Organizational Structure of Indian Agricultural Research Institute

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MANAGEMENT PRACTICES

Management

The Institute's Management Committee with the Director as the administrative head ensures the smooth functioning of its activities. The Director is aided by three Joint Directors, namely, Joint Director (Research), Dean and Joint Director (Education), and Joint Director (Extension) in the domains of research, teaching and extension. The Joint Director (Administration) and the Comptroller/ Chief Finance and Account Officer support in managing the administration and finance of the Institute. The Board of Management, Research Advisory Committee, Executive Council, Academic Council, Extension Council and Staff Research Council facilitate in the smooth functioning of the Institute with their support in various ways. The two other important statutory bodies for the smooth functioning of the Institute are the Joint Staff Council and Institute Grievance Cell.

The Institute Research Council, Research Advisory Council and Board of Management meetings are held every year. The recommendations and suggestions emerging from these meetings are implemented in true spirit which helps in fine tuning the research, education and extension of IARI.

Major decisions of the meetings

The major decisions taken during the Board of Management during the period include:

- Construction of boys' hostel and girls hostel at IARI, Jharkhand.
- Purchase of vehicle in replacement of the condemned vehicles.
- Proposal for redevelopment plan of Loha Mandi and Krishi Kunj complex, New Delhi
- Establishment of "IARI Endowment Foundation"
- Conversion of Type I to Type II quarter at IARI RS, Karnal.

The salient decisions taken in the Extension Council during the period include:

- Institution of "Best Extension Scientist" award to be conferred biennially. Till date, two scientists have been bestowed with the award.
- A one credit course entitled, "Science and Society" was introduced to sensitize and enhance the enthusiasm and skills of the students in problem identification and village development with their engagement in MGMG program.
- Gender based nutrition sensitive extension has been initiated with in-house as well as externally funded projects (DST, DBT, and UNDP).

The important decisions taken in the Academic Council include:

- Switching over from Trimester to Semester System from academic session, 2020-21.
- Nomination of two distinguished IARI alumni and world Food Prize winners namely, Dr. Sanjaya Rajaram and Dr. Rattan Lal for the conferring the Doctorate of Science (*Honoris Causa*).
- Introduction of three new awards i) Best Woman Scientist Award ii) Dr. H.K. Jain Memorial Young Scientist Award, iii) NABARD Young Scientist Award.
- Institution of NABARD-Prof. V.L. Chopra Gold Medal Award.
- To initiate Diploma and PG Diploma Courses at IARI, in some of the areas like (i) Organic Farming; (ii) Good Agriculture Practices for Basmati rice cultivation.
- Creation of Supernumerary seats to grant 5% reservation to the candidates belonging to children/ widows of eligible personnel of security forces in Master and Ph.D. programme.
- Introduction of UG programs at IARI and off-campuses in 2022 academic session.

Table 7.1. Meetings of IRC, RAC, Academic Council, Extension Councils and BoM held during the period, 2017-2022

Year	IRC-I meetings	IRC-II meetings	RAC meetings	BoM meetings	Extension Council Meetings	Academic Council Meetings
2017	Jun 1-29	Sep 13-23	21-22, Dec	29 Mar	17June	8 Feb; 7 Jul; & 16 Dec
2018	May 15, Jun 21	Nov 5-28	17-18 Dec	8 Feb & 13 July	12 Sep	8 Feb, 7 Jul & 14 Dec
2019	Jun 10 to Jul 04	Aug 20 to Sep 04	12-13 Dec	7 Feb	26 Sep	7 Feb, 25 Jul & 14 Nov
2020	Jun 01 to Aug 07	Oct 19 to Nov 18	29-30 Dec	13 Feb	16 Dec	13 Feb & 27 Jul
2021	Jul 20 to Aug 21	Nov 08 to Nov 26	Dec 22-23	11 Feb 2021 & 30 Sep	1 Nov	11 Feb & 1 Oct
2022	Jul 18 to Aug 26	Sep 17 to Sep 30	22-23 Dec	8 Mar	20 Oct	10 Feb & 27 Aug

Financial management

Trends in Resource Allocation for Agricultural Research in IARI

The category-wise expenditure made under revenue & capital head for IARI at 2021-22 price is provided below in Table 7.2 for the last five years. The analysis is entirely based on the budget under the main scheme only. It has not taken into consideration the budget of externally funded projects and other schemes like SCSP, NEH, and TSP. The total expenditure is categorized under five major heads: "Establishment expenditure," "Domestic & foreign travel," "Research & operational," "Civil work," and "Others." Each category has corresponding numerical values for each year and the percentage share of each category in the total expenditure for that year. The values are provided in ₹ Lakhs at 2021-22 price. The total expenditure of IARI under the main scheme increased from ₹ 42998 lakhs in 2017-18 to ₹ 59974 lakhs in 2021-22 at an annual growth rate of 6.88% per year. Out of the total expenditure, Establishment expenditure under the main scheme (includes Salary, Pension, OTA, Administrative expenses, Repair and maintenance) constitute the highest share i.e., on average, 87 percent of the total expenditure. Since 2017-18, this head has claimed more than 80 percent of total allocated resources, leaving meagre funds for research & operational activities.

Table 7.2. Level and composition of IARI Expenditure (Rs Lakhs, Constant 2021-22 prices

Heads	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	Average of 5 years
Establishment expenditure	40767.74	47505.12	44561.98	40099.38	53195.3	45225.9
Share (%)	94.86	83.61	80.88	86.51	89.32	86.71
Research and operational*						
(a)Research & operational expenditure only	1512.27	2666.8	3002.28	2041.48	1506.51	2145.87
Share (%)	3.52	4.69	5.45	4.4	2.53	4.11
(b) Research & operational expenditure including expenditure on new equipment	1568.59	3355.87	4445.48	2182.05	1994.86	2709.37
Share (%)	3.65	5.9	7.94	4.66	3.33	5.16
Domestic & foreign travel	72.88	306.21	253.56	16.49	97.74	149.38
Share (%)	0.17	0.54	0.46	0.04	0.16	0.29
Civil work	59.42	4670.92	3564.69	1862.87	2673.47	2566.27
Share (%)	0.14	8.22	6.47	4.02	4.49	4.92
Others	508.38	979.92	2271.29	2193.66	1594.86	1509.62
Share (%)	1.18	1.72	4.12	4.73	2.68	2.89
Total expenditure	42998.91	56886.15	56015.82	46827.87	59974.83	52540.72

* GST applied @ 5% in 2017-18 & 2018-19, and 18% in 2019-20 to 2021-22 for the head Research and operational expenditure and expenditure on new equipment

** Establishment expenditure includes Salary, pension, OTA, Administrative expenses, Repair, and maintenance

*** Expenditure under the Others category includes expenses made for fellowship, Loans and Advances, Publicity and exhibitions, Information and technology, Library Books & Journal, Vehicles and vessels, Livestock, Furniture and fixtures, HRD, Others.

The expenditure on the Research and Operational head increased from ₹ 1512 lakhs in 2017-18 to ₹ 3002 lakhs in 2019-2020, indicating a doubling of expenditure under this head during this period. However, it decreased drastically to ₹ 2041 lakhs in 2020-21 and ₹ 1506 lakhs in 2021-22. Even if we enlarge the definition of the Research and Operational expenditure by including the expenditure made on new equipment, the estimates improve only marginally from ₹ 1568 lakhs in 2017-18 to ₹ 1994 in 2021-22, with an annual growth rate of 4.93 percent. The expenditure under this head, though increased initially from ₹ 1568 lakhs in 2017-18 to ₹ 4445 lakhs in 2019-2020, indicating a near tripling, it decreased drastically to ₹ 2182 lakhs in 2020-21 and a further ₹ 1994 lakhs in 2021-22, which is a worrisome issue.

In the current price basis, share of research and operational expenditure excluding new equipment in the total expenditure was about 3.5% during last five years, whereas during 2022-23, it was as less as 2.6%. In the analysis, when salary, pension and OTA was excluded from total expenditure, the share of research and operational expenses was 14.8% while it went down to 11.4% during 2022-23.

Personnel

The consolidated statement of scientific positions in IARI is presented in Annexure IV. The scientist in position is 451, which accounts for 79.5 % of the total sanctioned scientific positions of 567. The scientist posted at IARI Headquarters are 376, which is 83 % of sanctioned position (Annexure V), while the scientist posted at regional stations are 44, which is 69 % of sanctioned position of 75 (Annexure VI). The technical personnel in position are 367, which is 72 % of total sanctioned strength (Annexure VII). The ratio of scientific to technical staff in position is 1:1.19, while the ratio of sanctioned position of scientific to technical ratio is 1:1.12. The ratio of scientific to technical ratio should be raised to a minimum of 1:1.5. The administrative staff in position are 270, which is 64 % of total sanctioned position (Annexure VIII).

The supporting staff strength (SSS) was reduced from 1301 to 740, and now it is abolished. This is a major issue in agricultural research as trained skilled supporting staff play a key role in supporting research.

Human Resource Development

IARI has been actively engaged in training its human resources belonging to different categories. During the period 459 staffs has been trained in advanced areas of research, education, extension, administration and financial management, which includes 172 scientists, 227 technical assistants and officers, 48 administrative officials and 12 supporting staffs over the five years. Seven faculty members and thirty-seven

PG students were supported for international training at world class universities and research institutes such as University of Maryland, Purdue University, Kansas State University, University of Edinburgh, Rothamsted Research, Heinrich Hein University, University of Queensland, CIMMYT, IRRI, etc.

As many as 359 training programmes have been conducted at the national level wherein 15,116 participants including scientists, professors, technical and students got benefitted.

LINKAGES

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Linkages with clients and other end users

IARI has strong linkages and partnerships for strengthening its extension system and enhancing its reach among the distant farmers. National Extension Programme through its innovative Public-Public partnership approaches like IARI-SAUs/ICAR Institutes Partnership; IARI-Voluntary Organizations (VOs); IARI-KVKs partnership for Biotech-KISAN Hub have been effective for location specific assessment and transfer of IARI technologies in different parts of the country. At present the partnership is functional with 10 SAUs, 25 Voluntary Organizations and 3 ICAR Institutes.

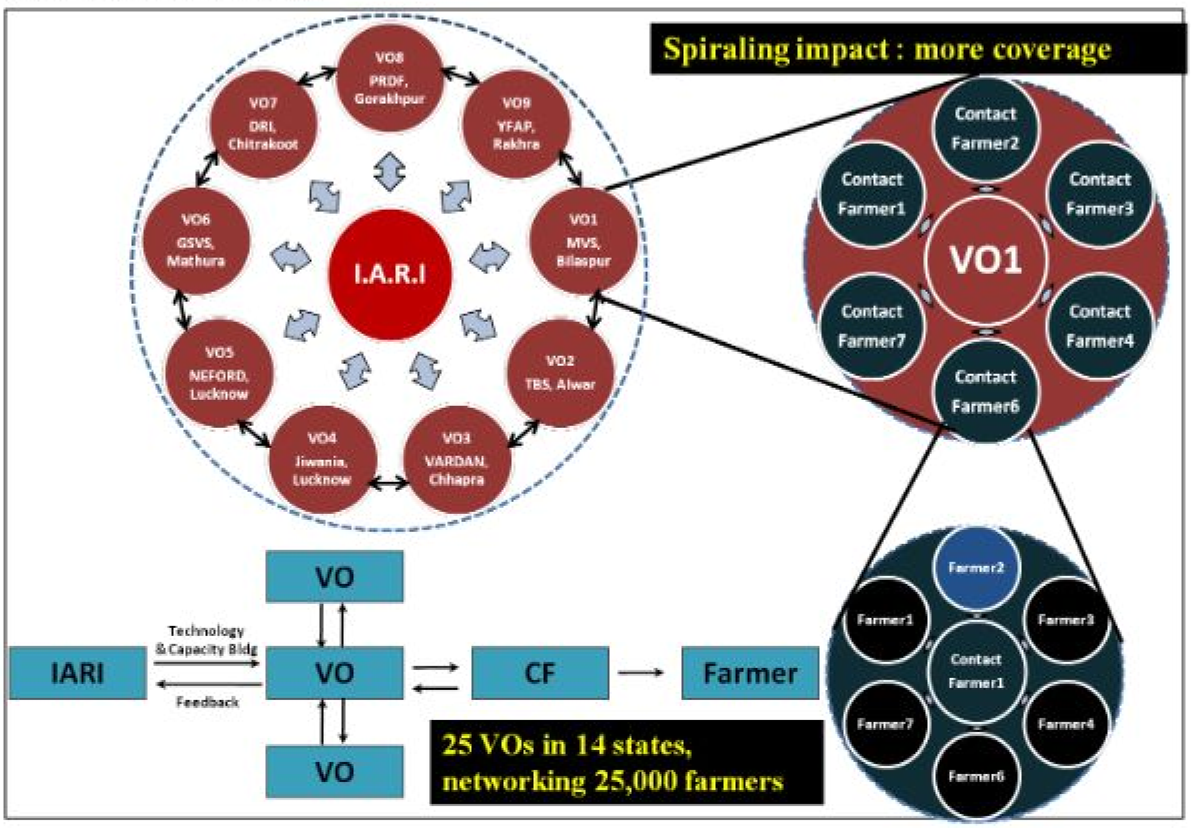

Fig. 8.1 IARI's extension linkage with voluntary organisations and contact farmers

IARI's seeds have been in great demand among the farmers. Realizing the demand of quality seeds among the farmers, IARI initiated partnership with Post-offices. As the Voluntary organizations (VOs) have strong presence at village level and their strength lies in mobilization and reaching out to the farmers, IARI started IARI-VO partnership programme to reach out the farmers spread over different states. Convergence based extension model was devised and validated, where-in with active partnership of line departments, KVK, voluntary organization (PRAN) and farmers' organization (Pusa Vikas Samiti) in district Gaya, Bihar 7 water harvesting structures were created and adoption of climate smart technologies (zero-till wheat, direct seeded rice, contingency planning of growing maize and millets, solar powered micro-irrigation, laser levelling, IPM, mulching, horticultural crops based diversification, etc could be promoted in more than 500 acres benefitting more than 5000 farmers. Through partnership with KVKs, IARI addressed the needs and problems of farmers of 8 aspirational districts of Rajasthan (Dholpur, Karauli and Baran), Haryana (Mewat) and Uttar Pradesh (Chitrakoot, Shrawasti, Balrampur, and Bahraich). Besides this IARI has developed four model villages in NCR at Kutbi in Muzaffarnagar (UP); Rajpur in Aligarh (UP); Khajurka in Palwal (Haryana); and Beenjpur in Alwar (Rajasthan). Where IARI has demonstrated the improved varietal technologies of wheat and basmati rice which has resulted in increased economic benefits i.e., net income worth ₹ 1.37 lakhs per hectare.

Linkages have been fostered with public (All India Radio, DD Kisan, KISAN SARATHI) and private firms (Krishak Jagat, TARA BLOOM Pvt Ltd, Crop Information) for dissemination of content related to technologies. Extension literatures are developed for the benefit of end users. More than 1 lakh farmers were supported with advisory services through Pusa mKRISHI and Direct 2 Farm mobile advisory systems in partnership with Tata Consultancy Services, Mumbai and CABI, New Delhi, respectively. Linkages have been fostered with more than 25 SHGs and 15 FPOs for enhancing their economic activities.

Linkages with NABARD, Punjab National Bank, and PI Industries have helped in contract research in extension. Operationalization of Mera Gaon Mera Gaurav (MGMG) programme in NCR covering more than 600 villages as well as SCSP and TSP programmes has strengthened the linkages and engagement of line departments to enhance the awareness and reach of govt schemes among the farmers.

162 technologies were commercialized to 301 industry partners generating a revenue of ₹ 3.02 crores during 2017-22. Out of these, 91% of the revenue is through commercialization of crop varietal technologies and the remaining 9% through commercialization of implements and bio-fertilizers and post-harvest technologies etc. Besides this, eight incubation programmes and 171 Start-ups have been incubated out of which 94 were supported with funding to the tune of ₹ 1185 lakhs.

They have raised an external funding of about ₹ 10,000 crores benefiting about 40.3 lakh farmers.

Under Agri-nutri smart village model technological interventions including biofortified nutri-rich varieties were demonstrated at Bagpath in UP and Sonipat in Haryana were in more than 4001 demonstrations were organized to impart knowledge and skill in food processing and value addition in an area of 316.7 hectares. IARI has been operating three outreach programmes namely SCSP, Tribal Sub-Plan and NEH programmes with aids worth ₹ 5390 lakhs. It has played an important role in reducing poverty and enhancing income of small and marginal, below poverty line SC farmers (69029 from 28 districts), tribal farmers (more than 1000 in Odisha and West Bengal) and farmers from North East (more than 23,000).

Extension and development agencies *viz.*, Farmers NGO, Farmers Associations, Agriwatch, DAC, VARDAAN, AGRI Watch and SKF are in active collaboration with IARI. Stable and good performance of the material with addition of quality traits has attracted the private seed companies, and five large seed producing companies have come forward to have Memorandum of Understanding (MOU) for seed production of six mustard varieties of IARI. MoU for HD 3086 has also been signed with 100 private companies.

Collaboration for NEH region

Under NEH component, massive exercise was taken up for demonstration of mustard varieties to utilize the rice fallow areas for improving cropping intensity and profitability of farmers. Large scale demonstration of mustard varieties (Total num ber of demonstration) of Pusa Mustard 25, Pusa Mustard 26, Pusa Mustard 27 and Pusa Mustard 28, all short duration varieties demonstrated in NEH states were conducted with the help of ICAR Research Complex for NEH Region, its Regional Centres and KVKs. The farmers were buoyed by the successful performance of these mustard varieties and efforts are being made to upscale their cultivation.

Collaboration with SAUs and other research institutions

Being leaders in all areas of agricultural science, the institute has strong linkages with many international and national institutes. During the period under report a number of externally funded projects have been sponsored by national and international organization/ institutes through 230 projects funded by different agencies. The projects include 14 projects funded by international agencies like UNDP, ADB, USIEFF, UKRI, JIRCAS, IRRI, CIMMYT, ILRI, IFPRI, ICARDA, Harvest Plus, etc; 206 projects funded by different national funding agencies such

Table 8.1 Research collaboration with different institutions according to funding agencies

Funding agency	Collaborating Centre
DBT	DWR Karnal; Amity university; NCL, Pune; NIPGR, New Delhi; NIT, New Delhi; IIRR, Hyderabad; NABI , Mohali; CSSRI, Karnal; ICGEB, New Delhi; CSAUA&T, Kanpur; IGKV, Raipur, Chhattisgarh; PDKV, Nagpur; BUA&T, UP; TNAU, Vridachalam; PAU, Ludhiana; JNKVV, Jabalpur; NBPGR; IASRI, New Delhi; BISA, Ludhiana; IIWBR, Karnal; MPKV, Rahuri, SKAUST, Jammu; ARI, Pune; CSKHPKV, Palampur; BHU, Varanasi; NDUA&T, Ayodhya; NRRI, Cuttack; IIRR, Hyderabad; SKUAS&T, Kashmir; AAU, Jorhat; ZARS, Mandya; TNAU, Coimbatore; ANGRU; UDSC, New Delhi; NISM, Raipur; IASST, Guwahati; CAU, Umiam; NRCPB; Guwahati University, Assam; MDF, Assam; ICMR-NIN; Acsen Hyveg Pvt. Ltd. Kullu; IIT, Guwahati, Assam; IIMR, Ludhiana; ICAR research complex for NEH region, Manipur; IRRI, Philippines
DST	ICRISAT; Agricultural University, Ludhiana; Advance Centre for Rainfed Agriculture, Dhinasar; HPKU, Palampur; NIPB; TERI, Faridabad; SPL Technologies Pvt.Ltd , New Delhi; ICAR-CITH,Srinagar
Others i.e., UPCAR; PPVFRA, CSIR	IIT Delhi; CSRI-NBRI, Lucknow; CC-MGKVK, Gorakhpur; KVK, Deoria; KVK,Siddharthnaga; CRC, Masodha; Gauria Karma, Hazaribagh; IISS, Bhopal; NBAIR-Bengalur; USPUHF-Solan, HP; College of Agriculture-Vellayani, Kerala; SASRD, Nagaland; GBPUAT, Pantnagar; DEI Agra; CCSHAU, Hisar; GNDU, Amritsar; IPFT, Gurgaon; ITRC, HP; UH&F, Solan, HP; RRL, Jorhat, Assam; GAU, Gujarat; BCKV, Kalyani, WB; KAU, Vellayani, Kerala; NIN, Hyderabad, AP; SBL, Cochin, kerala, NPQS, New Delhi, RPQS, Mumbai; RPQS, Chennai; PQS, Bangalore; IMD; IIVR, Varanasi; DDO&GR, Pune; VNIT, Nagpur
ICAR & NASF	NAARM, Hyderabad; National Bureau of Soil Survey and Land Use Planning, Nagpur; DKMA, Delhi; ICAR Headquarters; IIHR; CAZRI, Jodhpur; CIFA, Bhubaneswar; NDRI, Karnal; IVRI, Izatnagar; ATARI (11 zones); CICR; IIWM; CIFE, CIFRI; CIFA; KVK Shikohpur Gurgaon; Winter Nursery Centre, Hyderabad; NBAIR, Bengaluru; MACS-Agharkar Research Institute, Pune; IISR, Indore
Foreign Funded	Michigan State University, USA; BMGF, USA; CABI, UK; IFPRI; Center for Tropical Agriculture (CIAT); NERC Centre for Ecology and Hydrology, UK; IFDC, USA; HHU, Germany

as DBT, DST, DRDO, NABARD, PPVFRA, etc; five projects funded by state corporations such as DJB, UPJB, DMRC, etc; three projects funded by private companies such as Argi Biotech, RK overseas, etc; one project funded by philanthropic organization (BMGF) and one collaborative project with foreign university (HHU).

IARI has signed MoUs with one SAU, one Central Agricultural University, one NGO, one Government institute (QCI), three private companies for carrying out collaborations in research, education and extension. IARI is also engaged in contractual research projects with 12 private industry partners. Currently, IARI is running Off-campuses for education program through linkages with 1) IARI-Assam, 2) IARI-Jharkhand, 3) IIHR, Bengaluru, 4) CIAE, Bhopal, 5) NIASM, Baramati, 6) IIAB, Ranchi, and 7) NIBSM, Raipur.

The local ICAR institutes are inbuilt in the project programmes. Collaborations with NBPGR, DMR/IIMR, IASRI and NRCPB apart from inter divisional collaborations have been strengthened. National Institutes and Agricultural Universities *viz.*, CIAE, Bhopal, DRMR, Bharatpur, PAU, Ludhiana, CCS HAU, Hisar, CSSRI, Karnal, Delhi University South Campus, ICAR NEH RC, Barapani are part of collaborations. Strong collaborations exist in the form of extra mural projects with NIPGR, JNU, DU, BARC, Jadavpur University, Kolkata, and various crop-based institutes in all the mandate crops *viz.*, DWR (Karnal), DRR (Hyderabad), CRRI (Cuttack), DSR (Hyderabad), AICRPPM (Jodhpur), DMR (New Delhi), VPKAS (Almora), IIPR (Kanpur), DMR (Bharatpurand CICR (Nagpur). Collaboration exists with various international institutions *viz.*, CIMMYT, GCP, IRRI, ICRISAT, ICARDA and AVRDC.

PLANNING FOR THE FUTURE

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IARI has undertaken several initiatives to strengthen its position as a national leader in agricultural research, education, extension and development. These include establishing collaborations in research, partnerships, infrastructure development, and academic enhancement. The institute's new research programs incorporate cutting-edge areas such as genomics-assisted breeding, genomic selection, mapping genes for desirable traits in different crops, functional validation of genes and genome editing. Focus is towards development of multiple stress tolerant crop varieties biofortified with better nutritional profile so that the future crop cultivars are adopted to climate change and changing aspirations of the farmers, industry and consumers. It also focuses on Secondary Agriculture, prospecting new biomolecules including nanofertilizers/ pesticides/ herbicides/ biostimulants/ semiochemicals, integrating Machine Learning (ML), Artificial Intelligence (AI), and Internet of Things (IoT) in Robotics-aided Precision Agriculture, prospecting microbiomes in the rhizosphere and phyllosphere, genomics of pests, pathogens, and beneficial organisms, as well as synthesis, modification, and bioprospecting of molecules for crop management. These programs align with objectives such as Doubling Farmers' income, achieving more crop productivity with efficient water usage, promoting Poshan Abhiyan (nutrition campaign), ensuring self-sufficiency in oilseeds and pulses, developing stress-tolerant short-duration varieties, enhancing nutritional quality, and addressing the Sustainable Development Goals (SDGs) 2030.

To align with the New Education Policy 2020, IARI has introduced undergraduate programs in agricultural sciences, including B.Sc. (Agriculture), B.Tech. (Biotechnology), B.Sc. (Community Science), and B.Tech. (Agricultural Engineering). The institutes have adopted a hubs and spokes model, involving ICAR institutes from across the country to impart undergraduate and postgraduate education in agriculture and selected disciplines. Expanding collaborations with research institutions both within India and internationally, including the University of Western Australia, Murdoch University, and others, is planned to foster knowledge exchange and joint research projects.

IARI has initiated partnerships with various stakeholders such as agricultural industry, farmer organizations, and technology providers to promote research and technology transfer to farmers. Plans are in place to sign Memorandums of Understanding (MoUs) with State Agricultural Universities and Agricultural

Departments with the objective of playing leadership role in agricultural research, education, and development through research collaboration, faculty exchange, and infrastructure/ resource sharing. To leverage funding from Corporate Social Responsibility (CSR) initiatives, steps are being taken to establish a CSR fund, which can aid in innovative research projects, infrastructure development, and capacity building. Establishing a corpus fund and focusing on enhancing seed production activities, including developing improved varieties, seed quality testing, and multiplication, is also prioritized. Also, MoU has been signed with Western Sydney University for academic collaboration leading to Dual Degree PhD program since 2019. Similar efforts to sign agreements with University of Western Australia in Australia are in progress.

The institute's infrastructure development includes constructing new academic blocks, classroom complexes, and residential complexes to accommodate the growing needs of students, faculty, and researchers. Specialized research facilities such as an "Innovation Centre" for cutting-edge science, a Speed Breeding Facility to accelerate breeding programs, and a Central Instrumentation Facility providing access to advanced research equipment and technologies are being established. Collaboration with renowned foreign universities, faculty exchanges, joint research initiatives, and access to global agricultural knowledge and expertise are encouraged. Additionally, the appointment of adjunct faculty members from industry, research organizations, or international institutions aims to enrich the teaching and research environment with practical relevance and exposure to the latest advancements in agriculture.

Overall, these initiatives and collaborations will contribute to enhancing IARI's research capabilities, strengthening academic programs, promoting technology transfer, and fostering innovation in agricultural sciences.

ASSESSMENT REPORT

ASSESSMENT & RECOMMENDATIONS 10

Overall assessment

IARI has made significant achievements in research, education and extension during the reporting period of 2017-22. The overall performance and achievements made by the institute is graded at 8.5 on a scale of 1-10. Based on analysis of the achievements of IARI, the overall performance of the institute is graded as **OUTSTANDING**.

Consolidated Recommendation

The Institute has played a leadership role in basic and strategic research, technology development and commercialization during the period under review. The QRT reviewed the mandated IARI activities from 2017 to 2022 and discussed in depth with teachers, researchers, finance and administrative officials, technical and supporting staff, and a few end-user farmers and entrepreneurs. Finally, QRT arrived at a set of recommendations for consideration of the ICAR. The broader area-wise recommendations are as follows:

Research

1.1 The ATR on recommendations of previous QRT were examined and it was observed that the recommendations 3, 5, 6, 8, 12, 14, 19, 47, 64, 69, 72, 80, 85, 89 and 100 could not be implemented due to non-availability of funds. Since these recommendations had been accepted by the Council, and therefore, should be implemented for which necessary funds may be provided.

1.2 Agriculture is primarily dependent on nature and natural resources. Climate change and dwindling natural resources are the major challenges faced by sustainable development of agriculture. Therefore, basic, strategic, adaptive and applied research on landscape basis with system orientation is essential.

1.3 Understanding and improving the biochemical and physiological pathways and processes of plants involved in climate change adaptation, resource use efficiency, yield, nutritional quality, functional foods and products for preferential market requirements are crucial. This will include research on emerging areas such as systems and synthetic biology with specialized human resources, state-of-the-art laboratories and adequate financial resources.

1.4 Climate change-related risks pose a significant challenge for agricultural production. Hence, there is a need to intensify efforts to breed varieties and develop management practices for climate-resilient agriculture.

1.5 Genome editing is a powerful tool for creating precise and desirable genetic variations necessary for crop improvement in a shorter period. At present, the large-scale adoption of this tool is limited by its IP and non-availability of functionally validated genes in different crops. Therefore, there is a need to (a) acquire the IP rights for short and medium-term usage, and (b) focused research on the discovery of genes, development of indigenous editing tools and processes, and IP thereof, should be carried out.

1.6 A low rate of genetic gain is a major concern in crop improvement programs. In order to enhance the genetic gain for yield, hybrid breeding and modern approaches such as genomic selection and speed breeding need to be adopted with the provision of adequate financial support for research and training.

1.7 Consumer aspiration towards agri-foods is changing fast. Therefore, breeding programs must be re-oriented to develop products, including bio-fortified crops, as per consumer preferences and industry requirements. Lab-scale infrastructure in tune with the processing industry needs to be created.

1.8 Peri-urban agriculture, protected cultivation, aeroponics, hydroponics and vertical farming are gaining importance. At present, seeds of most of the varieties cultivated under these conditions are imported. Therefore, developing varieties befitting these diversified conditions need to be intensified.

1.9 DNA fingerprinting and barcoding of all the varieties and parental lines of hybrids developed by IARI and the development of database need to be taken up on priority.

1.10 Diversification of rootstock is considered absolutely essential for enhancing resilience to biotic/ abiotic stresses across diverse agro-ecological regions and for high-density planting. This would help in taking up horticultural crops in different adverse niches such as barren, degraded and problematic soils, viz., acidic, saline and sodic soils.

1.11 Research work on genetic purity evaluation and varietal identification needs to be strengthened. Research needs to be initiated to develop and validate the molecular markers for genetic purity testing of released varieties of various crop species with IARI as the nodal centre. Funding for the research may be explored from relevant sources.

1.12 IARI has played a pivotal role in heralding the Green Revolution by developing high-yielding wheat and rice varieties, which have been very effectively augmented with quality seed production through Farmers' participatory seed production programmes, particularly in Basmati rice. However, there is a need to develop and validate such effective models for high volume-low value crops such as wheat and other crops that are prone to climatic aberrations and pressure of biotic stresses like pulses.

1.13 ARI has developed waxy maize hybrids which have great potential to produce more bioethanol (>470 litre/ton) than the traditional maize (370-380 litre/ton) and even broken rice (420-430 litres/ton). This novel maize would pave the way for efficient bioethanol production in the country. The novel approach of introgressing variegated red pericarp (a trait taken from a landrace from Sikkim) in biofortified maize hybrids, would pave the way for market segregation from the normal maize, and help providing nutritional security, premium price and better livelihood to farmers. It is recommended that research on the above two significant aspects be intensified further with adequate financial resource.

1.14 IARI should establish a Seed Services Unit with an independent CEO with the freedom and flexibility to operate and required infrastructure such as a state-of-the-art seed processing and packaging plant, seed enhancement technology solutions, sensor-based modern storage capacity and digital and physical marketing network development. Such facilities should be established at IARI HQ (New Delhi) and its Regional Stations at Karnal (Haryana), Indore (MP) and Pusa (Bihar). With projected seed production targets of 60000 quintals per annum (20000 quintals at IARI New Delhi, 25000 quintals at Karnal 10000 quintals at Indore and 5000 quintals at Pusa), would require a onetime grant of about ₹ 100 crores. Thereafter, it will be self-sustainable.

1.15 IARI Regional Station, Indore, has made a significant contribution to the development of wheat varieties for the central zone (Madhya Pradesh, Kota and Udaipur divisions of Rajasthan, Jhansi division of Uttar Pradesh, Chhattisgarh & Gujarat) and peninsular zone (Maharashtra, Karnataka). Durum wheat is used for preparation of diversified products such as pasta, semolina, dalia, etc. IARI RS, Indore is strategically located for durum wheat improvement. In order to capitalize on the existing and emerging potential, the Centre should concentrate on durum wheat research with a specific emphasis on end-use and nutritional quality as per industrial and consumer requirements. It would call for strengthening the infrastructure including quality laboratory.

1.16 *Dicoccum* wheat demand is increasing among consumers due to its low glycaemic index, high protein, fibre and micronutrient content. IARI Regional Station, Wellington, has done significant research on assessing nutritional properties, improvement and popularization of *dicoccum* wheat in peninsular India. Therefore, the station should focus on *dicoccum* breeding to improve yield and nutritional quality to meet the requirement of growing *dicoccum* market.

1.17 IARI, Regional Station, Wellington is also a hotspot for biotic stresses such as stem rust, powdery mildew and head blight of wheat, white rust, and powdery mildew in mustard. The infrastructure for disease screening needs to be strengthened.

1.18 IARI and its regional station, Wellington, are involved in the utilization of wild species of wheat and synthetic wheat as sources of genes for biotic stress resistance. Research on utilizing wild species and synthetic wheat to improve disease resistance and grain quality of *Triticum aestivum* needs to be strengthened.

1.19 The IARI Regional Station, Wellington serves as a national off-season nursery for generation advancement in different crops. The station's infrastructure needs to be augmented by providing new office and lab buildings and a guest house to accommodate visiting students and scientists.

1.20 IARI Regional Station, Karnal, is a hub for maintenance breeding, breeder seed production and scaling up of improved crop varieties. The maintenance breeding program must be strengthened further. The centre should play a catalytic role in training human resources for quality seed production.

1.21 IARI Regional Station, Shimla, should focus on prospecting sources of resistance to leaf rust, stripe rust and powdery mildew of wheat.

1.22 Recent landslides in Himachal Pradesh had severely damaged the existing farm, roads, glass houses, etc., at the IARI Regional Stations located at Shimla and Katrain, which are beyond repair. Hence, these facilities need urgent reconstruction. Further, " retention walls" need to be constructed to prevent any such damage in future.

1.23 IARI Regional Station, Pusa, is of historic importance. It had contributed enormously in the varietal development of different crops. This station is also involved in the production of quality seeds. It acts as a gateway for showcasing IARI technologies to the farmers of the eastern region. Its strategic location is paramount and has enormous potential to meet the emerging challenges through accelerating agricultural technology development. The infrastructure facilities, including the administrative building, fencing and roads, are in shabby conditions, which are not commensurate with the requirements of research and technology development, to meet the requirements of the region. Presently, only two scientists are in position, which is one-fifth of the sanctioned scientific manpower. Considering the historic importance and strategic locational advantages, utmost attention is urgently required to revamp the facilities, fill the vacant positions and make this station functional.

1.24 IARI Rice Breeding and Genetics Research Centre, Aduthurai, serves as an off-season nursery for the main rice breeding program of IARI, New Delhi. The station should focus on accelerating the breeding cycles and employing molecular tools for rice improvement.

1.25 For advancing important genetic material, mapping populations during off-season under protected conditions, and screening breeding material for biotic and abiotic stresses in chickpea, soybean and maize, adequate rainout shelter facilities must be created at the Regional Research Centre, Dharwad.

1.26 Research on bio-prospecting and developing functional biomaterials and quality products from agro-industrial wastes needs to be pursued. This will facilitate generating wealth from so called waste.

1.27 Considering the increased level of damage caused by diseases, pests and plant parasitic nematodes to cope with the outbreak of invasive pests, research on forewarning, modelling pest dynamics, and pest surveillance needs to be strengthened in different cropping systems.

1.28 IARI has a rich collection of insects/ pests, pathogens and nematodes, their digitization with symptoms will further assist farmers as ready reckoners. However, research facilities for the maintenance of cultures, controlled environmental facilities for phenotyping and High-end biosafety facility (BSL-III) also need to be established. It needs to be appreciated that different insect pests and microbes are likely to be important genetic resources for future development.

1.29 Focus need to be given on discovery of new molecules, modification of available molecules and the processes, and development of innovative formulations for addressing emerging insect pests and disease problems.

1.30 Rapid diagnostic tools and pesticide residues detection technologies should be developed on priority.

1.31 The research under NRM School must be organized under two programs, namely (i) Containing Climate change and (ii) Sustainable soil, water and crop management integrating specific components of the Divisions of Agronomy, Agricultural Physics, Environmental Science, Microbiology, Soil Science and Agricultural Chemistry, Agricultural Engineering, Water Technology Centre (WTC) and Agricultural Knowledge Management Unit (AKMU) as sub-projects under multi-disciplinary mode.

1.32 For developing climate-resilient agriculture technology, addressing the Sustainable Development Goals and achieving Net-Zero targets, there is a need to work out pathways for minimizing carbon emission from agriculture by the year 2050 through Food-Systems Integrated Modelling for exploiting opportunities in climate and ecosystem services, and carbon markets. At the same time, research efforts must be concentrated on developing and evaluating the nanoparticles, microbial formulations and agro-biomass utilization-based technologies for mitigating GHGs and environmental pollution. Additional research efforts must focus on enhancing fertilizer nitrogen use efficiency in which IARI was a lead center during 1970s and 1980s. The key objectives of the research would be invention of new fertilizer molecules and application of novel management practices like substituting the basal dose with one-time deep placement. These new agronomic innovations for precision treatment are recommended to be strengthened by infusing use of modern agricultural tools (i.e., drones, soil sensors and robotic placement drills etc.) to reduce fertilizer input, time and labour, and above all to nurture ecological sustainability.

1.33 Research on sensor-based assessment of crop and soil health, disease pest identification and forewarning through Remote sensing derived co-variates, ML and AI, variable rate technology and agri-robotics need to be further intensified.

1.34 Emphasis must be given on the assessment of extreme weather, climatic variability and climate change on crop growth, yield, pests and diseases through modelling (including geospatial). Development of methodology for assessment of ecosystem services, crop insurance and regenerative agriculture at farm level to agro-ecosystem scales by integrating different tools are necessary.

1.35 New frontiers of NRM research should focus on rhizosphere engineering and management for enhancing nutrient use efficiency, novel fertilizer formulations to address balanced nutrients and minimizing losses, and quantifying soil ecosystem services.

1.36 Emphasis should be given to microbiome and metagenomics research as well as rhizosphere and phyllosphere engineering for augmenting crop nutrient supply and climate resilience. Modernization of microbial biofertilizer production with state-of-the-art production, value addition, packaging and storage facilities is essentially required.

1.37 Water scarcity and poor water quality are emerging as major challenges for crop production in the backdrop of climate change, thereby posing a severe threat to national food security. To address this, cutting-edge research in the field of water conservation, water harvesting, micro water resource development, river health and rejuvenation, canal automation, wetland restoration, groundwater recharge, phytoremediation and IoT-enabled precision irrigation are of paramount importance.

1.38 Integrated research on conservation agriculture, weed management, organic farming and carbon and energy efficient integrated farming systems model, design and development of Agri-robotics and agri-electronics and design and development of smart machinery for precision input application must be strengthened further to achieve the climate smart food production.

1.39 The School of Social Science has a critical role in responding to the demand for evidence-based policy research, particularly on emerging food and agricultural technologies which have the potential to enhance food and nutrition security, sustainable intensification, innovations in natural resource management policies, climate and energy policies, and collective action that can lead to improved farmers income, food security and sustainability. Advanced analytics are needed to attain desirable outcomes. Therefore, there is a need for capacity building and strengthening of computing facilities with the latest software.

1.40 Harnessing the potential of rural youth and women is key to rural transformation. The focus should be on action research on promoting agri-enterprises and start-ups with market linkages and convergence of related agencies. The stakeholders, players and partners are changing fast, and so are the tools, techniques and paradigm that are continuously emerging. Therefore, it is absolutely essential to do "Research in Extension" to develop globally competent human resources for developing effective production-to-consumption mode of operation with reorientation to system approach.

1.41 It is essential to capitalize on and harness coherent synergies in developing adoptable, bankable and implementable technologies. A number of so-called technologies that are being developed and propagated for adoption are the components of technologies in a broader framework. In this endeavour, programmatic alignments are considered absolutely essential. Considering school of thoughts in this endeavour is a step in the right direction. This would require enabling mechanism and critical financial resources to ensure logistics and semantics. For instance, if it is required to develop a virus management technology, having a Centre of Virology alone will not be able to solve the technological problem. Along with the virus, its carrier vector is of paramount significance, which is dealt with in the Entomology discipline. The vector, in turn, survives on a host plant, which comes in the domain of Plant Breeding. Therefore, interdisciplinary alignment and linkages in program mode become absolutely essential to solve existing and emerging complex problems. In this context, the development of effective mechanism and platforms with flexible funding provisions to serve the cause is considered essential.

1.42 Equipment in the Divisions and units are very old and require huge maintenance cost, and many high-end equipment and facilities are not available. Procuring equipment in each division and maintaining several labs will require a larger budget and manpower. Therefore, a Central Instrumentation Facility with all high-end equipment supported with operating technical manpower for basic, strategic and applied research needs to be established on priority for harnessing the frontier science.

Education

2.1 IARI has been playing a pivotal role in developing competent human resources in agriculture since 1923. It attained the status of deemed to be university in 1958 along with Indian Institute of Science, Bengaluru. The newly established two new campuses of IARI at Assam and Jharkhand are very well-positioned to impart undergraduate education. These campuses need to be supported with the immediate deployment of quality teachers/ researchers, laboratory staff, and provided with appropriate laboratory and farm infrastructure. Looking into the future requirements, creation of additional faculty, technical and supporting staff positions is required.

2.2 Experiential learning units such as Hybrid seed production, biofertilizers, protected horticulture, nursery raising, mushroom production, drone technology, etc., should be developed for the experiential learning of B.Sc. final year students at IARI, Assam and IARI, Jharkhand.

2.3 The QRT strongly feel that IARI, New Delhi should not dilute its limited resources, rather much more focus should be given only on higher education and research at M.Sc. and Ph.D. levels to remain globally competitive.

2.4 While implementing National Education Policy, the core strength of the Institute *i.e.* basic and strategic research, and higher education programs should be strengthened with quality manpower, resources and facilities. In new areas, wherever necessary new positions may be created.

2.5 The 21st century is a century of specialization and capitalization on technology led growth. For efficient, effective, and relevant human resource development, specialized human resources that fits the changing requirements must be developed. It is, therefore, essential that ICAR take an urgent view in broadening and bringing much-needed flexibility to meet existing and emerging requirements by broadening the ARS disciplines depending on the courses and commensurate with various discipline-oriented degrees awarded. The human resources developed by agricultural Institutions are not only for the ARS but also to cater to the requirement of other sister Institutions and Industries. Degrees could be awarded much beyond the specialized divisional boundaries, such disciplines which capitalize on complementarities and strength available at IARI, sister institutions in Delhi and going beyond to institutions such as IIT, CSIR, NPL, AIIMS and universities in the vicinity. This would require development of a system that brings much-needed flexibility with differential modalities. There could be different credit courses in specialized disciplines such as robotics, artificial intelligence, blockchain technology and sensor-based decision support system, Intellectual Properties, etc.

Establishment

3.1 The revised scientific cadre strength of the Institute is 567 of which 451 are in position. The remaining need to be filled as regional stations and some

Divisions have many vacancies. Technical staff strength of the Institute was reduced to 512 from 680, and of this only 367 are in position, and thus shortage of technical manpower is a major issue is all Divisions and regional stations. Similarly, administrative staff strength of the Institute was reduced to 442 from 457, of which only 270 are in position. Therefore, the vacant scientific, technical, and administrative staff positions must be filled urgently.

3.2 The Skilled supporting staff (SSS) strength was reduced from 1301 to 740, and now this cadre is completely abolished. This is a major issue in agricultural research as trained, skilled support staff play a key role in supporting research. ICAR may take up efforts to reestablish this cadre, or adequate funding must be provided for hiring sufficient contractual skilled supporting staff.

Administration and Governance

4.1 Autonomy to IARI in administrative matters such as collaboration with international organizations and industries, inviting foreign scientists to deliver lectures, planning collaborative research programs and foreign visits etc., is necessary.

Finance and Budget Provision

5.1 Procurement through GeM leads to procurement of poor-quality chemicals, consumables and equipment, and often costly. Relaxation should be given to the research Institutes to procure chemicals and consumables through rate contracts, and equipment through an open tender process.

5.2 The category-wise expenditure incurred under revenue and capital heads by IARI at 2021-22 price for the last five years showed that about 87% of the budget goes for Establishment expenditure, which includes salary, pension, OTA, administrative expenses, repair and maintenance. The Research and Operational expenditure estimates after adjusting GST is only 2.6% of the total budget provision. A payment of ₹ 25.36 crores to CPWD for the annual repair and maintenance services provided from 2017-2022 is pending due to a fund crunch. Thus, ICAR must increase this budget provision and sufficient funds under research and operational heads must be given to IARI. To keep pace with the changing advancement, new equipment to augment and support priority efforts would also be essential.

General Recommendations

6.1 IARI is the flagship institute of Agriculture of the Nation. It should serve as a clearing house of validated information and technologies and as an opinion leader in agriculture-related policy formulation for the country. It should *suo moto* as well as, on request, bring out white papers on national issues that clarify the objective and reasoned position based on science and scientific logic. Such documents prepared on the strength of objective scientific studies should be the main basis for National and state-level agricultural policy-making. The Institute should proactively address emerging issues and tendencies that could influence policy formulation with significant financial implications and either validate or repudiate claims based on experimental evidence. Science-based dissection of some proposals like Nano urea and Natural Farming are good examples of recent issues that require a scientific appraisal for sound policy formulations.

6.2 To be globally competitive in frontiers areas adequate funding must be provided for student exchange and faculty exchange programs with International Universities.

6.3 Realizing, recognizing and appreciating the very basic need for continued growth, attaining and sustaining competitive advantages nationally and internationally, the Council has provided ₹ 100 crores grant to selected institutions such as PAU, Ludhiana, MPKV, Rahuri, etc. in past. IARI has been a flagship of agricultural transformation in this country and has helped science, society, and humanity to a great extent. The Institute has provided yeoman service to the nation by contributing to research and human resource development for over 100 years of its existence.

6.4 Further, realizing the basic need for investment in education, research & development, the Hon'ble Prime Minister announced and ensured financial support for laying a concrete foundation for such activities in the country. Eight public sector institutions have been identified as Institutions of Eminence (IoE) and provided with a grant of ₹ 1000 crores each. It is contemplated to ensure excellence in the country to compete globally, effectively. However, not a single agricultural institution is included in this list. IARI is the premier institution and has all the potential to become world class. The peace, rural prosperity, and tranquillity ensuring inclusive growth in the country hinge on the basic contribution of agricultural institutions. For instance, the contribution of IARI to even forex earnings through improved Basmati rice varieties has been about

₹ 30,000 crores on an average per annum in last five years, and approximately ₹ 35,000 crores during 2022 -2023. IARI wheat varieties contribute about 50 million tons annually to the nation's granary. Hence, the QRT strongly recommend and request the Hon'ble Agriculture Minister to solicit the kind attention of the Hon'ble Prime Minister to declare IARI as an Institution of Eminence (IoE), so that the necessary work could start right from April 2024 and completed by the end of March 2029. With its due consideration, the committee strongly feel that this gesture of Hon'ble Prime Minister would be a tribute to agricultural community.

ENCLOSURES

ANNEXURE I

ICAR order constituting the Quinquennial Review Team for IARI

भारतीय कृषि अनुसंधान परिषद
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
कृषि भवन, डॉ राजेंद्र प्रसाद रोड, नई दिल्ली-११०००१
Krishi Bhawan, Dr Rajendra Prasad Road New Delhi 110 001

F.no.CS/16/08/2019-IA-IV (e.no-42673) — Dated the ~~May~~ 5 June, 2023

OFFICE ORDER

The Quenquennial Review Team (QRT) comprising of the following members is constituted with the approval of the Director General, ICAR to review the Research work done by the IARI, New Delhi during the period of 2017-2022:-

Sl.no	Name	Designation
1	**Dr. Mangala Rai,** Former Secretary, DARE and DG, ICAR, Kalindi Kunj, N-8/100 A-B, Ganesh Dham Colony, Newada, P.O. Sunderpur, Varanasi-221005, UP. Mobile: 9869630033, 09473199162 Email: mnglrai@gmail.com	Chairman
2	**Dr. Suraj Singh Baghel,** Former VC, CAU, Imphal and Assam Agricultural University, Jorhat Mobile-7999381192, 7587110035, Email- surajsinghbaghel@gmail.com	Membre
3	**Dr. S.N. Puri,** Former VC, MPKV Rahuri and Former VC, CAU, Imphal, Mob: 9999637566 email-Snpuri04@yahoo.co.in	Member
4	**Dr. J.C. Katyal,** Former DDG (Edn.), ICAR and Former VC, CCS, HAU, Hisar Mobile: 9284755567,8447806760 Email: jc_katyal@rediffmail.com	Member
5	**Dr. P.K. Joshi** Former Director, NCAP & NAARM Director South Asia International Food Policy Research Institute, NASC Complex, DPS Marg, New Delhi-110012 Add: D-7, Pusa Apartments, Sector-15, Rohini, Delhi-110085 Mobile: 09818506753 Email: p.joshi@cgiar.org pkj.ncap@gmail.com pkj.in@outlook.com	Member
6	**Dr. K.K. Narayanan,** Founder & Director, Sthayika Seeds Private Limited, Bengaluru. Mobile: 8110415074 Email : Kknaraya394@gmail.com	Member
7	**Dr. Manoj Prasad,** Staff Scientist VII & J.C. Bose National Fellow, NIPGR, New Delhi Phone No.: 26735160 Email : Manoj_prasad@nipgr.ac.in Manoj_pds@yahoo.com	Member
8	**Dr. C. Viswanathan,** Joint Director (Research), IARI, New Delhi-110012 Mobile: 9013805245 Email : jd_research@iari.res.in viswa.chinnusamy@gmail.com	Member Secretary

FUNCTIONS:

The QRT shall conduct the review of the work of the IARI, New Delhi keeping in view the relevant guidelines thereon and submit its recommendation on future research thrusts through its reports to the council **within 6 months** from the completion of period under review for further submission to the Governing body of ICAR.

PROCEDURE:

The Chairman of the review team will initiate action to convene the meeting of the team as early as possible. The Chairman will also inform the Director, IARI/ Project Coordinator to provide the information required by the team with regard to the work done and other relevant information, as may be required for conducting the review.

The Director/PC of the Institute/AICRP will provide necessary stenographic, technical, logistic administrative assistance etc to the QRT members for the efficient functioning of the committee and preparation of the report.

The T.A of the non-official member of the QRT for attending its meeting will be paid by the IARI, New Delhi in accordance with the relevant rules of the council.

(Yashoda Nayal)
Under Secretary (Crop Science)
T/F- 011-23384608

ANNEXURE II

Terms of Reference (ToR)

I. Research achievements and their impact

To examine and identify the research achievements of the Institute, Projects/KVKs, its Regional Station and Sub-stations, AICRPs operated by them ivs-a-vis sectoral programs since the previous QRT and critically evaluate them. Commensurate with the objectives, mandates and resources of the organization, the social-economic impact of research on farmers, beneficiaries and transferability of results to farmers through extension should be critically reviewed.

II. Research Relevance and Budget Allocation

To examine the objectives, scope and relevance of the research programmes and budget of the Institute for the next 5 year in relation to overall/state/regional/national plans, polices and long and short-terms priorities. The Committee may also draw its attention to the EFC/SFC memo in relation to recommendations of the previous QRT and also the Perspective Plan and Vision – 2025 document of the Institution.

III. Policies, Priorities and Strategies

To examine the policies, priorities, strategies and procedures adopted by the Institute and the system in relation to Perspective Plan in arriving at these decisions particularly the effectiveness of working of the Institute Research Committee, Research Advisory Committee and the Institute Management Committee as well as the Consultative Machineries like Grievance Cell and Institute Joint Staff Council.

IV. Relationship/Collaboration with SAUs and Other Stakeholders

Whether the research programmes of the past and proposal for future are in harmony with the Vision ICAR (HQ) and the programme of related Centres of research and Agricultural Universities, State Government, Private Sector and IARCs.

V. Linkages with Clients/End users

To examine the kinds of linkage established with the clients and end users of research results, i.e., farmers/fishermen and extent of interest displayed in conduction "on farm research", on farmers' fields and in organizing demonstrations/training course o demonstrations/training courses for the transfer of technology to extension agencies.

VI. Proposed Changes in Organization, Programmes and Budget

To examine whether any changes in the organizational set-up are called for, to achieve and improved and effective working. The Committee may also examine and draw attention to any imbalances in the staffing pattern consistent with the scientific, technical and administrative needs as well as the allocation of research funds towards capital works, establishment and research contingencies. Further the Committee may also examine the resource generation efforts and assess the problems and prospects of the same. The progress and problems of implementing project Based Budgeting may also be highlighted. While proposing major changes in organization and function their feasibility in relation to ICAR's rules, autonomy, resources, etc. need to be kept in view.

VII. Organization and Management

Whether the organization structure of the Institute is conducive to efficient functional/ working autonomy, decentralization and delegation of authority in day-to-day routine working and whether the Director and senior staff are interested in promoting a collegiate and co- operate method of administration is to be assessed. The committee may also critically examine the status of implementation of O & M reforms as introduced by the Council from time to time and suggest ways and means to implement them at the Institute level. They may also suggest further reforms to be considered by the Council. The suggested staff ratio by the Council may have to be kept in view white reviewing the staff position in the Institute.

VIII. Constraints

To examine constraints hindering the Institute in achievement of its objectives and implementation of its programme and goals and to recommends ways means of minimizing or eliminating them.

IX. Looking Forward

To look into any other points considered relevant by the committee or referred to it by the ICAR, the Institute Director or the Management Committee, in respect of future project development, research prioritization and management changes.

The above terms of reference may be modified at the suggestion of Director of Institute/ Project/Management Committee of Institute/Project/ICAR Headquarters/GB keeping in mind any specific problems of the Institute.

ANNEXURE III

Action taken Report (ATR)

Action taken on the recommendations of QRT (2009-2016) (as approved by the Governing Body of ICAR)

S. No.	Recommendation of QRT (2009-2016)	Action Taken
A. Research		
1.	Strengthen interdisciplinary genomics research with emphasis on horticultural crops, pulses, millets and oilseed crops for their genetic improvement	Interdisciplinary genomics research has been given emphasis in the genetic improvement of all the crops during 2017-2022: **Chickpea:** Two varieties namely, IPCMB19-3 (Samriddhi) and BGM20211 (Manav), resistant to Fusarium wilt have been developed and released for Central Zone. Five with >93% background genome recovery having resistance to Fusarium wilt race 2 were developed and registered with NBPGR. Large number of advanced MABC lines (BC3F4) resistant to Fusarium wilt have been developed in the genetic background of JG16, JG11, JAKI 9218, Pusa 256, Pusa 362, PBG 7, Vijay and L552 (Kabuli). Two robust QTLs (qab-4.1and qab-7.1) governing resistance to Ascochyta blight has been identified. **Indian Mustard:** Gene based markers were developed for genes governing low erucic acid (FAE1.1 and FAE1.2) and seed coat colour (TT8A and TT8B) and these markers are being used in MAS program for development of single and double zero mustard genotypes. **Tomato:** One tomato hybrid, Pusa ToLCV Hyb-6 resistant to tomato leaf curl virus has been identified for release and notification for Zone V by AICRP (VC)- 2022. Two Tomato Leaf Curl Disease (TOLCD) tolerant varieties namely, Pusa Prasanskrit, (with superior processing traits) and Pusa Candy Cherry Tomato-3 (suitable for protected and open field cultivation) carrying Ty3 gene have been identified for release. **Fruits:** Division of FH&T has initiated genomics research in mango and guava in collaboration with ICAR-NIPB, New Delhi. In mango, QTLs governing fruit quality related traits have been identified.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
2.	There is a need for greater utilization of the resources and their outputs and hence there is a need to integrate the NRCPB with IARI.	The outcome of genome sequencing projects of NIPB such as genome sequences, 50K rice genotyping array, and 60K arhar array are being utilized by IARI.
3.	Provision for additional funds for AMC/ CMC of the high value equipment should be made. Upgradation of old items of equipment should be taken up on priority so that the national needs are not left unattended due to want of equipment despite the availability of the know-how and human resource	On an average about Rupees 3.6 crores/year was spent on Repair & Maintenance of Equipment, Vehicles & Others, during the last five years. Considering the large number of Divisions/Units/Regional stations with several old equipment, the allocation for AMC/ CMC were not sufficient.
1.1	**Crop Improvement**	
	Genetics	
4.	To accelerate the breeding cycles, considering the excellent expertise available, it is recommended that an **Accelerated Breeding Centre** (ABC)- a centralized facility including high-throughput genotyping centre, doubled haploid facility, bioinformatics centre, rapid generation advancement facility and transgenic facility should be created.	A multidisciplinary Agricultural Innovation Centre (AIC) consisting of facilities for accelerated breeding such as high throughput genotyping, bioinformatics, Double Haploid production and Genome editing were approved by the ICAR. Construction work of AIC is in progress. A speed breeding facility has also been approved by DA&FW, for accelerated breeding which is being pursued.
5.	In order to maintain the active germplasm pool long term seed storage of 20,000 sample capacity is required.	Due to the paucity of funds, storage facility could not be created. Now with the implementation of ICAR Corpus Fund, efforts will be made to create storage facility.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
6.	In view of significant contributions by the Division, it is required to showcase the mega achievements of the excellent research with modern display tools and a museum for the benefit of farmers, students and scientists of the country and abroad	Due to the paucity of funds, storage facility could not be created. Efforts will be made to create the same through the implementation of ICAR Corpus Fund.
	Seed Science and Technology	
7.	To upscale the activities for seed testing and seed biology, state-of-the-art laboratories in the areas of physiology and biochemistry and molecular biology need to be established.	Existing laboratories of seed testing, seed physiology, seed biochemistry and seed molecular biology were available in the Division. Moreover, two new walk-in-germination chambers for seed testing were fabricated/ installed and several minor equipment were procured to upscale the activate for seed testing facilities in the Division.
8.	Large scale seed multiplication and maintenance of the notified and released varieties of field and horticultural crops is an essential activity for dissemination of quality seed to the farmers and seed producer agencies of the country. A large scale seed storage facility (for one year) with temperature and humidity control and processing plants are required to be created in Delhi, Karnal, Indore, Pusa Bihar.	At Seed Production Unit (SPU), large scale seed multiplication and maintenance is regularly taken up. The seed storage facility has been expanded during 2020-21 and added two godowns and also constructed a building for seed processing plant. Processing machineries could not be procured due to paucity of funds. Now process has been initiated to procure this by using the profit from the revolving fund scheme. Large seed storage facility could not be established due to paucity of funds.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
9.	The horticultural seed materials need protected system for maintenance and multiplication which needs to be created at IARI and RS, Karnal.	Chain link fencing has been created for the protection of horticultural plants from the wild animals. For maintenance and multiplication of horticultural planting materials the requirements of protected structures and manpower are being appropriately addressed as per the availability of funds.
	Regional Station, Pusa, Bihar	
10.	Pusa Bihar station is at the moment in deteriorating conditions. No new wheat or pigeonpea varieties have been developed for over two decades and no new project proposal for funding support has been submitted in the recent 5 years.	As only one scientist was working in the station, major emphasis was given on breeder seed production and supply. This station developed a Pigeonpea variety **Pusa Arhar 151** (**Pusa Shreejita**) was developed released by CVRC for NEPZ in July-2020. The institute is making efforts to strengthen the station with additional manpower. With the joining of two new scientists, the recommended activities will be taken up now.
	Regional Station, Wellington	
11.	In order to facilitate the excellent off-season nursery, seed multiplication and full –season rust genetics work, the station needs to be provided with one additional controlled condition glasshouse and two laboratories, one for field-based work and another for molecular marker analyses.	Two existing glass houses were renovated and are being used for screening against rusts & SRT in wheat. A small molecular lab facility was also created to take up MAB in wheat.
	Regional Station Shimla (Wheat & Barley), Tutikandi	
12.	The wheat breeding and geneticist team should be provided with infrastructure for doubled haploidy production including culture room, net-house and controlled greenhouse for rapid DH production	Doubled haploidy work using *Imperata* mediated chromosome elimination technique is undertaken with the available facilities. A genetic stock named as DH1 is developed for yellow rust resistance using doubled haploidy approach and registered with NBPGR, New Delhi. However, modern culture room and controlled greenhouse could not be developed due to paucity of funds.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	Off-season Rice-Breeding & Genetics Unit, Aduthurai and Pulses and Maize Unit, Dharwad	
13.	The irrigation facilities at both Aduthurai and Dharwad have to be fully equipped with micro-irrigation system to meet the needs of the off-season materials as well as the main season work	An additional borewell has been made for irrigation at RRC, Dharwad and irrigation supply pipelines are in place at IARI-RBGRC, Aduthurai.
14.	Seed storage systems and equipment required for quality analysis need to be provided.	Seed storage systems and equipment required for quality analysis could not be established due to paucity of funds.
1.2	**Basic Sciences**	
	Plant Physiology	
15.	Towards identification of germplasm/traits/genes for resource use efficiency and abiotic stress tolerance, the work in automated controlled environment facility needs to be strengthened with establishment of Field phenomics facility including UAV/drone/air-borne phenotyping sensors, metabolite and mineral-nutrient profilers.	IARI established a state-of-the art plant automated controlled environment phenomics facility with the NASF funding. Hon'ble Prime Minister of India, Shri Narendra Modi inaugurated and dedicated the "Nanaji Deshmukh Plant Phenomics Centre (NDPPC)" to the Nation on 11th October 2017. Additionally, for field phenotyping, drone/ air-borne phenotyping sensors have been created in under HAHEP-CAAST project at Division of Agricultural Physics. A dedicated nutrient analysis lab for nitrogen analysis was established. ~300 rice germplasm phenotyped for NUE in NDPPC were validated through wet lab using CHNS analyser.
16.	Rhizosphere phenotyping facility to identify donors and genes for better root system architecture for enhancing water and nutrient use efficiency of crop	Different methods for rhizosphere phenotyping were developed and used for root phenotyping. A high throughput method for phenotyping root angle, and a modified pin-board method was made using polyfoam and toothpick grid for study of root architecture were developed. • Root studies on seminal root angle showed variability raging from narrow to wider angles (25° to 87°) in wheat. Relatively drought tolerant genotypes *viz.* N59, HD2985, DBW-14 and C-306

S. No.	Recommendation of QRT (2009-2016)	Action Taken
		showed narrow root angles in comparison to the genotypes sensitive to drought. • High throughput root scanning using root scanner and WinRhizo software facility is established in the Division. ~89 diverse wheat genotypes were studied for root architectural traits in response to low phosphorus stress and identified genotypes (BABAX, CARAZINHO, HD 2891, MARINGA and SUNCO) with improved root traits.
17.	Emerging genome editing tools need to be used to identify and validate physiological pathways and processes for resource use efficiency and stress tolerance. For this Genome editing Lab needs to be established.	• The Division is leading multi-institutional NASF project on genome editing, established a genome editing lab and developed the first genome edited rice lines, and human resources. Five new projects were initiated for genome editing in rice: (1) Transformative Strategy for Controlling Rice Disease in Developing Countries (BMGF-HHU, Germany), (2) Improvement in grain yield and lodging stress tolerance of black rice Chakhao amubi by CRISPR/Cas9 mediated genome editing (DST-SERB CRG), (3) Investigating the roles of matrix metalloproteinase (MMP) gene family in abiotic stress adaptation by generating CRISPR-mutants through multiplex-knockout approach in rice (DST-SERB CRG), CRISPR Crop Network: Targeted Improvement of Stress Tolerance, Nutritional Quality and Yield of Crops by using Genome Editing (NASF-ICAR) and Establishing Speed Breeding (Rapid Generation Advancement) Facility for Genome Editing Research" (NFSM, DoF&FW, MoA&FW, Govt of India) were initiated. In addition, ICAR EFC project on Genome editing is approved. These will help strengthen the genome editing lab and validate genes for physiological pathways and processes.
	Biochemistry	
18.	Biochemical metabolite analysis lab: Equipped for metabolic profiling, UPLC, GCMS, ChemiDoc gel	A well-equipped Nutrient Analysis Lab has been established in the Division with ICP-OES and UPLC to undertake metabolite profiling work. Gel imaging system and plate reader facilities were created. GCMS

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	imaging system, plate reader, etc.	facility established at Agricultural Chemicals division is available for use by all scientists.
1.3	**Plant Protection**	
	Agricultural Chemicals	
19.	A Pilot Reactor for bulk hydrogel/chemical synthesis and for prior art search on novel molecules, a Scifinder facility are needed	These facilities could not be created due to paucity of funds.
20.	Support for pesticide testing laboratory (NABL accredited) up gradation and scope enhancement from the current 9 pesticides to more than 150 with corresponding infrastructure, so as to utilize the same for high-end research on design and development of bioactive molecules, formulations (characterization and analysis).	Research on design and development of bioactive molecules and formulations were strengthened with the procurement of NMR (400MHz) and HPLC. Division has upgraded its capability to analyse ~140 pesticide using Divisional LCMSMS facility (not under NABL). Meanwhile, as per the thrust area of Government of India, a state of the art regional honey testing laboratory has been established. These facilities are being used for development of bioactive molecules and formulations.
	Nematology	
21.	Microscopy facilities need to be strengthened with better equipped microscopes and the scanning electron microscope is needed with cryostat for quick and efficient sample preparation for better results.	A motorized microscope Zeiss Axioimages was purchased. SEM with Cryostat costs > 1 Cr, and it could not be procured. However, it is now approved under Agricultural Innovation Centre, a central facility for all scientists.
	Plant Pathology	
22.	Some facilities and activities which are to be supported are listed: Climate Chambers and BSL III facilities: The Division needs Climate Chambers to conduct research on rust,	• Semi-automated chambers (temperature and RH control) and fully automated plant growth chambers are available in the Division and are being used for rusts, mildews, blights and other diseases. A containment facility was also developed and is being used for fungal diseases.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	blast, mildews, blight, spots and wilt for working throughout the year. BSL III level plant growth facilities are required to conduct research on threatening plant pathogens and exotic diseases. Create bioinformatics facilities	• One project proposal was submitted in DBT, Govt. of India under the "Plant Virus Pathogenomics Network Programme" where creation of a BSL-III facility has been proposed. A small BSL-III facility has been approved under ICAR EFC program on Genome Editing. • The scientist of Division have gained expertise and facilities for bioinformatic analysis. To further strengthen the bioinformatics facility, a Genome Work Station with option for functional analysis, genome analysis, transcriptomics and metagenomics is being procured.
	Regional Station, Pune	
23.	The station should develop system for providing virus free planting materials for clonally propagated plants like banana and citrus.	Due to presence of several major plant tissue culture based companies providing certified tissue culture plants to the farmers in this region, there is limited scope for this activity.
24.	The greenhouses should be refurbished.	Three new green house were constructed at a cost of Rs 100 lakhs.
	Regional Station, Kalimpong	
25.	There is a requirement of Staff quarters of Type IV and Type II and this should be protected by RCC boundary wall.	These facilities could not be created due to paucity of funds.
26.	The greenhouses should be refurbished.	The proposal is under consideration, and will be refurbished.
27.	The station should develop system for providing virus free planting materials for clonally propagated plants like large cardamom and citrus.	Virus free Cardamom plant generated from suckers in model nursery and distributed among farmers; budded plant of Darjeeling Mandarin generated but yet to test the presence of virus before distribution as there is no screening facility and man power
	Entomology	
28.	The laboratory which was destroyed by fire four years ago needs to be refurbished	The laboratory has been renovated
29.	Field level insect screening facility of fine net and rearing system at field	Fine net facility is being used for field level screening of insect pests. The Division also has Insect Proof Climate Control Chamber (IPCCC), one glasshouse,

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	environment needs to be created for epidemiological investigations	one net house and one polyhouse. Efforts are being made to create a field level rearing system in the upcoming years.
30.	Facility for intensifying IPM	Facilities for IPM are available in the Division.
1.4	**Social Sciences**	
	Agricultural Extension	
31.	Both Economics and Extension division should intensify work on impact analysis of IARI technologies in the country.	The scientists of the Division of Agricultural Extension and Agricultural Economics together are working in the project on impact assessment of IARI technologies.
32.	Mobile training vans with multimedia facilities are needed for effective transfer of technology and capacity building of farmers at theirdoorstep to enhance adoption of improved technology and enhance income	The Centre has proposed procurement of a mobile van for training.
33.	Should undertake data collection through Computer Aided Personal Interview (CAPI). This will help researcher to monitor data collection on a real time basis. It will also help to quickly analyse the data. Scientists and technical staff may be given training of using CAPI for data collection.	The Division conducted a Collaborative Training Programme with IFPRI, New Delhi on "Impact Assessment Methodologies and Techniques" under ICAR network project on New Extension Methodologies and Approaches (NEMA) during October 14-19, 2019. An exclusive session was held on CAPI i.e. "Use of digital data collection in Survey CTO/ ODK". CAPI based surveys are taken under externally-aided projects.
34.	Special norms for TA and hiring skilled enumerators for data collection may be made for undertaking pan India surveys for research studies	Adequate TA is being provided for survey work
35.	Modernization of	Facilities including advanced software like Adobe

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	Audio- Visual Laboratory	Premier Pro CC, Adobe Flash, Photoshop, Corel draw for preparing multimedia modules, and equipment such as Digital Video camera,Computer, accessories, Voice recorder, PICO Projectors have been established.
	Agricultural Economics	
36.	Should undertake studies on barriers (institutional and policy) in scaling up promising varieties and technologies.	The In-house project on 'Commercialization and impact of agricultural technologies', regularly studies the constraints in the adopting and scaling up of promising varieties and, and the findings are shared/ communicated through presentations and publications across different platforms.
37.	Scientists should be given training on advances on policy tools, econometric analysis and models for policy analysis.	The scientists undergone training in advanced analytical tools and techniques organized by the International Food Policy Research Institute, International Rice Research Institute, ICAR-National Institute of Agricultural Economics and Policy Research, ICAR-Indian Agricultural Statistics Research Institute, and they are using these tools and skills gained in the research work.
38.	It should establish a MarketingIntelligence and Forecasting Cell (Artificial intelligence cell) with (Computers and accessories) to regularly monitor prices of essential food commodities at farm and retail level to provide information to the government for taking informed decision well in advance.	A separate cell was not established. However, this area is included in In-house project on Agricultural Marketing, and the prices of essential food commodities regularly analyzed. The findings were published as research articles and presented at national and international conferences. However, further strengthening is required.
	Centre for Agricultural Technology Assessment and Transfer (CATAT)	
39.	Developing model villages for demonstrating doubling farmers income needs to be taken up by CATAT.	With approach of Integrated Development of Villages, interventions were made to develop four model villages in NCR namely, Beenjpur, Alwar (Rajasthan); Khajurka, Palwal (Haryana); Rajpur, Aligarh and Kutbi, Muzaffarnagar in Uttar Pradesh. Improved varieties, crop intensification, bio-fertilizers, bio-pesticides, micro irrigation, etc. were

S. No.	Recommendation of QRT (2009-2016)	Action Taken
		demonstrated in the adopted villages. Assessment of the yield and income showed that improved cereal and vegetable varieties performed better (yield advantages:14-22%) incomparison to local check. It was alsoobserved that average net return and BC ratio (1.52 to 2.86) was more under the demonstrations.
	Zonal Technology Management and Business Promotion & Development Unit	
40.	There is a need to decentralize the Council's power at institute level for decisions on PCT/National phase application filing for patents, collaboration with other marketing agencies, institute situated outside etc.	The Pusa Krishi, ZTM & BPD unit provides technical support to start-ups and scientists for the drafting and filing of Patent Applications. Further, it connects them with the Law firms for PCT/national phase filing.
41.	Farmer enterprises, whether in the form of FPO, cooperatives or startups, have to be recognized/ hand held/ supported in a very systemic way to address the requirements such as value chain development and promoting the processing part.	The Pusa Krishi, ZTM & BPD unit regularly organize the incubation program to handhold the startups and further connected them with the FPO to provide Agri-innovations at farmers' field. Also, the unit conducts Agri-entrepreneurship development programs to handhold them for the institute's technologies.
1.5	**Natural Resource Management**	
	Soil Science & Agricultural Chemistry	
42.	X-Ray Diffractometer (XRD)	XRD purchase could not be made. EDXRF has been approved under Agricultural Innovation Centre
43.	Atomic Absorption Spectrophotometer (AAS)	Plant Physiology Division has procured ICP-OES machine which is being used by scientists for different division.
44.	Microwave digestion system:	Two microwave digestion systems are available and are in working condition.
45.	Nitrogen analysis facility including digestion & distillation systems:	Only one system working. One CHNS facility is under repair. One CHNS facility at Plant Physiology Division is working.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	Microbiology	
46.	Strengthen and focus research in the areas of microbial ecology of soils, metagenomics, microbial genetics/genomics and proteomics under abiotic stresses for nutrient management of the soils	• Research on the use of metagenomics and other 'omics' approaches has been initiated. A Flagship project of IARI on "Functional importance and translational applications of microbiomes for crop productivity (2021-2026)' has been approved to strengthen and develop core competence and development of microbiome-based technologies. Abiotic stress (moisture) tolerant fungal/ bacterial/ endophytic formulations have been developed for improved crop nutrient, moisture availability and soil health.
47.	Scaling up production of Bio-fertilizers and bio-ethanol using bioreactor-based technologies by setting up a pilot plant and at least 3 bioreactors of 50L capacity.	• Division of Microbiology produces formulations of more than 10 potential biofertilizers in solid carrier based and liquid formats. Pusa biofertilizers have covered more than 20,000 ha of land in 25 states of India during last 3 years in organic and integrated nutrient management of different crops. Rs. 21.85 lakhs were generated from sale of different microbial formulations in the current year (2022). • Pusa Decomposer, a consortium of seven fungi, has been developed on the basis of their lignocellulolytic enzyme production potential for accelerated *in-situ* composting and decomposition as well as improvement in soil health. • Bioreactors with 50L capacity could not be created due to paucity of funds.
	Agricultural Physics	
48.	Explore the potential of drone remote sensing for soil and crop environment parameters. Work should be initiated on sensor based image processing techniques	IARI's first Drone Remote Sensing Laboratory in the Division with necessary infrastructure and equipment was established under funded projects. Drone remote sensing has been explored for crop health monitoring for biotic and abiotic stresses since 2016 using RGB, Thermal, Multispectral and Hyperspectral cameras under research projects on plant phenomics and precision agriculture. Image processing techniques for visual, thermal and hyperspectral imaging sensors have been developed. A Big Data Analytics Laboratory was established for the purpose under NAHEP CAAST.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
49.	Satellite data based products should be developed for crop yield prediction infrastructure facilities need to be created for the above.	The "Satellite Ground Station" was strengthened with new computer workstations, upgradation of software licenses and added new storage devices. An operational system of generating satellite data products of Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Evaporative Stress Index (ESI) was established. Besides, established "High Power Computing Lab" and "Big Data Analytics Lab" to support analysis of large amount of satellite data for crop condition assessment and yield prediction.
	Agronomy	
50.	Complete support system for Precision farming, Integrated farming system and organic farming needs to be provided	Precision equipment were procured for precise application of inputs. In collaboration with agricultural engineering division, precision seeding machine have been developed and evaluated for System of Wheat Intensification. Biomass unit has been created and maintained for organic input supply to organic farming. Various IFS models for irrigated and rainfed ecology have been developed at IARI farm.
51.	Complete refurbishing of laboratory and field facilities needs to be done	All the laboratories of the division have been regularly maintained and some of the instruments have been repaired for analysis of plant, water, soil, and measuring physiological parameters.
	Agricultural Engineering	
52.	One-time catch-up grant for renovation of old workshop and laboratories of Agricultural Engineering Division	Renovation work in one portion of the divisional workshop has been carried out.
53.	Develop technologies and designs for bulk cold-storage, bulk storage, short-term small/ medium storage systems at farm-gate or local community level along with low-cost cold-storage transport systems employing solar/wind energy	The division has developed Pusa Farm Sun Fridge for on-farm storage of fruits and vegetables. The technology was tested at different locations and commercialized. The division has also developed solar power operated equipment for different pre- and post-harvest unit operations (Solar powered low-cost mobile cold storage, Hybrid solar dryers, Solar powered evaporative cooled storage structure, etc.)

S. No.	Recommendation of QRT (2009-2016)	Action Taken
Centre for Environment Science and Climate Resilient Agriculture		
55.	Environmental Science division should upscale the crop production technologies throughout the Indo-Gangetic plains. The climate resilient technologies in rice-wheat cropping system with vegetables and utilization of m-Krishi to be strengthened for wider application.	The climate resilient technologies are being demonstrated under NICRA project in Mumtajpur (in Gurugram Dist, Haryana), 6 villages of Mirzapur, Chadouli and Sohanbhadra districts of UP, one village in Gaya district of Bihar and one village of 24 South Paraganas in WB from 2016 onwards. In addition, some of these technologies are demonstrated in 4 villages of Jhansi district in UP and 2 villages of Niwada district in MP under DST-MRDP Project during 2018-2022. The adaptation intervention gains were in the range of 10-40% increase in productivity under various production systems (Rice, wheat, maize, mustard and vegetable) in these villages. In addition, the ***PUSA m-Krishi*** (developed in collaboration with Tata Consultancy Limited) has been operational at the Division of Extension Education connecting to the farmers to provide solutions till 2019.
56.	The impacts of primary and secondary air pollutants and suspended particulate matter (SPM) on the productivity and quality of important field, vegetable and fruit crops and also the level of food chain contamination especially heavy metals through environmental pollution such as soil and water pollution need to be assessed.	Assessed the impact of air pollutants (primary and secondary) on the growth and yield of major crops such as rice and wheat in 12 villages nearby the NTPC, Auriya, UP. In addition, the water and soil quality were also assessed in these villages. The remedial measures are also suggested to the NTPC for improving the local environmental conditions. The heavy metals contamination study was carried in Delhi NCR. This study investigated the heavy metals content (As, Cd, Cr, Hg, and Pb) in the soil, water and vegetable samples of cultivated and marketed sites in Delhi region.
57.	The crop simulation modeling activities needs to be strengthened at the division	The Environmental Modeling lab is recognized by the DST as the A National Facility for Capacity Building on Simulation Modeling in Agriculture under National Mission for Strategic Knowledge on Climate Change in addition to the NICRA (under National Mission on Sustainable Agriculture); Lead of Agriculture Task force Network Project under National Mission for Sustaining Himalayan

S. No.	Recommendation of QRT (2009-2016)	Action Taken
		Ecosystems with 10 Himalayan Institutes. The climate change impact, adaptation and vulnerability assessments for 12 crops under climate change scenarios are provided to the Ministry of Environment and Forests for the Third National Communication to United Nations Framework Convention on Climate Change and to IPCC Reports. The lab is also involved in Global AgMIP project led by NASA and Columbia Univ., USA. The modeling lab also got the copyrights of the DRAKSHA (grape simulation model v1), InfoCrop V2.1 and CocoSim v.1 (a coconut model). In addition, the simulation models-based decision support systems for green gram, cauliflower and spinach are developed. Efforts are going on develop InfoCrop v3, Spatial InfoCrop and simulation models for some other important crops such as onion, tomato and sugarcane.
	Water Technology Center	
58.	Water Technology Centre should undertake the responsibility of managing and maintaining the irrigation/water reservoir and prioritized recharging with precisely assessed distribution of the dwindling water resources for irrigation by quantifying available water in the production system (reservoirs, ground water, water-bodies) with appropriate WUE and micro-irrigation systems	As per the advisory of QRT, Water Technology Centre studied the status of 450 water bodies in Mewat district, Haryana, and quantified water availability. Out of these, detailed water quantity and quality of 80 water bodies was studied, irrigation water quality index was developed and rejuvenated one village pond in Untka after developing the scientific protocol of revival under DST project. Similarly, 390 water bodies were studied and quantified water availability using WEAP model in Nuh watershed and optimal management plan developed under another DST project. Two medium size ponds of 5,40,000 litre capacity were constructed in IARI farm and optimally used through micro-irrigation system and different crop diversification models. Similarly, Amrit Sarovar with a storage capacity of 50 million litres capacity is under construction in IARI farm.
59.	While the waste water treatment plant is being highlighted, there are several infrastructural or system linked activities require appropriate	The wastewater treatment technology involves engineering of not only the biological processes but of also the chemical and physical processes along with the Civil engineering of the system/ infrastructure through algorithms/ modelling of the underlying biological, chemical and the physical processes for

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	positioning in the concept for it to assume a repeatable/predictable Technology package. The system is more biological and ecological in orientation than physics or engineering angle while the research infrastructure is inadequately ad-hoc. Mechanism for remediation of waste water needs to be studied in multidisciplinary mode.	which ample extensive research has been conducted at the Centre to get an in-depth mechanistic insight of the whole process. This technology was published as a Success Story by the ICAR and also formally released by the honorable Union Minister of Agriculture in the year 2020. The technology has also been trademark- registered as Jalopchar by the institute (under class 11 and 42) and is also being supported by the Government of India for its replication at 6-ICAR institutions (4-commissioned; 2-under construction) and 1-SAU (to be commissioned shortly) under Swachhta Action Plan of its flagship Programme i.e. Swachh Bharat Abhiyan, since 2018-19. Thus, since 2018, the wastewater treatment technology has been transferred to 16 sites under various government schemes and consultancies and is performing to the best of its performance efficiency, as per its design specifications for the commissioned sites. Hence as per the QRT advisory, the wastewater treatment technology has been appropriately positioned as a technology package and is now already out in the market which has successfully contributed to the resource generation of Rs 44.75 Lakh to the institute through various consultancies, between 2018 till date.
Agriculture Knowledge Management Unit		
60.	Strengthening of AKMU with respect to latest servers and operating systems is urgently required with adequate training, skill and expertise in field of large data handling, data analytics and web services which can go a long way to fully exploit technical advancement in ICT for the benefit of agricultural sector.	We have initiated for procurement of rack as well as blade server which will strengthen the AKMU and meets the requirement in future for host the web application of IARI. We have revamped the IARI website (Jan., 2023) with latest technology. We have initiated the process for online collection of information/data. Also utilizing the ICT based technology advancement specially the artificial Intelligence (AI) approach for identification of pests / diseases in crop which will benefit the agriculture.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
61.	Facility for tele-teaching needs to be developed	The institute has developed video conferencing facility for conducting classes and international / online trainings.
1.6	**Horticulture**	
	Fruits and Horticultural Technology	
62.	Basic processing unit with fruits handling and over-season maintenance systems need to be created either separately or integrated over the School, with proper maintenance in the space vacated by the Directorate of Floriculture.	Due to lack of funds and specialized man power on post-harvest, basic processing unit could not be created. However, integrated research on fruit crops is being carried in collaboration with the Division of Post Harvest Technology, ICAR-IARI, New Delhi. Laboratory for analysis of fruit and other related parameters have been established in the space vacated by the Directorate of Floriculture.
63.	Strengthening of infrastructure for pre-breeding as well as application of molecular marker technology and *in vitro* methods in crop improvement	Infrastructure for pre-breeding as well as application of molecular marker technology and *in vitro* methods in crop improvement was strengthened.
64.	The research laboratories dealing with tissue culture, physiology and molecular breeding need to be modernized.	The modernization of laboratories could not be done due to the paucity of fund.
	Vegetable Science	
65.	Efforts to be made for introgression or recombination breeding of desired genes in commercial varieties/hybrids and for rich in phyto-nutrients, nutraceuticals and processing	Following varieties/germplasm were developed which are rich in phyto-nutrients and nutraceuticals: **Varieties**: Broccoli : Pusa Purple Broccoli-1 (Anthocyanin) Spinach: Vilayati Palak (Vitamin C) Carrot : Pusa Prateek (Lycopene) Okra: Pusa Lal Bhindi-1 (Anthocyanin) **Germplasm registered with NBPGR:** Cucumber : AZMC-1 (β-carotene) Purple cauliflower: PC-1 (Anthocyanin) **Introgression of genes:** Cauliflower: *Or* (β-carotene) and *Pr* (for anthocaynin) gene introgression in Indian cauliflower are in progress

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	Floriculture and Landscaping	
66.	Infrastructure including expertise in the science related to molecular marker technology and *in vitro* methods in crop improvement needs to be strengthened for success in the marketable products development.	Infrastructures for molecular marker, In-vitro methods i.e. tissue culture for In-vitro mutagenesis, induction of double haploids etc. for crop improvement were strengthened through externally funded projects, divisional funds and PG funds in recent years. The scientists are working on above mentioned aspects in collaboration with other relevant divisions of IARI, New Delhi for developing expertise in these areas.
	Post-Harvest Technology	
67.	There is a need to utilize horticultural waste in value added products in order to reduce environmental pollution and for this purpose upgradation of fruit handling and food processing laboratory and processing unit are required.	Extraction of starch from jackfruit, tamarind, and mango kernel are also being characterized.
	Regional Station (Amartara Cottage: Horticulture), Shimla`	
68.	Development of rootstock for temperate and stone fruits having wider adaptability for biotic and abiotic stresses	Developed an apple root stock, Pusa Apple Rootstock 101, which is semi vigorous and resistant to woolly Aphid. Pusa Rootstock 102 has been identified which imparts dwarfing trait, and is compatible for all stone fruits viz; apricot, peaches, nectarine, almonds, cherry & plum etc.
69.	Farm roads, storage & irrigation facilities need to be developed	Due to the paucity of funds, these works could not be taken up.
	Regional Station, Katrain	
70.	There is need for extension of tissue culture laboratory to expand its capacity	Old tissue cultural lab has been renovated and extended.
71.	Standardization of seed production and processing of vegetable crops.	Standardized hybrid seed production technology of carrot, cauliflower, cabbage and cucumber.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
72.	Renovation of tissue culture and molecular laboratories is required along with new equipment like Flow cytometer for Double haploid breeding programme.	Tissue culture and molecular laboratories have been renovated. Flow Cytometer could not be purchased due to lack of sufficient fund.
73.	Work should be concentrated to upgrade integrated viral diseases management for vegetables and fruits to cope up with emerging diseases and pests.	Due to non-availability of scientists of concerned discipline work on viral disease management has not been undertaken.
Centre for Protected Cultivation and Technologies		
74.	Need to emphasize on designing of protected structures for different agro climatic conditions/ situations.	Different types of protected structures *viz.* naturally ventilated greenhouse, climate-controlled greenhouse, net house, tunnel type greenhouse design have been developed and standardized for different climatic conditions including semi and arid conditions.
75.	Multi utility structures for protected cultivation need to be exploited to achieve the maximum crop response for higher productivity.	Multi utility structures involving soilless hydroponics and aeroponics technology in single and multi-layered vertical farming models have been designed and installed in various conditions for higher crop yield and higher crop water productivity.
76.	The use of solar operated poly houses may be explored.	2000 m^2 semi-climate-controlled greenhouse was designed and installed with 2 kW solar powered vertical farming model has been developed with 6 layer grow bag soilless facility.
B. Policy Issues		
77.	The original institution's relics and remains of Naulakha building (Phipps Laboratory) is in a corner of the Central Agricultural University. As per the policy of the Government to preserve the historical heritage of the country, it is	The proposal for restoration of this monumental site i.e., Naulakha Building (Phipps Laboratory) is under consideration.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	recommended to consider proper archeological excavation/restoration of this monumental site with a "**National Heritage**" recognition as well as making it an official *agri-science history spot* for enabling the agriculture students and researchers of the country to be inspired of the national needs as envisaged in the late 19th century despite lack of any civic facility including approach to the site.	
78.	The institute has to evolve a transfer policy for scientists between Delhi and its 10 outstations. There has to be a term-transfer at all approved cadres with a ready replacement. A roster of replacement in each discipline should be in place within the ICAR guideli*nes such that Regional St*ation postings are neither construed as punishment postings nor secondary at IARI.	Transfer of scientists is implemented as per ICAR guidelines
79.	The Council may make a special effort to maintain high scientific standards of performance comparable to any of the contemporary institutes of National Importance such as IISc or IITs. To this end, it is most critical to minimize lateral entries by transfer into IARI	The transfer of scientists can be done on administrative grounds by ICAR through online system due to following reasons: To correct imbalance in the cadre strength of scientists in various disciplines at different institutes and also within an Institute including Regional Station/Centre/Unit. https://cari.icar.gov.in/pdf/rti/New-Transfer-Policy-of-ICAR.pdf

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	from other ICAR institutes. Whenever, such a lateral transfer is effected, the Director of the institute has to be consulted by the Council based on merit for appropriateness in the standards and vacancy in the discipline concerned.	
80.	Provision of special budget for overseas post doc training in emerging areas for young and mid-level scientists.	Under NAHEP-CAAST, we have trained 8 scientists in different institutes abroad. Due to budget crunch, the recommendation has not been implemented in toto.
81.	Training of technicians for high end equipment and providing highly trained technicians for this equipment will ensure that they are put to efficient and long-term use.	In Discovery Centre and Phenomics, it has been already implemented. Currently, the number of technical manpower is very less. Now IARI is making effort to recruit technical manpower. Once the recruitment is done, technical manpower will be provided to high end equipments.
82.	To inspire the newly joined ARS scientists, one-time catch-up grant as is followed in UGC/DST should be provided (within six months of their joining) for creation of lab facility, procurement of equipment and hiring ad-hoc personnel.	Due to budget limitation, this recommendation could not be implemented. Further, establishment of IARI Endowment Foundation was proposed and approved by BOM. Council approval is awaited. This will five financial freedom to take need based activities.
83.	Currently, Scientist: technical staff ratio is 1:0.8 – which is not adequate. A minimum ratio of 1:1.5 for technical staff is desired, thus provisions for allotment of more technical and supporting staff should be made.	Centralized recruitment process for filling up the vacant positions of T-1 and T-3 is under process and recently, ASRB advertised the notification for recruitment of T-6/ SMS in ICAR institutes. After these technical staff join, the ratio is expected to increase.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
84.	IARI has excellent opportunities to harness the solar power. So that the power consumption can be saved and also we can produce enough for providing to the research facilities. With an initial investment this can be functional and serve as a model for other institutes in the country.	The solar panel of 2 Mega Watt capacity has been already installed in the institute. It is connected with the main grid. Ministry of new and renewable energy (MNRE) has recognised IARI as Centre of Excellence on AgriPhotoVoltaics. Effort is being made to harness solar energy through this.
85.	Institute should be able to use the HRD funds for sending scientists for training abroad, at least to a permissible limit such as 30% of the grant available in a year.	Due to the paucity of funds, it could not be implemented. Under NAHEP-CAAST, we have trained 8 scientists in different institutes abroad
C. Education		
86.	**Upgradation of academic environment** – Regular financial support to be provided for modernizing & strengthening of academic facilities and course curriculum delivery	Presently Institute is facing acute shortage of funds. Also, very limited funds have been received under PG Strengthening from the Education Division of ICAR that to under the Head: Capital. The fund received is being utilized for strengthening UG Degree programme as it has only started from academic session 2022-23. The proposal for upgradation of university facilities for academic activities and administration is being developed for submission to Council at the earliest.
87.	**Provision of Post-Doctoral Programme** - To improve quality research, Post-Doctoral programme need to be initiated at IARI. Provision of at least two Post-Doctoral Fellow in each teaching disciplines could be made and separate allocation of funds for Post-Doctoral programme under	At IARI, New Delhi ICAR-Post-Doctoral fellowship programme has been initiated in 2019 under the ongoing "Strengthening & Development of Higher Agricultural Education in India" scheme of Agricultural Education Division, ICAR and has been successfully completed for 2019-20 and 2020-21. The result of ICAR-PDF for year 2021-22 has been put up hold due to non- availability of funds and will be resumed as soon as IARI, New Delhi is in receipt of funds from Council.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	funds received for PG Strengthening from the Education Division of ICAR needed.	Presently Institute is facing acute shortage of funds and the proposal could not be materialized. Request for separate funds for post-doctoral programme under PG Strengthening from the Education Division of ICAR will be submitted in the next financial year.
88.	**Provision for sandwich Ph.D. programme**– Institute has signed MoUs with several International institutes. In order to develop competent human resource, provision for sandwich Ph.D. programme with these institutions is desirable. Similar programme was in operation earlier at IARI with the International Rice Research Institute, Philippines.	The sandwich/dual degree program provision has been initiated with Western Sydney University (WSU), Australia. As approved by the Academic Council of IARI, more such institutions abroad are being identified for students and faculty exchange and sandwich programs.
89.	Incentives for the faculty to promote quality teaching - Participation in international seminar/ symposium once in five years to update knowledge and also in building confidence. Provision of short-term and long-term overseas associateship. A minimum of 20 faculty members every year should receive international exposure.	During the last five years, a total of 200 faculty have been facilitated for participation in training / conferences / seminars / symposiums / post-doctoral programmes through NAHEP, schemes of DST, DBT, etc.
90.	IARI needs to introduce a post-graduate course in Agri-business Management	The Division of Agricultural Economics, IARI is running agribusiness-related courses in the M.Sc. & Ph.D. programme as per new BSMA-approved courses such as Agricultural marketing & price analysis, Rural marketing, Commodity future trading etc.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
91.	The course curriculum on Agricultural processing and food processing needs to be advanced with supporting facilities for practicals extended to all commodities of agricultural produce	The Division of Food Science & Post Harvest Technology, IARI is in the process of streamlining the facilities. The course curriculum has also been updated and includes advanced processing techniques for all agricultural commodities.
92.	**Provision for establishing Chair to attract talent** – In order to attract young talent from outside in certain identified areas, the Institute should have freedom to establish Chair (at least one per School) on the similar lines of IITs and traditional universities.	The Institute submitted two proposals for establishment of Chairs namely; (1) NABARD Chair in educational institutions to harness the benefit of knowledge of distinguished scientists, and (2) Dr. Archana Sharma, Woman Scientist Chair of Ministry of Women and Child Development (MWCD), Govt. of India. • Further, efforts are being made with ICAR to provide funds for establishing Chairs in different Schools at IARI, New Delhi.
D. Establishment		
Scientific Staff		
93.	At the time of reporting, as in March 2017, the scientific staff approved at IARI stood at 578 of which 506 were in position. Though the number looks healthy, it is critical to fill positions in certain disciplines at both Regional Stations and Divisions so that the continuity is maintained in the experiments for meeting the objectives set out in the research projects and institutional mandates are not left unattended.	Recruitments of Scientific staff are done by council. Requisitions/ demands for filling up of Scientific posts are being sent to Council timely.
Renaming CESCRA		
94.	The institute renamed the Division of Environment Sciences as Centre for	It is renamed as Division of Environment Sciences.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	Environment Science and Climate Resilient Agriculture (CESCRA) in 2009 which could be restored as the Division of Environment Sciences.	
	Renaming Division of Fruits and Horticulture Technologies	
95.	It is recommended to rename the Division as **Division of Fruit Science** in sync with nomenclature of the Divisions of Vegetable Science or Floriculture & Landscaping.	The recommendation to rename as Division of Fruit Science was not accepted in view of the observations of the 245th General Body meeting of ICAR
	Technical & Supporting Staff	
96.	There is a general shortage of Technical and supporting staff in almost all divisions, Centres/Units, Regional Stations as well as PME section and an acute shortage of technical and supporting staff was particularly noted in the Schools of Horticulture, Crop Improvement and Divisions of Agronomy, Soil Science and Agricultural Engineering. The required strength is essential in order to keep the experiments and equipment in correct order and functional. The recommended technical staff and supporting staff is indicated in the Table as Annexure XI which has to be put in place for IARI to function efficiently to meet	IARI is making efforts to recruitment of technical staff. The recruitment process is in progress. The technical posts are expected to be filled during 2024. The skilled supporting staff cadre is abolished by the Government. Hence, no recruitment could be done.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
	the agricultural research requirements of the country.	
	Administration & Governance	
97.	Tele-conferencing facility with the HoDs and the Regional Station Heads should be established.	Online meeting platforms are being established. Board Room of the directorate is modernized and equipped with online meeting facility.
	Finance	
98.	Auditing and accounting require to be decentralized within the GFR 2017 limits for faster processing of proposals for approvals as well as completing the procurement liabilities.	The work of audit and accounts has already been decentralized among nine sections for faster processing of proposals and bills as per details given below: • PRAS • Audit III • Audit IV • Audit V • Payment • Budget & compilation • GPF • Audit-Pension • Internal Audit
99.	The grants on operational and maintenance head should earmark a proportion for AMC, Division-wise, of all items of equipment so that their utilization is always ensured without any break.	As per ICAR norms, the budget under repair & maintenance of the equipment is allocated under Administrative expenses. It includes both repairs &maintenance within AMC and outsider AMC, however, the Grant in Aid-General under Unified Budget of IARI is being allocated under various divisions of the IARI for incurring expenditure on AMC of equipment, other administrative expenses, Research and Operational expenses, etc.
E. General Recommendations		
100.	One-time Catchup Grant for infrastructure	IARI has not received it.
101.	Autonomy at par with IISc, IITs or CAUs.	The proposal was placed in rules and byelaws revision committee 2020 of ICAR, but was not considered. Request for an autonomy at par with IISc was submitted to ICAR Committee chaired by Dr. P. L. Gautam for making IARI as a Global University in 2020 which was recommended for the consideration of the Council.

S. No.	Recommendation of QRT (2009-2016)	Action Taken
102.	Item No. 20, 23 and 29 of the ATR of last QRT from 2000-2008 (Page No. 162) is once again recommended for action. They are as follows:	**Given below:**
103.	Item No 20 of QRT (2000-08) The QRT is of the considered opinion that the names of the Division of Genetics and the Division of Fruits and Horticultural Technology be changed as "Division of Genetics and Plant Breeding" and Division of Fruit Science", respectively	The Division of Fruits and Horticultural Technology name is retained in view of the observation of the 245th General Body Meeting of ICAR
104.	Item No 23 of QRT (2000-08): The position of Professor in each discipline may be filled by direct recruitment with the designation of Principal Scientist (Professor)	ICAR has decided to continue with the present system.
105.	Item No 29 of QRT (2000-08): The post of the Division be made RMP.	It is a policy issue for consideration of the Council.

Annexure IV

Consolidated statement of IARI/ Divisions/ Centres/ Projects/ Regional stations

Office	Sanctioned strength				Scientist in position				Vacant position			
	Sci	Sr. Sci.	Ps	Total	Sci	Sr. Sci.	Ps	Total	Sci	Sr. Sci.	Ps	Total
A. Head quarters												
IARI, Divisions	310	93	51	**454**	**261**	75	40	**376**	-49	-18	-11	-78
IARI, Centers	22	6	1	**29**	**20**	3	0	**23**	-2	-3	-1	-6
IARI, Projects	0	2	2	**4**	**1**	1	1	**3**	1	-1	-1	-1
Total	*332*	*101*	*54*	*487*	*282*	*79*	*41*	*402*	*-50*	*-22*	*-11*	*-85*
B. Regional Stations												
IARI-Regional Stations	41	27	7	75	29	9	6	44	-12	-18	2	-31
Sub-total (A+ B)	*373*	*128*	*61*	*562*	*311*	*88*	*47*	*446*	*-62*	*-40*	*-9*	*-116*
RMP Posts				5				5				
Grand Total				*567*				*451*				

Annexure V

Scientific Manpower at IARI

Name of Divisions/ Units, etc.	Division wise statement												
	Sanctioned posts					Scientist in Position				Vacant posts			
	Sci	Sr Sci	Ps	Head	Total	Sci	Sr Sci	Ps	Total	Sci	Sr Sci	Ps	Total
AGRONOMY	19	7	2	1	**29**	18	7	2	27	-1	0	-1	-2
GENETICS	39	17	5	1	**62**	38	13	5	56	-1	-4	-1	-6
PLANT PHYSIOLOGY	14	2	1	1	**18**	14	1	1	16	0	-1	-1	-2
SEED SCI. & TECH.*	10	7	2	1	**20**	8	5	2	15	-2	-2	-1	-5
NEMATOLOGY	13	3	1	1	**18**	9	3	2	14	-4	0	0	-4
BIOCHEMISTRY	10	2	1	1	**14**	8	2	2	12	-2	0	0	-2
ENTOMOLOGY	17	3	1	1	**22**	10	1	3	14	-7	-2	1	-8
FRUIT & HORT.TECH.	11	3	1	1	**16**	9	2	2	13	-2	-1	0	-3
VEGETABLE SCIENCES	15	5	4	1	**25**	12	5	3	20	-3	0	-2	-5
FLORI. & LAND SCAP.	13	2	1	1	**17**	10	2	2	14	-3	0	0	-3
F.S. & PHT	9	3	0	1	**13**	7	1	1	9	-2	-2	0	-4
(A) MICROBIOLOGY	10	5	1	1	**17**	10	6	1	17	0	1	-1	0
(B) B.G.ALGAL	3	2	0	0	**5**	2	2	0	4	-1	0	0	-1
AGRIL. EXTENSION	13	5	1	1	**20**	13	3	1	17	0	-2	-1	-3
AGRIL. ECONOMICS	15	3	2	1	**21**	12	1	2	15	-3	-2	-1	-6
PLANT PATHOLOGY	19	9	3	1	**32**	16	6	3	25	-3	-3	-1	-7
AGRIL ENGINERING	19	3	1	1	**24**	14	2	1	17	-5	-1	-1	-7
SOIL SCI AG CHEM	19	1	1	1	**22**	17	1	1	19	-2	0	-1	-3
AGRIL. CHEMICALS	13	1	1	1	**16**	10	3	1	14	-3	2	-1	-2
CESCRA (ENV. SCI.)	15	2	0	1	**18**	13	3	2	18	-2	1	1	0
SPU	1	0	0	0	**1**	1	0	0	1	0	0	0	0
AGRI. PHYSICS	8	4	1	1	**14**	8	3	3	14	0	-1	1	0
CPCT	2	0	0	0	**2**	0	0	0	0	-2	0	0	-2
OUT REACH EXT													
(A) CATAT	1	4	0	0	**5**	2	3	0	5	1	-1	0	0
(B) ATIC	1	0	0	0	**1**	0	0	0	0	-1	0	0	-1
NAT. PHYTOTRON FACILITY	0	0	0	0	**0**	0	0	0	0	0	0	0	0
DIRECTORS OFFICE	1	0	0	0	**1**	0	0	0	0	-1	0	0	-1
FLEXI DISCIPLINE	0	0	1	0	**1**	0	0	0	0	0	0	-1	-1
TOTAL	*310*	*93*	*31*	*20*	*454*	**261**	**70**	**40**	**376**	**-49**	**-18**	**-11**	**-78**

(+) EXCESS (-) VACANT; Note: *Including (6 post of CSTF (PS - 1, Sr. Sci. - 2, Sci. - 3),

Annexure VI

Statement of scientific staff in IARI Regional stations/ Centres

REGIONAL STATIONS	Sanctioned posts					Scientist in Position				Vacant posts				
	Sci	Sr Sci	Ps	Head	Total	Sci	Sr Sci	Ps	Total	Sci	Sr Sci	Ps	Head	Total
R.S. INDORE	6	3	0	1	**10**	4	0	2	6	-2	-3	1	0	-4
R.S. KATRAIN	6	3	0	1	**10**	4	0	1	5	-2	-3	0	0	-5
R.S. KARNAL	10	4	0	1	**15**	7	1	0	8	-3	-3	0	-1	-7
R.S. PUNE	2	3	0	1	**6**	2	2	0	4	0	-1	0	-1	-2
R.S. PUSA BIHAR	4	6	0	1	**11**	2	0	0	2	-2	-6	0	-1	-9
R.S. KALIMPONG	2	1	0		3	2	1	0	3	0	0	0	0	0
R.S. ADUTHURAI	1	1	0	0	**2**	1	0	0	1	0	-1	0	0	-1
R.R.C., DHARAWAD	1	1	0	0	**2**	1	2	0	3	0	1	0	0	1
R.S. WELLINGTON	3	2	0	1	**6**	4	2	1	6	1	0	0	0	1
R.S. AMARTARA & TUTIKANDI, SHMILA	6	3	0	1	**10**	2	1	2	5	-4	-2	1	0	-5
TOTAL	*41*	*27*	*0*	*7*	*75*	**29**	**9**	**6**	**44**	**-12**	**-18**	**2**	**-3**	**-31**

(+) EXCESS (-) VACANT; Note: *Including (6 post of CSTF (PS - 1, Sr. Sci. - 2, Sci. - 3),

Annexure VII

Position of Technical Personnel (as on 1/6/2023)

S. No.	Category/ Grade	Sanctioned Strengths	In Position	Vacant Post
1	Category III/T-6	10	8	2
2	Category II/T-3	241	136	105
3	Category I/T-1	261	223	38
	Total	512	367	145

Annexure VIII

Administrative Staff strength (as on 30/6/2023)

POST	Sanc.	Filled	Total vacant	SC	ST	Male	Female
Group A							
JD(A)/ Sr Registrar	1	1	0	0	0	1	0
Registrar							
CAdO. (SG)	1	1	0	0	0	1	0
CAO	2	2	0	0	0	2	0
Sr. Comptroller	1	1	0	1	0	1	0
Comptroller (L-13)	1	1	0	1	0	0	1
CF & AO	2	0	2	0	0	0	0
SAO	5	6	0	0	0	6	0
AO	10	7	3	1	3	5	2
Sr. FAO	1	1	0	0	0	1	0
F & AO	4	2	2	1	1	2	0
Dir (OL)	1	0	1	0	0	0	0
PPS	4	4	0	2	0	1	3
Sub total	*33*	*26*	*8*	*6*	*4*	*20*	*6*
Group B							
AAO	50	50	0	11	4	29	21
AF & AO	4	0	0	0	0	0	0
Asstt.	158	90	68	11	6	52	38
PS	37	19	18	1	0	5	14
PA	30	4	26	1	0	2	2
Sub Total	*279*	*163*	*112*	*24*	*10*	*88*	*75*
Group C							
UDC	70	37	33	13	4	34	3
LDC	40	41	0	6	4	34	7
Steno Grade III	0	3	0	0	0	1	2
Sub total	*110*	*81*	*33*	*19*	*8*	*69*	*12*
Total	*422*	*270*	*153*	*49*	*22*	*177*	*93*

Including one post of St. Grade III at KVK in the total sanctioned post of St. Grade III Excluding one post of asst. at KVK in the total sanctioned post of asst. 9 posts to be filled in feeder cadre i.e., LDC under GFR 25


Pusa 1201
PSSC 1
Pusa Soybean 6
Pusa 3043
L 4717
Pusa 1431
Pusa Abhinav
Pusa Sona
Pusa Deep
Pusa 1201
Pusa STFR Met
Pusa Aditi
Pusa Mustard 33
2023
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