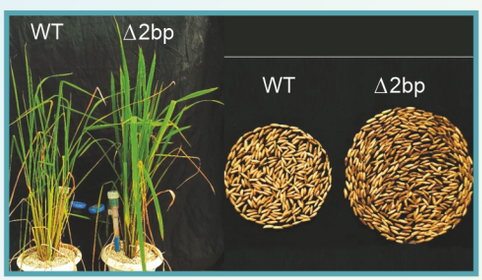
Glimpses of National Agricultural Science Fund

(2006-2023)



भाकृअनुप
ICAR

Indian Council of Agricultural Research

New Delhi 110 001

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GLIMPSES OF NATIONAL AGRICULTURAL SCIENCE FUND | (2006-2023)

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सत्यमेव जयते

FOREWORD

INDIAN Council of Agricultural Research (ICAR) is the apex body for co-ordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. It has played a critical role for fostering a strong and viable science, research & innovation ecosystem for the country, with its vast network of research institutes, central and state agricultural universities. National Agricultural Science Fund (NASF) is one of the very important schemes of ICAR engaged in supporting innovative projects in basic, strategic and cutting-edge application research, translational research, international cooperation, extra mural research, scientific validation of farmers innovations etc. Several multi-institutional projects in consortium mode in the frontier areas catering towards the development of new & improved crop varieties, enhancing the health and productivity of indigenous cattle breeds, development of veterinary vaccines, diagnostics, augmenting aquaculture through innovative technologies has been carried out. Some of the important technologies that have emerged from NASF funded projects are namely diagnostic kits for detection of Covid-19 infection in animals, pregnancy detection kits for cows, animal cloning technology, CRISPR/Cas9 based technologies in maize and rice, E-nose sensors for scab prediction in apples etc. Besides, the scheme has led to development of quality human resources and their capacity building through advanced knowledge and skills.

This publication depicts the various projects and their achievements supported by NASF in ICAR and other organizations across the country. It is hoped that this publication would be useful to showcase the success of the NASF scheme in promoting basic, strategic and translational research in the frontier areas of agricultural science.

I would like to compliment the authors, team of NASF for bringing out this publication which shall be useful to academicians, researchers and policy makers in the future.

(Himanshu Pathak)

PREFACE

ICAR activities on agricultural research, extension, education, and capacity building have significantly contributed to food, nutrition and livelihood security of the country. The outcomes of these activities have led to many innovations, growth and sustainability in Indian agriculture sector. National Agricultural Science Fund (NASF) is one of the very important schemes of ICAR engaged in supporting innovative projects in basic, strategic and cutting-edge application research, translational research, international cooperation, extra mural research, scientific validation of farmers innovations *etc.* This scheme was created to address issues which can be solved by intensive basic and strategic research jointly by team of organizations/institutions to make India a global leader in research for agricultural development.

The frontier research carried out in past decade has resulted in many achievements including genome sequencing of many species of plants and animals, identification of trait-specific genes in crops, livestock and fish. Gene modification experiments for improved resistance to biotic stresses especially in pigeon pea, potato and banana. Using CRISPR/Cas9 highly efficient herbicide-resistant maize lines as well as genetic improvement in rice were carried out. With the cloning technology in *Murrah* buffalo few cloned calves have been produced. The diagnostic kits for detection of Covid-19 in animals was developed. Encapsulated nano particle phytochemicals developed which combat anti-microbial resistance in poultry. Many sensor-based technologies were developed for detection of pests and in farm machineries. Decision Support Systems for insects, pests have been developed and entrepreneurship models through farm led innovations and Farmer producer companies have been established. The scheme also led to establishment of mega facilities on phenomics research, agro-processing centres *etc.* for reducing post-harvest losses. Development of quality human resources in agriculture sector and their capacity building through advanced knowledge and skills is achieved through this scheme. The document is an effort to highlight the achievements of NASF since its inception for promotion of agricultural research.

(Jitendra Kumar)
Assistant Director General
(NASF)

Acknowledgements

INDIA is an agriculture-based country and its prosperity is dependent on the quality research and innovation in this sector. Also, research and innovation are the key visible tangible and intangible knowledge resource contributing to its technological development. National Agricultural Science Fund (NASF) was created to give a boost to the basic and strategic research in various fields of agriculture and generate quality human resource. The publication "Glimpses of National Agricultural Science Fund" (2006-2023) portrays the diverse research projects undertaken in agriculture and allied areas across the country. The first chapter provides an overview of the NASF, its processes and the data of the funded projects in last two decades. The following chapters detail out the work undertook, the achievements, state-of-the art-infrastructure created and major outputs in research projects helping the researchers to upgrade their knowledge, develop skills and train quality human resources.

We are extremely grateful to all the Project Investigators (PIs) and Cooperating Centre Principal Investigators (CCPIs) for sharing their research achievements of the funded projects. We thank the support of NASF team for compiling and also thank the experts who have put their sincere efforts in editing this document. We specially thank the administration and finance division for their continuous support. The guidance and advise of the Empowered Committee, Expert Committee and the Advisory Committees are duly acknowledged.

We sincerely thank Secretary, DARE & DG ICAR for his guidance and support in bringing out this publication.

We hope that this publication would be useful to the students, researchers, policy makers, and administrators.

Authors

Abbreviations

Abbreviations	Full Form
1H3MAQ	1-hydroxy-3-methyl anthraquinone
AC	Advisory Committee
ACP	Atmospheric cold plasma
ADG	Assistant Director General
AFRR	Anthracnose Fruit Rot Resistance
AICRIP	All India Crop Research Integrated Programme
AMP	Antimicrobial peptide
APM	Amiprophos-methyl
AUC	Audited Utilization Certificate
BMS	Breeding Management System
BSA	Bovine serum albumin
BSV	Banana streak viruses
CCPI	Cooperating Centre Principal Investigator
CIAE	Central Institute of Agricultural Engineering
CIBA	Central Institute of Brackish water Aquaculture
CIPHET	Central Institute of Post harvest Engineering & Technology
CIRG	Central Institute for Research on Goats
COH	Continuous ohmic heating
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSI	Cumulative Stress Index
CSIO	Central Scientific Instruments Organization
CSS	Central Sector Schemes
DARE	Department of Agricultural research and Education
DBT	Department of Biotechnology
DEG	Differentially expressed genes
DEGs	Differentially expressed genes
DSS	Decision Support System
DST	Drought and salt tolerance
EC	Empowered Committee
eHRA	Electronic Health Records for Animals
FFE	Free fatty acids
Fn-GNPs	Functionalized gold nanoparticles
GA	Green Accelerator
IAPs	Integrated Analysis Platforms
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research

Abbreviations	Full Form
ICT	Information Communication Tool
IIPR	Indian Institute for Pulse Research
IIRR	Indian Institute of Rice Research
IIVR	Indian Institute of Vegetable Research
IMTECH	Institute of Microbial Technology
LDA	Linear Discriminant Analysis
MSC	Mesenchymal Stem Cells
MSTN	Myostatin
NAIP	National Agriculture innovation Project
NARS	National Agricultural Research System
NASF	National Agricultural Science Fund
NCBI	National Centre for Biotechnology research
NCBI	National Centre for Biotechnology Information
NDPPC	Nanaji Deshmukh Plant Phenomics Centre
NDPs	National development Priorities
NDRI	National Dairy Research Institute
NEB	Negative energy balance
NFBSFARA	National Fund for Basic, Strategic and Frontier Application research in Agriculture
NIANP	National Institute of Animal Nutrition and Physiology
NRCPB	National Research Centre on Plant Biotechnology
NRRI	National Rice Research Institute
OTC	Open Top Chamber
OUAT	Orissa University of Agricultural Technology
PAU	Punjab Agricultural University
PCR	Polymerase chain reaction
PFA	Psychological First Aid
PGs	Prostaglandins
PI	Principal Investigator
PLA	Poly lactic acid
PMSG	Pregnant mare serum gonadotrophin
PPRV	Peste-des-petits ruminants' virus
PRI	Psychological Resources Index
PRSV	Papaya Ring Spot Virus
PSVs	Peer Support Volunteers
RCGM	Review Committee on Genetic Manipulation
RCT	Rennet coagulation time
RFS	Rice false smut
RIL	Recombinant inbred line
SCNT	Somatic cell nuclear transfer
SDGs	Sustainable Development Goals
SDW	Shoot dry weight
SEM	Scanning electron microscopy

Abbreviations	Full Form
SKAUST	Sher-e-Kashmir University of Agricultural Sciences and Technology
SMD	Subject Matter Division
SOD	Superoxide dismutase
TiLV	Tilapia Lake Virus
TPS	True Potato Seed
VRT	Variable-rate-technology
WUE	Water use efficiency

Contents

1
Introduction of NASF

Research and innovation are the key visible tangible and intangible knowledge resource of a country contributing to the prosperity of the nation. During the past 75 years, the Indian National Agricultural Research System (NARS) has been in the forefront, finding solutions for the problems of farming community as well as kept its competence in technology development through innovative research and development. Basic and strategic research and applied research in the frontier areas of agricultural sciences has accelerated the technology development. Realizing its importance, the Government of India established a national fund to support basic and strategic research with the objective of building capacity in basic and strategic research for solving agricultural problems of immediate, long-term and anticipatory nature. This would help in building partnership of required expertise available in various disciplines and institutions across the country to make India a global leader in research for development. The fund was named as 'The National Fund for Basic, Strategic and Frontier Application Research in Agriculture' (NFBSFARA). Indian Council of Agricultural Research (ICAR), New Delhi in consultation with the Empowered Committee of the NFBSFARA took cognizance of the results and base created during X & XI Plan Periods to have a wider perspective and arena for the scheme. It was realized that a strong and sustainable platform would help to develop scientific capacity, temperament and culture in the NARS to ensure continuous flow of knowledge, best & appropriate frontier technologies for solving problems in agriculture as well provide directions for science policy in agriculture. With this intension, the name of the fund was changed to 'National Agricultural Science Fund' (NASF) during the XII Plan.

1.1 Genesis of NASF

Based on recommendations of various reviews e.g., Peer Review Committee of ICAR, Third Party Review of ICAR Schemes, Priorities and Vision of Government and to fulfill the National Development Goals and Programs, and UN Sustainable Development Goals (SDGs), the programme was modified to provide funding

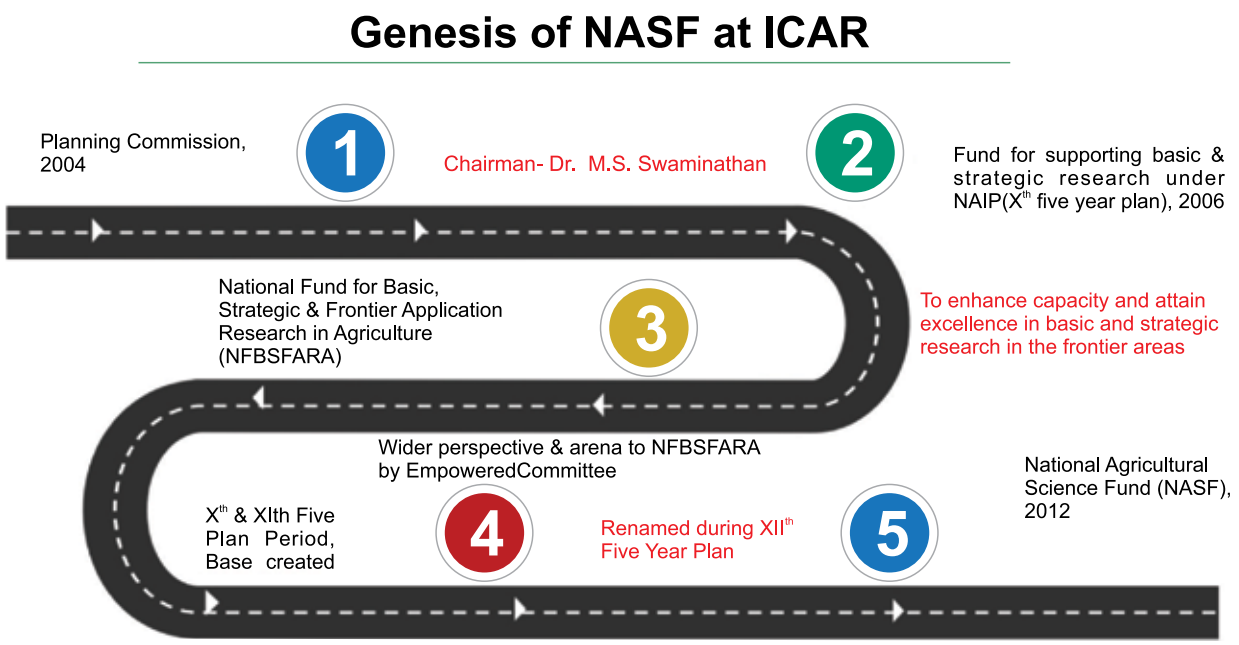


Figure1: Genesis of NASF at ICAR

support in the following five components of research:

Basic and Strategic Research: This is the main component of the sub scheme and has been redefined by broadening the scope to include emerging frontier areas of importance. Based on the feedback and requirement in different sectors, the seven major areas identified are as (i) Biotechnology, genomics and allele mining in plants, animals and fisheries (ii) Abiotic and biotic stress and quality traits in plants, animals and fisheries (iii) Precision agriculture and management of natural resource and application of sensors in crops, animals and fisheries (iv) Nanotechnology in agriculture (v) Metabolomics in agriculture (vi) Farm mechanization and energy and (vii) Social Sciences and policy research in agriculture.

Translational Research: During past 15 years of implementation of this project, significant contributions have been made in basic research on very important aspects in microbes, plants, animals and fishes. To convert the output of Basic and Strategic Research into technology and to fill the critical major gap, the projects under competitive mode has been funded to the organizations having proof of concept, leads from the major projects like Transgenics and Functional Genomics, QTLs to variety. Incentivizing agricultural research in areas such as Semen Sexing, Genome Editing etc. has been supported for testing the efficacy of events, functional validation of cloned genes and promoters & molecular breeding using mapped genes/QTLs. Likewise, development and upscaling of technology for thermostable vaccines, evaluation of cloned bulls, algorithms and sensors, microbial consortia, nano-fertilizers/ pesticides, novel formulations for enhancing resource use efficiency, addressing biosafety issues in conducting trials and environmental release *etc.*, has been given priority.

Research in International Collaboration: A number of International MoUs have been signed and workplan has been finalized with different countries. To implement the workplan under the International MoUs, assured funding is required in order to provide the matching grant. Such collaborations are important for sharing the knowledge, material and technical knowhow. Moreover, some of the very specific projects are also formulated based on the earlier international collaborations, conceptualized during the visits of scientific delegations or scientists' trainings and international programmes like Vaishwik Bhartiya Vaigyanik (VAIBHAV) Summit held in 2020 on the initiative of Principal Scientific Advisor to the Government of India. To promote the cutting-edge research in frontier areas, the funding provision is made under NASF so that exposure of the scientists through these international collaborations can be further expanded.

Extramural grant for research: Extramural grant for research to fill critical gaps has been included in NASF. It caters to the needs of scientist to take up research to fill small gaps in order to conclude a research programme and complete the process. The young scientists starting their career also submit small projects on proof of concept. Concerned Subject Matter Divisions (SMD) recommends such projects for funding by NASF following the prescribed criteria of selection through open competitive call from the scientists working in NARS.

Scientific Validation of Farmers' Innovations: A number of farmers' innovations have been reported in the past but with limited adoption for want of their scientific validation and upscaling. This requires handholding and collaboration with research organizations and industry. The funding support for validation of such Innovations would be provided from NASF.

1.2 Objectives

The main objective of the scheme has been to build capacity for basic, strategic and cutting-edge application research in agriculture and address issues which can be solved by intensive basic and strategic research jointly by team of organizations/institutions. The project also aims to bridge critical gaps in translational research and enable validation and promotion of Farmers Innovations in a participatory mode. The following specific objectives have been defined:

- Foster research and a research culture that will use and advance the frontiers of scientific knowledge to effectively meet the present, anticipated and unanticipated problems of agriculture through various modes and critical investments in research projects.

- Build the capability of the National Agricultural Research System (NARS) through development of wide partnerships in science through projects.
- Build a storehouse of advancement of knowledge in science related to agriculture and awareness of the national importance of basic and strategic research in agriculture.
- To provide policy support to the decision makers for use of basic and strategic research in agriculture.
- Organization of workshops, seminars, conferences etc. to create awareness, prioritization, scientific popularization and related issues.

1.3 Vision

Harnessing science at the frontier of current knowledge and beyond for continually replenishing the well of scientific knowledge for agricultural development and prosperity of the farmers.

1.4 Mission

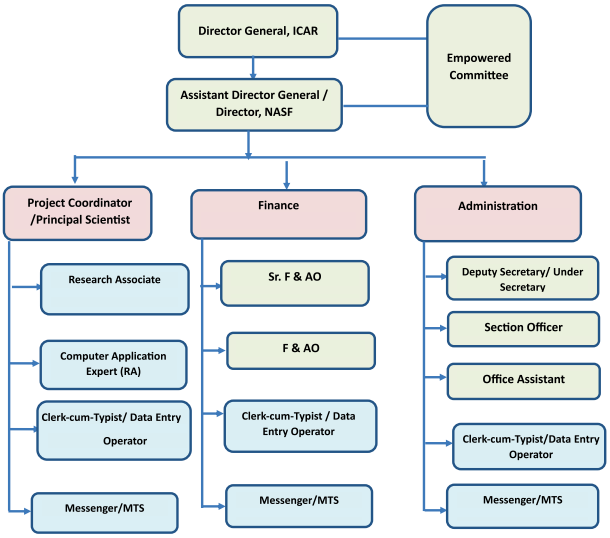
To use frontier science and the national scientific talents to advance the problem-solving capacity of the extended NARS and the development of a dynamic knowledge base of Indian agriculture.

1.5 Strategic priority areas of NASF (as per the IX call)

Seven strategic areas of NASF to cater funding in agriculture are as follows:

- **Biotechnology, genomics and allele mining in plants, animals and fisheries:** Genomics, transgenics, genome editing (CRISPR), genomic selection, animal cloning, gene/ QTLs mapping and tagging, nutrigenomics enriching the diversity of genetic resources, allele mining.
- **Abiotic and biotic stresses and, quality traits in plants, animals and fisheries**
- **Precision agriculture and management of natural resources; and application of sensors in crops, animals and fisheries:** Conservation agriculture, climate change, water quality and productivity, soil health, vertical farming, protected agriculture, Block chain technology, robotics, variable-rate-technology (VRT), image analyzers, sensor technology and post-harvest management.
- **Nanotechnology in agriculture:** Nano-diagnostics and monitoring systems, design and fabrication of nano-agri inputs, nano food systems, nano remediation and biosafety of agri-nano products.
- **Metabolomics in agriculture**
- **Farm mechanization and energy:** Mechanization in agriculture, farm machinery, sources and utilization of energy, alternate sources of energy, post-harvest and value addition, food processing, health food, use of agricultural wastes.
- **Social Sciences and policy in agriculture**

1.6 Organogram of Directorate of National Agricultural Science Fund (NASF)



1.7 Governance of NASF

NASF Board (Empowered Committee)

The NASF Board is constituted and the terms of its reference (TOR) is approved by the Hon'ble Minister of Agriculture, Government of India, consist of the following

External Members

An eminent agricultural scientist as the Chairman

Three to four subject matter experts

Two representatives from other scientific research funding agencies (of not below the rank equivalent to an Advisor in the Department of Biotechnology or Department of Science

and Technology), nominated by the respective Secretaries by the approval of the Hon'ble Minister of Agriculture on recommendation of the Council.

Ex-Officio Members

Director General, ICAR

FA, DARE or his representative (not below the rank of Director, Finance)

Director/ ADG, NASF (Convenor/ Member Secretary)

The NASF Board is the apex body responsible for the governance of NASF and for all policy decisions including the matters of finance and administration, required for efficient execution of the objectives of NASF towards achieving its vision. The Board lays out the areas and manners of funding projects and provides overall guidance to the NASF Secretariat. The Board also in whatever manner it decides, guides in the project selection, monitoring & evaluation process. The Board provide policy guidance to the Council, the NARS at large and when asked for, to the Minister of Agriculture, Govt. of India or any State Govt. in the matters under its jurisdiction. The NASF Board hires or requests for voluntary consultancies or constitute committees for obtaining consultancies in various policy matters regarding basic and frontier areas of science in agricultural research. The Board meet as frequently as required to fulfill its TORs. The tenure of the Board is for the period of three years or longer at the discretion of Hon'ble Minister of Agriculture and Farmers' Welfare, Government of India.

The Director/ ADG is the Chief Executive Officer of the NASF. He/she is the Convenor / Member Secretary of the NASF Board. The Director/ ADG reports to the Director General of ICAR for administrative purposes.

The NASF Board (Empowered Committee) have the following major roles

Empowered Committee (EC) has a tenure of three years. EC guides the policy, governance and priorities for funding. EC makes need-based modifications in Rules and Procedures while adhering to the guidelines in the EFC document of NASF. EC evaluates and approves the projects beyond Rs.5.0 crores. EC ratify the projects up to Rs.5.0 crores approved/ recommended by the Experts Committee.

Experts Committee

Experts Committee is constituted by the NASF in different theme/ broad areas based on the guidance of EC/ Director General (ICAR) and approved by the Director General (ICAR). Members from private industry/ NGOs are also nominated in the Experts Committee. Experts Committee screens pre-proposals, evaluate full proposals and approve/ recommend projects up to Rs.5.0 crores. Experts committee may recommend/ approve need based additional fund for projects during the review meeting in consultation with the ADG/ Director, NASF.

Advisory Committee

The Advisory Committees is constituted by the ADG/ Director, NASF. Individual ACs are available for each project. ACs supports mentoring, monitoring, evaluating and reviewing the project(s) once in a year. Besides, it visits laboratory/field/sites in consultation with NASF office.

Project Funding/ Review/ Monitoring

Funding up to Rs.5.0 crores is approved by the Experts Committee and ratified by the Empowered Committee. Projects more than Rs.5.0 crores is approved by the Empowered Committee. The project(s) are reviewed once by the Advisory Committee and once by the Experts Committee in a year. A Cost Committee chaired by the ADG/ Director, NASF examine all the aspects of the budget/finance of the projects before it is awarded.

1.8 Modes of funding of projects

The projects are awarded under the two modes *viz*., Competitive and Sponsored Modes.

Competitive mode:

Steps for project submission, selection and approval under competitive mode: Generally, brain storming conference/ meeting is held before inviting the pre-proposals under different components and specific areas. Pre-Proposals for projects in the identified strategic areas in prescribed formats are called through open call. The submission process is entirely electronic through web base platform. The proposals having multi-institutional collaboration are preferred. The Pre-Proposals are first screened at the Secretariat level on the basis of whether the basic eligibility criteria are

met. The screened Pre-Proposals are further screened by subject matter Experts Committees duly constituted. The Pre-Proposals recommended by the expert committees are developed into full proposals in prescribed formats. The PIs are asked to present their full proposals before the respective committees.

Proposals approved & recommended by the Experts Committees, are examined by a Cost Committee for finalizing the budget of each project. The finally selected proposals are modified/improved according to the recommendations of the respective committees and submitted to the Director for verification and acceptance. The selection of the projects under competitive mode is a three/four-stage process given as under for different components:

Basic and Strategic Research and Translational Research

The selection of the competitive projects will be a three-stage process.

Advertisement for submission of Pre-Proposals

↓

Screening for selection of Pre-Proposals by Experts Committees

↓

Full project proposal development & evaluation

↓

Presentation by PIs and Selection by Experst Committees

↓

Approval by Board

Rest of the guidelines for implementation, monitoring, evaluation, finance, extension etc. remain same as per projects selection and award process under NASF.

Extramural Competitive Grant

The selection of the competitive projects is a four-stage process.

Advertisement for submission of Pre-Proposals

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Recommendations of Pre-proposals through Subject Matter Divisions of ICAR

↓

Screening for selection of Pre-Proposals by Experts Committee

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Full project proposal development & evaluation

↓

Presentation by PIs and Selection by Experts Committee

↓

Approval by Board

Rest of the guidelines for implementation, monitoring, evaluation, finance, extension etc. remain same as per projects selection and award process under NASF.

Scientific Validation of Farmers Innovation

The selection of the competitive projects is a four-stage process.

↓

Advertisement for submission of Pre-Proposals

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Recommendations of Pre-proposals through Subject Matter Divisions of ICAR

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Screening for selection of Pre-Proposals by Experts Committee

↓

Full project proposal development & evaluation

↓

Presentation by PIs and Selection by Experts Committee

↓

Approval by Board

Rest of the guidelines for implementation, monitoring, evaluation, finance, extension etc. remain same as per projects selection and award process under NASF. Experts committee can have members from Private Industry/ NGOs.

Sponsored Mode:

Some of the larger problems of national level importance and emerging areas of research

of high anticipated value in Indian agriculture requiring substantial improvement in research infra-structure are also addressed under NASF (in sponsored mode), as decided by the Board. Topics of the sponsored projects are selected by the Board on its own or through a consultation mechanism or on recommendation of the Council or on recommendations of a competent committee constituted by the Board.

For approval of international collaborative projects under different approved workplans and international obligations, the following steps are followed and funding is provided to Indian component only:

Grant for International Collaborative Research

The selection of the sponsored projects is a three-stage process.

Submission of Proposals by Institutes through Subject Matter Division

↓

Recommendations of Pre-proposals through International Relations Section of ICAR based on MoU signed and work plan developed, international obligations

↓

Full project proposal development & evaluation

↓

Selection by the Committee constituted by ICAR

↓

Approval by Board

1.9 Implementation of NASF

NASF has effectively implemented 282 projects involving about 282 Lead Centres and 531 Cooperating Centres located at different parts of the country. The data in table 1 reflects the stringent measures used to screen the potential project proposals.

1.9.1 Number of Concept Notes/Pre-Proposals/Full-Proposals:

NASF receives large no. of concept notes/ Pre-proposals for the funding from various organizations across the country. The Table 1 provides the glimpse of the number of concept notes/pre-proposals/ full-proposals received at the NASF unit. From the VII call onwards, the concept notes are received through a digital platform developed by Indian Agricultural Statistics Research Institute (ICAR-IASRI). Very robust and stringent screening is carried out by the division as well as by the experts committee for approval of the projects.

Table 1: Data of the number of Concept notes/ pre proposals/Full proposals

No. of Call	No. of Concept Notes/Pre-Proposals Received	No. of Full-Proposals Approved
I	145	21
II	159	26
III	191	35
IV	597	22
V	723	20
VI	996	36
VII	976	31
VIII	680	32
IX	1345	39
X	629	28

1.9.2 Project funded under different calls:

NASF awarded 282 multidisciplinary and multi-institutional projects in all strategic areas under different calls (Figure 2). The projects were awarded to public and private organizations associated with basic and strategic research in the field of agricultural science. The funded organizations include ICAR institutes, State agricultural universities, Central agricultural universities, general universities, IITs, AIIMS, NGOs, CSIR, DST and CGIR institutes and private universities. The projects consist of all the commodities viz. crop, horticulture, natural resources management, biotechnology, plant protection, animal, fisheries, social sciences etc. (Figure 3).

Since the initiation of the scheme in 2006, ten calls for projects have been made which are mentioned as Call I (2006), Call II (2010), Call III (2011), Call IV (2012), Call V (2013), Call VI (2015), Call VII (2017), Call VIII (2018), Call IX (2019) and Call X (2023). A total of 282 projects have been awarded with a total budget of Rs.688.01 Cr. Currently, the projects in Call X have been awarded except five projects under the theme of social science & policy in agriculture.

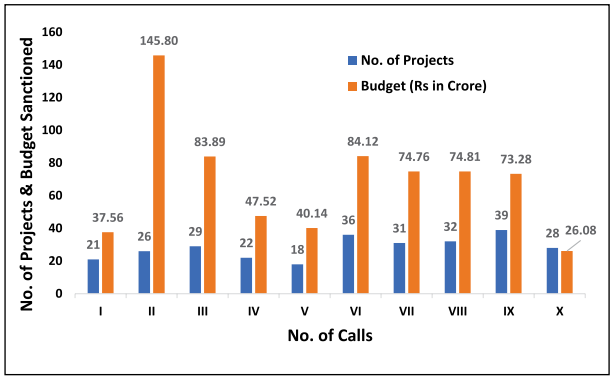


Figure 2: Call wise No. of projects and budget sanctioned

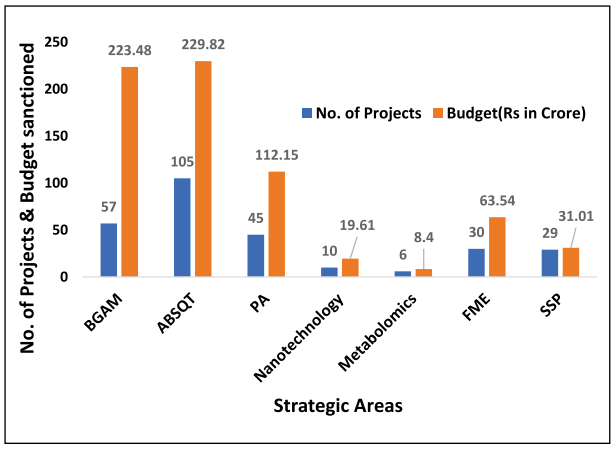


Figure 3: Projects funded under different Strategic Areas & budget sanctioned

SSP – Social Science & Policy, FME- Farm Mechanization & Engineering, PA- Precision Agriculture, ABSQT- Abiotic Stress & Quality Traits, BGAM- Biotechnology & Genomics,

Year-wise on-going projects

The details of the year wise ongoing projects are shown in Fig.4. During the last 10 years, on an average, more than 65 projects are running on y-o-y basis.

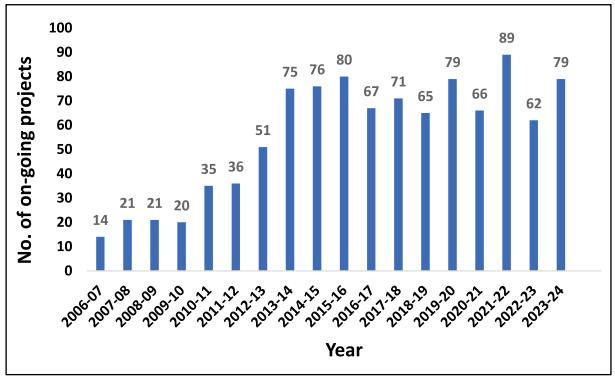


Figure 4: Year-wise on-going projects

1.9.3 Participating Organizations in NASF Projects:

The NASF scheme has been effectively implemented through 813 Implementing centres located across the country involving about 282 Lead centres and 531 Cooperating centres as shown in Table 2.

The pluralistic nature of NASF has been exhibited by association of a wide array of institutions/agencies from the public sector, private sector and civil society organizations.

Their level of participation varied across the various themes in accordance with the priority thrust areas identified under each one of them. The scheme involved about 60% of project implementing institutions in ICAR, 14% in SAUs and 1% in CAUs apart from other organizations. The spread of the projects in various organizations is depicted in Fig.5.

The state-wise distribution of the projects showed that Delhi (20%), Uttar Pradesh (14.7%) and Haryana (9.8%) had the largest number of projects as lead centres. This indicates that Northern region has the highest no. of lead

Table 2: Participation of Lead Centres and Cooperating Centres under different Themes

Theme	No. of Lead Centres	No. Cooperating Centres	Total No. of Implementing Centres
BGAM	57	117	174
ABSQT	105	186	291
Precision Agriculture	45	93	138
Nanotechnology	10	16	26
Metabolomics	6	11	17
FME	30	44	74
SSP	29*	64	93
Total	**282**	**531**	**813**

*Five projects under SSP are under process

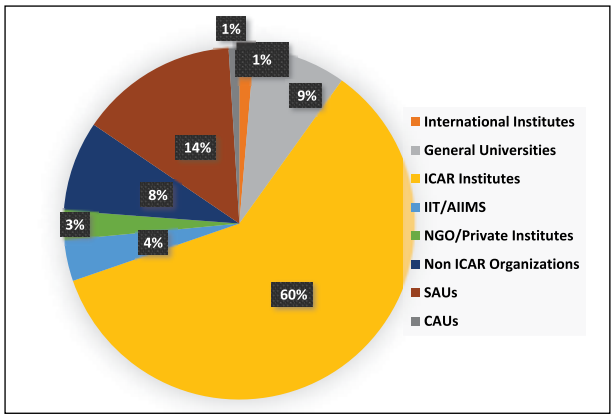


Figure 5: Participating organizations in NASF

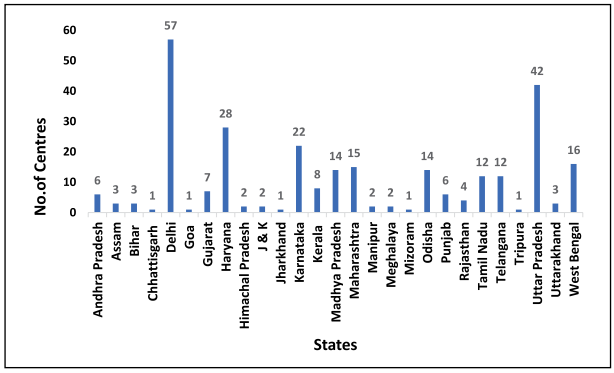


Figure 6: State wise spread of project implementing lead centres

centres. Nine projects are being implemented in NE region as indicated in Fig. 6.

1.9.4 Human resource in NASF Projects:

This scheme gives a platform to appraise and nurture the upcoming talent pool of the country for greater inclusion of institutions in the scientific growth of the nation thus providing direct/indirect employment. Besides supporting the projects, creating infrastructure for advanced research, generating technologies, products, capacity building through training and skill development of scientists, a large number of human resource i.e. >1200 SRF/RAs/YPs/others have benefitted (Fig.7) and received knowledge and developed skill base in different areas of agriculture and allied sectors. In addition, large number of skilled/semiskilled workers get employment in the projects.

Under NASF, equal opportunities are given to both genders for award of projects. Among the implemented total projects of 282 the gender distribution among the PIs/CCPIs indicates a skewed distribution of only 7%

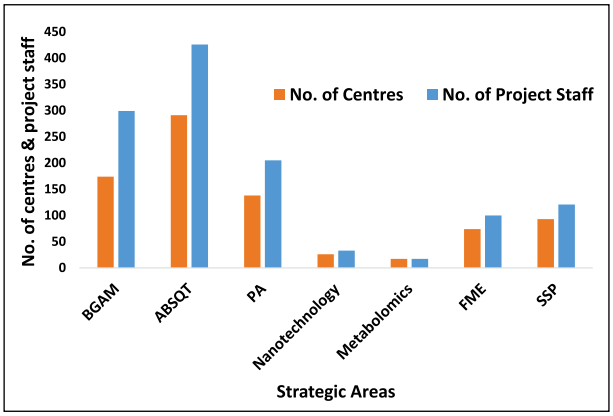


Figure 7: No. of project staff/SRF/RA in different theme-based projects

projects to women researchers while a majority of 93% projects are being implemented by men researchers (Fig. 8). This could be attributed to fact that the more proposals are being submitted by men researchers. The data indicates the need for the popularization and awareness generation of the scheme among women researchers.

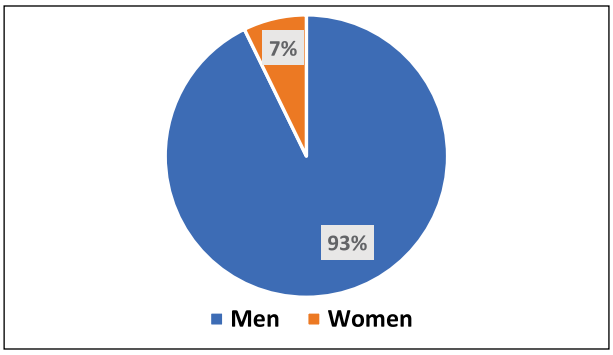


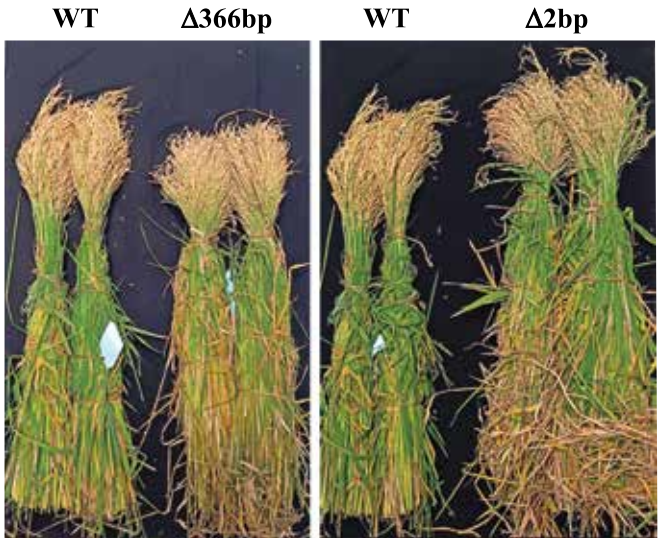
Fig. 8: Gender-wise distribution among PI/CCPIs

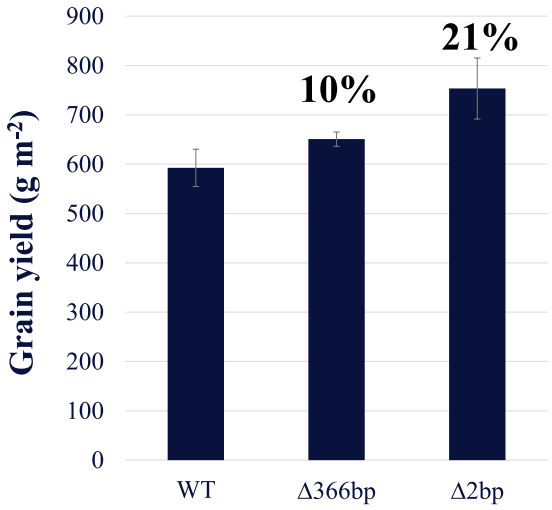
NASF has also supported projects on many new initiatives like award of projects on Scientific Utilization through Research Augmentation- Prime Products/ Panchagavya from Indigenous Cows (SUTRA-PIC) and Extra Mural Research (EMR) and also developed CRISPR Crop Network: targeted improvement of stress tolerance, nutritional quality and yield of crops by using genome editing. Four projects have been supported under SUTRA, eleven projects under EMR and few projects under novel aspects of CRISPR. NASF is directly and indirectly contributing to SDGs and NDPs through its funding thus creating a stronger ecosystem and cohesion across the agricultural science research, generating more diverse outcomes, driving the nation's commitment towards sustainable and national development goals.

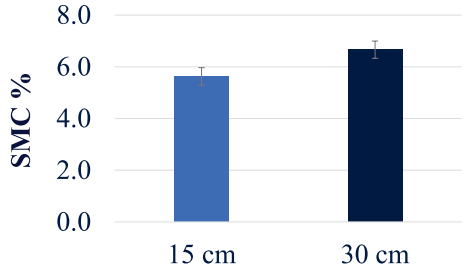
2
Salient Achievements of the Projects

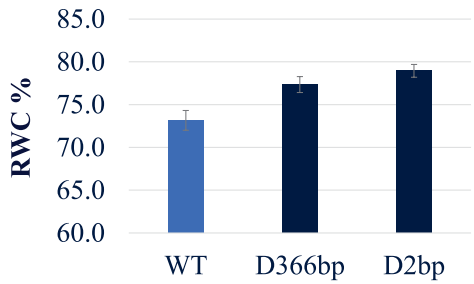
2.1 Biotechnology, genomics and allele mining in plants, animals and fisheries

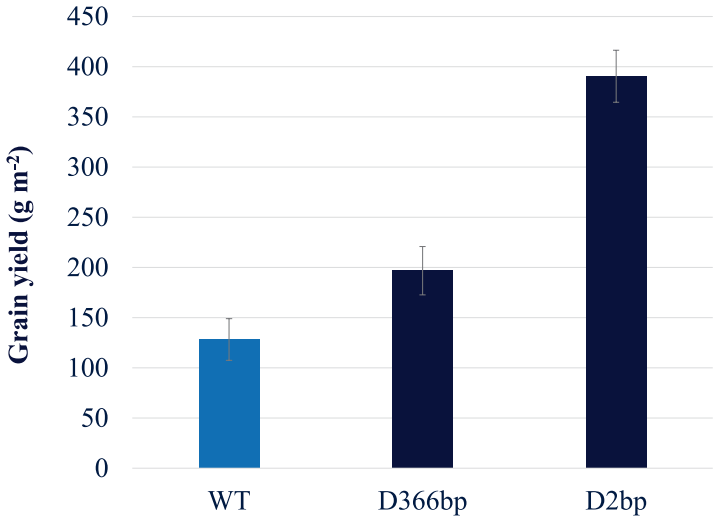
Targeted improvement of crops by using genome editing: Gene editing with CRISPR-Cas9 technology was employed to develop mutants of the drought and salt tolerance (DST) gene, a zinc finger transcription factor, in rice cultivar MTU 1010. In all, five different mutants were generated, and from this two SDN1 type mutants free from introduced exogenous DNA were identified. As per Department of Biotechnology (DBT) SOPs for regulatory review of genome edited plants under SDN-1 and SDN-2 categories, data were generated. These two mutants identified, produced significantly higher grain yield in Summer 2023 under transgenic field condition in irrigated environment. Two mutants of DST gene free from exogenous introduced DNA are being evaluated in AICRIP 2024.











Grain yield of DST gene edited mutants (Δ366bp and Δ2bp) produce significantly higher grain yield than WT MTU1010 under irrigated (top panel) and drought stress (bottom panel) conditions.

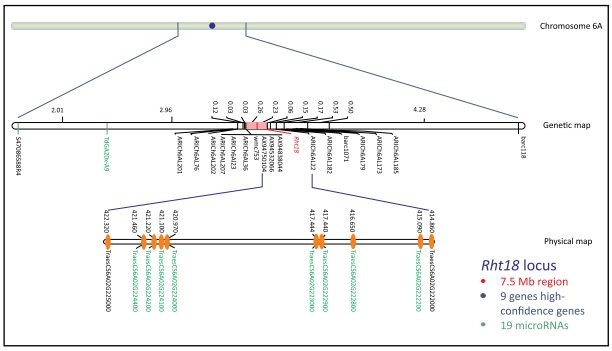
Earlier, high yielding CKX2 mutants of rice cultivar BPT5204 (Samba Mahsuri) were developed. Molecular analysis led to the identification of one homozygous and transgene free edited line, referred to as GeD7-26. Under transgenic network conditions, the GeD7-26 showed significant increase (>35%) in grain yield as compared to BPT5204 (WT). The required molecular/physiological/morphological data have been generated. The mutants of CKX2 gene free from exogenous introduced DNA were evaluated in AICRIP 2023. Thus, the DST and CKX2 mutants are the first set of genomes edited mutant lines that have been exempted from Rules 7-11 of Rules 1989 (noted in 259th RCGM on 31st May 2023) and were evaluated under AICRIP.

Climate resilient high yielding genome edited Samba Mahsuri (GeD-SM): the first CRISPR Crop of India

- √ High grain yield
- √ 15-20 days early
- √ Strong culm
- √ NUE and WUE
- √ Suitable for DSR

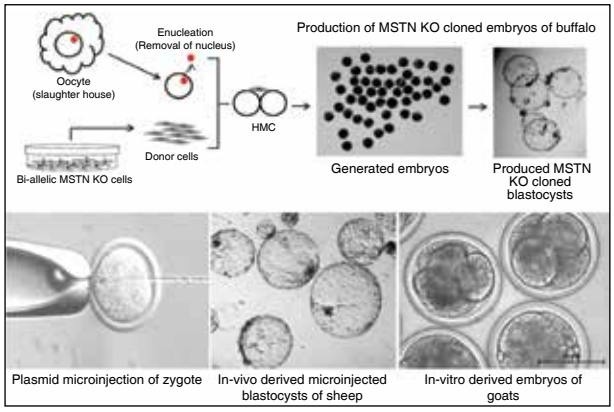
- √ Exempted by IBSC and RCGM
- √ Entered in AICRPR 2023
- √ Patent filed for novel alllele of gene

Fine mapping and marker-assisted breeding for alternative dwarfing genes *Rht14* and *Rht18* to develop semi-dwarf wheat genotype: The fine mapping was carried out to understand the molecular mechanism of alternative dwarfism in wheat. The *Rht18* region was delimited to 7.5 Mbp with closest SSR marker at 0.23 cM. Three new KASP SNP markers were developed for faster selection of Rht18 in breeding lines. InDels and SNPs were identified in the potential candidate genes in *Rht18* locus, which were used to confirm the candidate gene. The fine mapping studies provided the precise map position of important alternative dwarfing loci *Rht14* and *Rht18* in wheat. The closely linked markers are available for their deployment in wheat breeding programs. About 24 differentially expressed genes from *Rht18* and *Rht14* region were identified at two stem elongation stages. The RNAseq and the qRT-PCR results showed a significant correlation (r^2 = 0.82; P < 0.01) between the methods. The results obtained by the RNAseq experiment were in agreement with qPCR, and hence, considered reliable. Six miRNAs with differential expression in dwarf phenotype were identified. BC_3F_4 seeds carrying alternative dwarfing genes *Rht14* and *Rht18* were obtained in the background of HD 2967, HD 3086, HI 1544 and HI 1500 by marker-assisted backcross breeding. Similarly, BC_3F_4 plants in the background of C-306, HI 8498 and NP 200 carrying *Rht14* and *Rht18* were selected for further advancement. The average genetic background recovery observed in Rht14 and Rht18 introgressed lines were 85.35% (HI 1544), 88.90% (HD 3086) and 79.24% (HD 2967). Lines with improved coleoptile length, seedling shoot length, plant height and resistance to leaf and stripe rust were identified. These results provided advanced wheat breeding lines with alternative dwarfing genes and better seedling establishment traits suitable for conservation agriculture.



Fine mapping of Rht18 loci in durum wheat using SNP and SSR markers

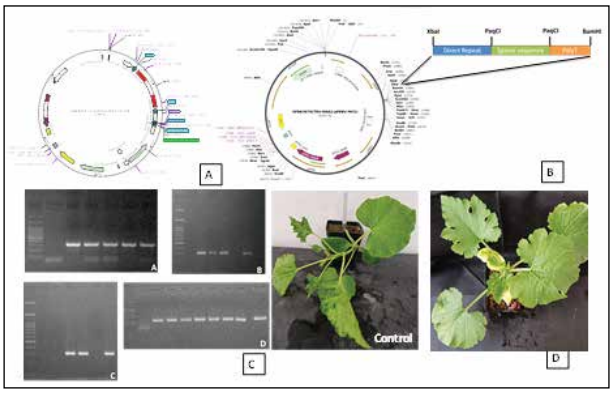
Double muscled-mass farm animals using CRISPR: Myostatin (MSTN) is a negative regulator of muscle mass, related to muscle growth and differentiation. The primary objective of the project was to utilize the CRISPR/Cas9 system and somatic cell nuclear transfer (SCNT) technologies to knockout the MSTN gene. The genomes of fibroblast cells of buffalo, sheep, and goat were modified using CRISPR tool kits specifically designed to target the MSTN gene. Through rigorous selection processes, single-cell clonal populations with MSTN gene edits were successfully established. These edited cells served as the donor genomes for the development of blastocyst-



stage embryos using handmade cloning technique. Explored zygote electroporation and microinjections to produce MSTN gene-edited embryos. Following these processes, the genetically modified embryos were transferred into recipient animals, resulting in the establishment of successful pregnancies. These achievements mark a significant milestone, laying the groundwork for generating genome-edited farm animals to promise avenues for improving agricultural traits, particularly meat industries in India.

White grub (*Holotrichia serrata*) resistance in sugarcane and groundnut by deploying novel cry toxin holotype genes: To identify the individual role of two crystal toxin genes (cry8Sa1 and cry8IB) on mortality of the white grub *H.serrata*, the cloning and expression of these *cry8* toxins genes individually in crystal negative (acrystalliferous) *B. thuringiensis* HD73$^-$ strain was accomplished. Based on the data generated from whole genome sequencing, full length coding sequence of *cry8Sa1* and *cry8Ib* were cloned in shuttle vector pSTK and transformed in to *E. coli* DH5α. Before transforming in *B. thuringiensis* HD73$^-$, recombinant plasmid was isolated from DH5α and transformed into methylation deficient *E. coli* strain E7 (*Dam*$^-$ *Dcm*$^-$) to remove methylation sensitivity in *Bacillus* background. The recombinant plasmids isolated from the E7 were transformed into *B. thuringiensis* HD73$^-$ through electroporation. The electron microscopy clearly revealed the separation of spore and crystal protein. To study the individual toxicity of the Cry8Sa1 and Cry8Ib, purified crystal protein fraction was used to conduct bioassay against 1st, 2nd and 3rd larval instars. The bioassay results indicated that only Cry8Sa1 toxin exhibited significantly higher mortality of up to 96% in the replications. The study showed that Cry8Sa1 is an ideal and potent candidate for developing white grub (*H. serrata*) resistant transgenics in sugarcane.

Genome editing for imparting PRSV resistance: In order to impart resistance against Papaya Ring Spot Virus (PRSV), a high throughput papaya transformation and regeneration protocol towards genome editing of the eIF4E gene family was established and CRISPR/Cas9 mediated editing of eIF4E gene family was undertaken. For CRISPR-Cas13A mediated editing of PRSV genome, two different constructs were developed. The first construct was developed in a binary vector where LshCas13a and gRNA expression cassette were introduced. The second construct was developed in a TRV RNA2 vector which could express a specific gRNA expression cassette under *PEBV* promoter. For the gRNAs, spacer sequences were designed from Vpg and other genes like CP, HC-Pro. The binary construct was agro-infiltrated into leaf of squash plant (a host of PRSV) followed by rub inoculation of PRSV. The treated plants did not show any symptoms, while only PRSV inoculated plant showed severe symptom of the disease.



CRISPR-Cas13a mediated editing of PRSV genome by transient delivery systems and evaluation of their efficacy against PRSV infection in squash plant. A) Binary vector harboring LshCas13a and gRNA expression cassette, B) Modified TRV RNA2 vector expressing LshCas13a-specific gRNA expression cassette under PEBV promoter, C) Cloning of spacer sequences in Cas13a modules and D) Assay of the Cas13a-gRNA construct followed by challenge inoculation of PRSV. Only PRSV inoculated plants as Control showed severe mosaic while Cas13a-gRNA treated plants did not show any symptoms after challenge inoculation.

Targeted editing of potato genome to develop variety specific True Potato Seed (TPS): The potato homologues of three MiMe and CENH3 genes namely StOSD1, StRec8, StSPO11 and StCENH3 were identified using

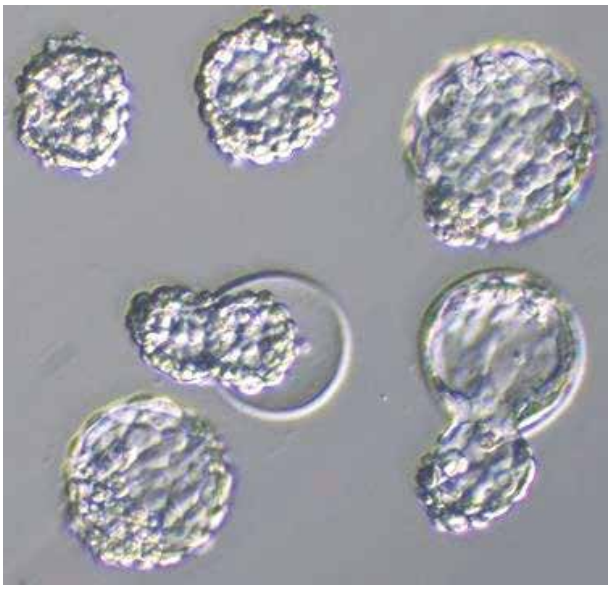
CENH3 mutant lines were used as a female parent to cross with wild-type K. Jyoti plants (a); CENH3 mutant lines were used as a male parent to cross with wild-type K. Jyoti plants (b); TPS collected from berries where CENH3 mutant lines were used as female parent or male parent (c); Seedling obtained from TPS (d) and (e), which were screened for haploid induction efficiency; using FACS and Sanger sequencing (f)

NCBI BLAST from *AtOSD1*, *AtRec8*, *AtSPO11* and *AtCENH3* sequences. Two gRNA targets were also identified in each gene and were assembled into pHSE401 CRISPR/Cas9 vector independently for MiMe and CENH3 and were confirmed by restriction digestion. Out of 32 putative transformants *MiMe* generated lines, 16 lines showed mutation in the region other than target area of *StOSD* gene, 7 lines showed mutation in *StREC8* gene and only one line showed modification for *StSP011* gene; however, it was present within the gene. Overall, the average editing efficiency (number of edited plants/numbers of transgenic plants) for *MiMe* genes was 50% for *StOSD* gene, 21.8% for *StREC8* gene and 3% for *StSP011* gene. Similarly, forty-six CENH3 edited/mutated lines were selected, in which, 35% mutation (insertions or deletions) were analysed at the target sites. Fourteen independent events for CENH3 mutation were selected and crossed with control Kufri Jyoti plants for evaluation of haploid induction efficiency. The TPS were germinated and screened for haploid induction efficiency using FACS and Sanger sequencing. Five CENH3 edited lines *viz.* CENH3 1a (4), CENH3 1a (32), CENH3 2a (20), CENH3 2a (19) and CENH3 1a (11) showed the 11%, 15.7%, 10.9%, 10.8% and 15.6% efficiency of diploid induction with tetraploid wild-type Kufri Jyoti respectively.

Identifying the genomic regions and genes for drought and heat tolerance in groundnut: In order to identify the genomic regions for drought and heat tolerance in groundnut, eight parents and 500 lines of the MAGIC population, 432 RILs of TMV2 × TMV2-NLM and 250 RILs of JL 24 × 55-437 were subjected for DNA sequencing. The linkage map constructed with 700 SNP markers could identify major main effect QTLs for pod yield with the highest PVE of 10.5%. Nine QTLs with the highest PVE of 18.4% were identified for shoot dry weight (SDW). A few of them were involved in epistatic interactions, and formed multiple QTL mapping models. Five major QTLs for SDW were found to be stable over both the locations. The candidate genes with SNPs and *AhMITE1* insertion were identified for the major QTL regions. Map was also constructed using 478 SNPs for the RIL population of JL 24 × 55-437. Forty-five major main effect QTLs were identified for 21 traits. Three QTL clusters (Cluster-1-Ah03, Cluster-2-Ah12, and Cluster-3-Ah20) harboured more than half of the major QTLs for target traits, explaining as high as 38.6%, 44.6%, and 49.5% of PVE, respectively. The candidate genes encoding heat shock protein, heat shock transcription factors, and flowering regulation genes were identified at QTL clusters. The population structure analysis identified four subgroups. Seven significant marker-trait associations for five traits were identified in 374 kb (carrying 348 genes) genomic region on chromosome Ah18.

CRISPR/CAS9 guided functional analysis of genes regulating early embryonic survival in buffalo: Early embryonic mortality is a major impediment hampering the reproductive efficiency and accounts for a main component of post fertilization losses in buffalo. Prostaglandins (PGs) are the crucial regulators of implantation, decidualization, embryo development and survival in ruminants. Targeted genome editing by CRISPR/CAS9 technology has emerged as novel approach to modify endogenous genes in various cell types. In-vitro over-expression studies, PTGES and PTGFS coding sequences (462 bp PTGES and 972 bp PTGFS) were cloned in CT-GFP Fusion vector followed by sequence confirmation of the clones. Cloning of two sgRNAs against COX-2 gene into CRISPR/Cas9 expression vector (PX459) was confirmed by sequencing. The

resultant CRISPR/Cas9-sgRNA constructs were subsequently used for transfection into *in vitro* cultured buffalo endometrial and luteal cells. RT-PCR data revealed that mRNA expression profile of COX-2 gene following CRISPR/Cas9 mediated editing using two gRNAs exhibited significant decline in $PGF_{2\alpha}$ production and COX-2 gene expression. An inexpensive, yet efficient, methodology for microinjection of CRISPR/Cas9 constructs into mouse zygotes was developed. This methodology was applied for microinjection of PTGFS Cas9-gRNA construct into mouse embryos. For supply of zygotes, super-ovulated the female mice by intraperitoneal injections of pregnant mare serum gonadotrophin (PMSG), followed by (post 47 hrs) human chorionic gonadotrophin (hCG). Following the hormonal induction of ovulation, females were allowed to mate with stud males. On the next day (0.5 dpc), the females positive for mating plug were sacrificed and dissected to obtain zygotes. Each zygote was injected with 3-5 pL of COX-2 and PTGFS Cas9-gRNA construct according to the standardized hypothetical divisions of microinjection needle. The microinjected zygotes were in vitro cultured in vitro up to the blastocyst stage. The knockout efficiency was determined using the T7 endonuclease assay. The T7 assay revealed the effective knockout of COX-2 and PTGFS gene in blastocysts. Simultaneously, the embryos were transferred to foster mice. No pregnancy has been achieved till date.

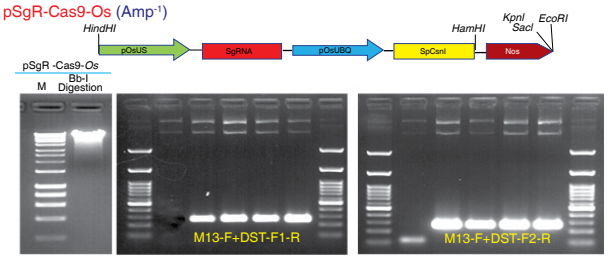


PTGFS knockout blastocysts.

Genetic improvement of rice through RNA guided genome editing (CRISPR-Cas9/Cpf1): Genome editing technology (CRISPR-Cas9) was used to create loss of function mutants of the *DROUGHT AND SALT TOLERANCE* (*DST*) gene, a Zinc finger transcription factor, in rice cultivar MTU1010. Three homozygous mutants were developed with reproductive stage tolerance to salinity stress. These lines were further evaluated for yield under drought stress and non-stress conditions. The *DST* gene mutants showed >25% increase in grain yield under normal conditions due to increase in reproductive tillers per plants and grain number per panicle. Under drought stress (-75 KPa), genome edited mutants showed significantly higher grain yield as compared with MTU1010.

Genome editing of DST gene enhanced grains per panicle and grain yield in rice.

OsDST specific gRNA spacer sequences were designed from CRISPR-PLANT (https://www.genome.arizona.edu/crispr/) software. Random colonies were selected, and plasmids were isolated by alkaline lysis method. PCR was performed using M13-forward and gene-specific primers. The results revealed the confirmation of cloning, and plasmids were also confirmed by DNA sequencing.



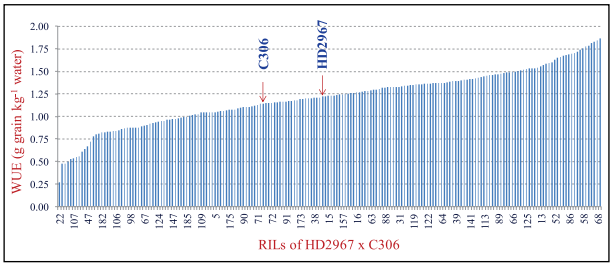
Confirmation of cloning of DST-F1 and DST-F2 sgRNAs in pSGR-Cas9-Os vector. M13-F and gene-specific primers were used for PCR. Expected amplicon size (256 bp) were obtained in recombinant plasmids.

Refinement of haploid/doubled haploid induction systems in rice, wheat and maize involving molecular and *in-vitro* strategies: About 396 DHs in rice and more than 800 DHs in maize were evaluated, and promising

lines were identified for further advancement and used in breeding programme. In case of wheat, 560 DH lines carry rust resistant genes *Yr15*, *Yr5*, *Yr36* and *Lr34*, *Lr57* in different combinations. Besides, about 150 high tryprophan+high provitamin A maize DH lines were generated and evaluated, and promising lines were identified for use in development of biofortified maize hybrids. In rice, significant achievements were made in establishment of *in vitro* androgenic method in *indica* rice where callus induction frequency was observed to be 30.4-52% and green shoot regeneration ranged from 61.00-85.99%, cumulatively. No haploids were observed among the regenerants which signified 100% spontaneous doubling without the treatment of antimitotic agents.

In wheat, application of colchicine for 12 hours after pollination (HAP) was found to produce higher doubling percentage as well as a greater number of seed per plant compared to colchicine application for 24 HAP. The frequency of full plant doubling was also high in 12 HAP of colchicine application. Among colchicine alternatives, APM (10 µM) + Trifluralin (350 µM) was confirmed as the best treatment compared with Amiprophos-methyl (APM) (10 µM) and Trifluralin (350 µM) when applied individually 24 hours after pollination. Further, use of Phloroglucinol in embryo rescue media showed positive effect on plant regeneration. In case of maize, based on preliminary observations, three treatments - APM 20 ppm + Pronamide 2 ppm + Trifluralin 1 ppm for 12 hours, APM 20 ppm + Trifluralin 1 ppm for 8 hours and APM 20 ppm + Pronamide 1 ppm for 12 hours were found promising. Pigmentation on dorsal basal portion of seed identifed as a putative trait for haploid classification in the hybrid CMVL 55, which is expected to help in haploid classification in source populations with anthocyanin inhibitor genes.

Phenomics of Moisture Deficit Stress Tolerance and Nitrogen Use Efficiency in Rice and Wheat Phase-II: During the project period a recombinant inbred line (RIL) population consisting of 183 RILs derived from HD2967 x C306 cross were phenotyped at Nanaji Deshmukh Plant Phenomics Centre (NDPPC), ICAR-IARI, New Delhi under normal and drought stress conditions to identify QTLs and superior genotypes for water use efficiency (WUE). Drought tolerant wheat cv. C306 used

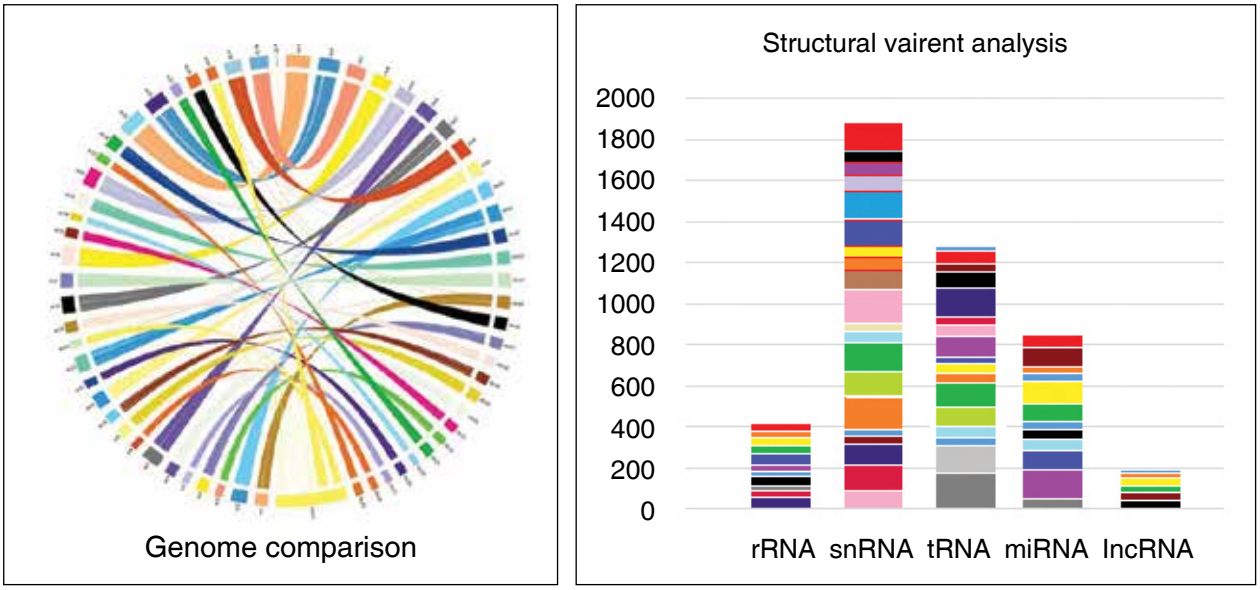


WUE for grain yield of RILs of HD2967xC306 under drought stress conditions.

577 and 872 litres of water to produce one kg of grain under normal and drought stress conditions, respectively. Phenomics analysis led to the identification of RILs which use 20% less water and 10% more yield over the both the parents under well irrigated conditions. Under drought stress conditions, RILs which use 30% less water and 25% more yield over the both the parents were identified. These RILs and parents were genotyped with 35000 SNPs using 35K Wheat Breeder Array. Two major QTLs for WUE with phenotypic variance of 11.57 and 13.18% were mapped on chromosome 2B and 7B, respectively.

During the project period trait prediction models, Integrated Analysis Platforms (IAPs) and phenome data bank for high throughput estimation of phenotypic traits from various imaging sensors was developed. Diverse set of 60 rice genotypes were used to standardize image acquisition, segmentation and analysis. Diverse rice genotypes were used to develop relational models to predict component traits (biomass, leaf area, chlorophyll content, tissue temperature, relative water content, etc.) of drought tolerance and NUE from the image data. Developed rice transgenic overexpressing ABAR6 and showed that ABAR6 transgenics use less water and tolerant to drought stress at vegetative stage. By using chlorophyll fluorescence imaging, the photosystem II function under drought stress was analyzed. The results revealed that ABAR6 transgenics maintained better photosystem II function under drought stress.

An OMICS approach for elucidating the mechanism of Pashmina fibre development: Transcriptomic approach was used for identification of markers for the fibre yield. Eight skin samples (4 each from low fibre producing and high fibre producing pashmina goat) were

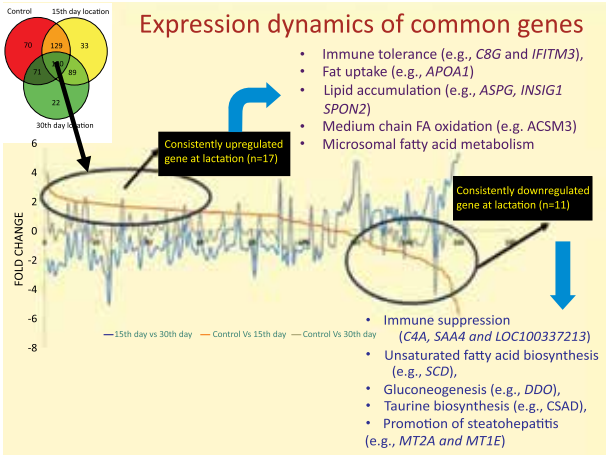


Whole genome assembly and structural variant analysis of Pashmina goat genome.

collected for RNA-Sequencing. Thirty candidate genes and 5000 high impact SNPs were identified to be associated with high fibre yield. High fibre growth is mainly associated with the upregulation of growth factors in HY group, major growth factors up-regulated in HY group includes FGFR4, FGF21, FGF22, IGF1 and IGF2. And BMP and mTOR signalling pathway have major role for enhancing hair growth. Skin transcriptome profiles associated with coat colour in Pashmina goat were studied. Six skin samples (2 white, 2 black and 2 brown) were collected for RNA-Sequencing. A total of 33 gene in melanogenesis pathway have been identified which act as key regulators for fibre colouring. The sequencing data were submitted to the Genome Expression Omnibus (GEO) database (Accession Number GSE107249) in National Centre for Biotechnology research – NCBI. Skin transcriptome profiles associated with different cycling stages were also studied. All data were made available online through an intuitive, researcher-friendly and interactive web interface called *Pashmina informatics database (PIDB)*, available at http://pashminainformatics.skuastk.org/

Proteome profiling of Pashmina skin using various methods of protein extraction was carried out using different extraction protocols by LC-MS/MS and generated data were searched using swissprot mammalian database and data generated from transcriptomic experiments. Identified genes are involved in fibre keratinization, fibre cycle, fibre color (melanogenesis), cell differentiation, cell apoptosis and cell proliferation.

Lactation stress associated postpartum anoestrus SNP array in buffaloes: Serum free fatty acids (FFA) were estimated by colorimetric assay. Among the lactating and heifers Results showed significantly higher (P <0.05) levels of FFA in lactating buffaloes than in heifers till 4 weeks postpartum, suggesting that there was a negative energy balance in lactating buffaloes till week 4 on the basis of FFA. Bioinformatic analyses to identify the differentially expressed genes between heifers (control) and lactation stress buffaloes was done. The top 30 selected pathways from KEGG, Reactome and Wikipathways are presented. Significant pathways with FDR < 0.05 were encircled. A total of 17 genes were consistently upregulated



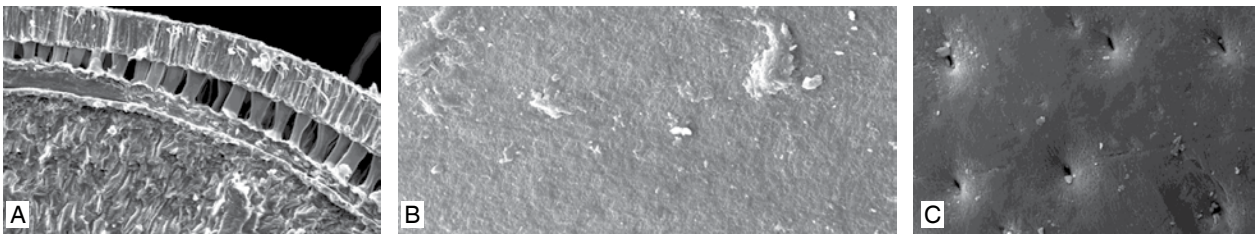
Expression dynamics of common genes among control, 15th day and 30th day of lactation.

on 15th and 30th day of lactation and a total of 11 genes were consistently downregulated on 15th and 30th day of lactation.

Study showed that high serum FFA and low leptin levels could be the plausible indicators of negative energy balance (NEB) in buffaloes. A total of 509 and 332 significantly differentially expressed genes (DEG) were identified in the liver and adipose tissues, respectively, between heifers and early lactation (15th and 30th day) buffaloes by NGS analyses. Functional annotation and network analyses of DEG revealed that the immune tolerance and insulin resistance are the major adaptive mechanisms in the liver and adipose tissues, respectively, in buffaloes during early postpartum. The transcriptome data were further supported by proteomics data. On the basis of *Bos Taurus* genome, a total of 1,39,964 and 1,58,688 intergenus SNPs were identified from the liver and adipose transcriptome data, respectively. A total 368 intragenus SNPs in 317 genes were identified from the liver and adipose tissue transcriptome data.

Genetic transformation and development of elite transgenic maize (*Zea mays* L.) for biotic and abiotic stresses tolerance: Novel plant transformation constructs capable of imparting herbicide tolerance and the required modules or components were used for development of elite transgenic maize. Transformation via biolistic and agro-mediated methods were undertaken. A novel method for *in-vitro* regeneration from nodal explants of tropical maize inbred (KDM varieties from SKAUST) and hybrid (K65 variety) lines were optimized. Amongst them, K65 variety exhibited robust Type II embryogenic calli in the modified media. Constructs employing CRISPR/Cas9-based gene editing of native *EPSPS* was designed at International Centre for Genetic Engineering and Biotechnology (ICGEB) for nutritional improvement of crops. More than 7000 immature embryos were harvested from field grown CM300 inbred line and cultured on callus induction media. The embryogenic calli were transformed with CRISPR/Cas9 based EPSP gene editing construct for herbicide tolerance. These putative transgenic plants were screened through PCR using *Cas9* gene-specific primers. Maize transformation with already available codon optimized *Cry1Ac* gene construct and the T1 putative transformants were analysed to develop stem borer resistant maize transgenic, codon optimized *Cry1Ac* gene construct was used for transformation of embryogenic maize callus of inbred line VQL2 at VPKAS. For herbicide resistance, 300 calli were bombarded with gene editing construct of CRISPR/Cas9 along with EPSPS sgRNA. In all, sixty-seven plants were regenerated, which were confirmed by PCR analysis.

Cellular, genetic mechanisms and identifying molecular markers for seed viability in soybean: Breeding lines with higher seed viability and permeability was identified which maintained >70% seed viability even after 3 years of ambient storage of soyabean. These lines were subjected to testing for other traits including content of oil in the seeds. It was observed that in general, higher the oil content (%) in the seeds, lesser the viability. However, few lines maintained higher viability even with higher oil content. In depth characterization of the associated genomic variation and two genotypes with contrasting seed coat properties *Glycine soja* (hard seed) and DS9712 (*Glycine max*, soft seed), revealed 2 genes (Type I- Inositol polyphosphate 5 phosphotase1 and E3 Ubiquitin ligases) with a preliminary, but a strong association with the soybean seed permeability trait. The experiments carried out at Indian Agricultural Research Institute (IARI) and National Research Centre on Plant Biotechnology (NRCPB), New Delhi, indicated that genes differentiated parental genotypes, revealed protein conformational deformations



Electron microscopy of seed coat showing variations in permeable and impermeable seed coat. A: Intact hourglass cell layer; B. Impermeable seed coat; C. Permeable seed coat.

and demonstrated segregation among RILs in coherence with their permeability scores, and hence could be used to develop PCRbased markers for accelerated soybean breeding.

To generate a transcriptome profile from good storer versus poor storer genotypes, RNA was isolated from *G. max* and *G. soja* seeds at three different time points during the priming phase and was assessed for RNA integrity. Out of 40614 differentially expressed genes (DEGs), all 265 DEGs, and 1434 DEGs of *G. max* and *G. soja*, respectively at 0 to 48 hours were identified. Analysis of DEGs between *G. max* and *G. soja* at 12 hours revealed 884 DEGs. These were annotated using BLAST 2GO annotation. Based on literature and fold change values, a total of 23 genes were selected which could potentially be involved in seed longevity of *G. soja* in comparison to *G. max*.

Mechanisms of tolerance to low light intensity in rice: One hundred rice genotypes were evaluated for their adaptability to low-light environment under two light regimes i.e., open (100%) and 75% light intensity by putting agro shade nets in kharif season-2017.

Grain yield and percentage of yield loss among the 50 National Rice Research Institute (NRRI) rice genotypes showed highest grain yield under low light in Pyari (3.93t/ha), followed by Panindra (3.82 t/ha), Pabitra (3.57 t/ha) and Supriya (3.16t/ha) which were more than the susceptible checks and at par with the tolerant check. Among the 50 Assam collection the highest grain yield under low light environment was recorded in Bihari Sali (3.78 t/ha), followed by Nalini Sali (3.71 t/ha) and Lota Sali (3.53 t/ha). The yield loss in low light grown rice genotypes was recorded in BAS-370 followed by CSR-35 and Pabitra among the NRRI varieties. Rice genotypes (Lota Sali, Sagara Sali, FR-13A, Kolabardhan, Kati Sali, Hati Sali, Mekuri Sali, Na Sali, Bodumoni Sali, and Tora Bali) from ASSAM collection showed their tolerance in terms of higher Specific Leaf weight (SLW) under low light environment for both the seasons.

The rice genotypes grown under agro shade nets (NRRI, Cuttack) for their evaluation under low light tolerance.

Rice samples of contrasting genotypes were collected from the fields of NRRI, Cuttack, grown under both natural and low light. These genotypes included NRRI-2, NRRI-5, NRRI-18, NRRI-49, Assam-1, Assam-2, Assam-44, Swarnaprabha, IR-8 and IR-64. The activities of photosynthetic enzymes *viz*., RuBisCo, phosphoribulokinase, NADP-malic enzyme and ferredoxin-$NADP^+$ reductase (FNR) was assayed in the collected samples. Similarly, cloning of 3987 bp long phytochrome A gene (*phyA*) was accomplished from cv. Swarnaprabha. The cDNA library of Swarnaprabha genotype was constructed and *phyA* cDNA (3387 bp) was cloned for site directed mutagenesis. Genomic DNA from 200 rice samples (100 each from low light and natural light conditions) was isolated for Allele mining and SNP genotyping. Powdered leaf samples of above-mentioned 200 samples were analyzed by IRMS to estimate the difference in photosynthetic capacity.

Dominant nuclear male sterility system in rice for hybrid seed production: Efforts were made to develop a dominant nuclear male sterility (NMS) system using *Syn orfB* gene in different genetic backgrounds and evaluation of fertility restoration system using *Cre-lox* mediated excision, RNAi-mediated down regulation of the male sterility inducing *Syn orfB* gene. Tapetum specific *RTS2* promoter was cloned from cv. IR64 and characterized in transgenic tobacco. The Real- time PCR and histochemical study confirmed higher expression of *Gus* gene in anther as compared to leaf and root. The transformed plantlets having *Cre* gene construct were regenerated.

Transgenic IR 64 with orf B.

Based on standard heterosis,the best heterotic combinations identified were: Reeta/CR3854, CR3813-2-2-5-1-1/R261 and improved Tapaswini/MTU1010.

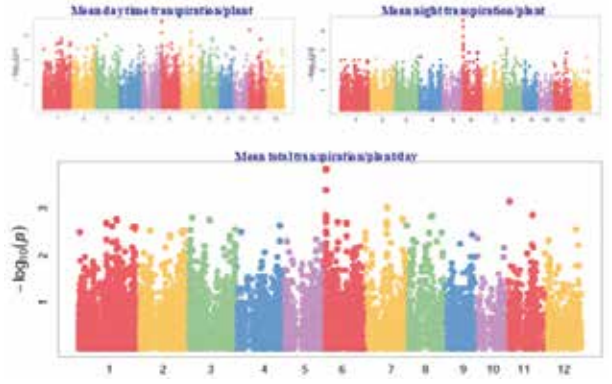
Phenomics of moisture deficit stress tolerance and nitrogen use efficiency in rice and wheat Phase-I: Hyper-spectral reflectance-based models which predict relative water content (RWC) with high accuracy were developed for high throughput non-destructive phenotyping drought tolerance of rice. Further, to differentiate rice genotypes, hyper spectral method-based separability index was developed. Twenty-five candidate genes from rice were cloned and validated. Analysis of rice F-box protein genes *OsFBX257* and *OsFBK10*, and homeodomain protein gene, *OsHOX22*, in *Arabidopsis* showed that these genes are negative regulators of stress tolerance. Transgenic analysis showed that ABA receptor (*OsABAR6*) gene confers enhanced drought tolerance to rice.

Genes for drought tolerance: RNAi silencing and overexpressing transgenic lines of ABA receptor 6 (ABAR6), MYB transcription factor (MYB TF), Protein Kinase SnRK2 and Expressed Protein (EP) genes were developed and analyzed. Transgenic rice lines overexpressing *OsABAR6* gene showed enhanced drought tolerance. Analysis of physiological indices for drought tolerance conferred by ABAR6 revealed that the transgenic plants had enhanced root growth and stomatal closure, low excised leaf water loss and reduced whole plant water use. Rice transgenics overexpressing *SnRK2* and *EP* genes also showed enhanced hypersalinity and

State-of-art plant phenomics facility at IARI, New Delhi.

drought tolerance, respectively at seedling stage. Analysis of *Arabidopsis* transgenics overexpressing rice HD-ZIP I class homeobox gene *OsHOX24* revealed that this nuclear localized HOX24 is a negative regulator of abiotic stress tolerance.

Water use efficiency and transpiration (diurnal and nocturnal) rate of 150 rice germplasm lines were analyzed at Nanaji Deshmukh Plant Phenomics Centre (NDPPC), IARI, New Delhi. Genotypes with contrasting diurnal and nocturnal transpiration under well-watered and moisture-deficit stress conditions were identified. A low correlation between leaf area and mean transpiration in rice germplasm suggested that large portion of genotypic variation in transpiration is controlled by physiological mechanisms that involved in stomatal regulation, besides the leaf area. A total of 18 QTLs for mean day time transpiration and 12 QTLs for mean night time transpiration per unit leaf area were mapped. A region on chromosome 6 appears to control whole plant transpiration. Similarly, 183 wheat germplasm lines and 184 RILs of HD2967 x C306 cross were

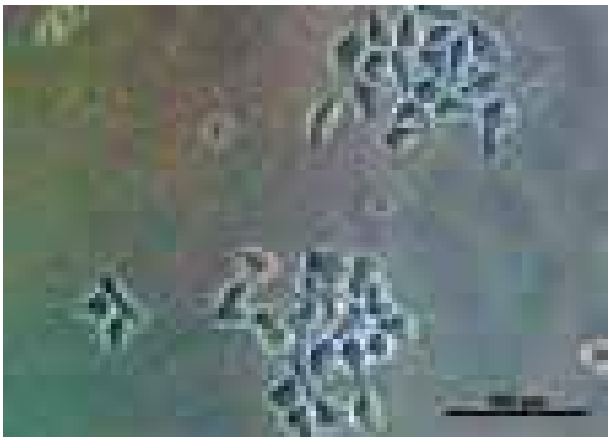


Manhattan plots of GWAS for transpiration.

phenotyped for WUE and drought tolerance, and genotypes with higher WUE and grain yield were identified.

RNAi mediated comparative functional analysis of immune response genes in ruminants and fish against *Mycobacterium avium ssp. paratuberculosis* and *M. fortuitum*: A method has been developed for isolation and maintenance of peripheral blood mono-nuclear cell (PBMC). *In-vitro* model of PBMC-derived macrophages has been developed for functional analysis of immune- response gene against *Mycobacterium avium* ssp. *paratuberculosis* (MAP) and *M. fortuitum* (MF) for goat/buffalo and MF for fish. An *in-vivo* model for studying infection parameters due to MF infection in fish has been developed. Whole genome has been sequenced for goat. Transcriptome and small RNA profiles of macrophages of goat and buffalo when infected with MAP and MF have been worked out to understand immune-response genes in goat.

Regulation of fatty acid synthesis by RNA interference in pig: siRNA against SCD1 gene in porcine mesenchymal stem cells were screened. Out of the three siRNA sets, one was found to down-regulate expression of SCD1 in a dose dependent manner., Induced pluripotent stem (iPS) cells were produced from mesenchymal stem cells for transgenesis. Mesenchymal stem cells (MSC) were transfected three sets of siRNAs designed against porcine SCD1. One of these sets was found to down-regulate the SCD1 gene in a dose dependent manner. These iPS cells were highly prolific, primarily grew in colony, morphologically distinct, different from mesenchymal stem cells, possessed higher volume of nuclei, compared to cytoplasmic



Porcine induced pluripotent stem(iPS) cell colonies.

content and expressed species specific iPS markers. *In vitro* production of porcineembryos was standardized. The supplementation of testicular tissue lysate was found to improve developmental competence of porcine oocytes matured and fertilized *in vitro*.

RNAi technology in developing low phytate soybean and rice: Putative transgenic rice-plants were developed using RNA*i* technology. These plants showed 5-7-fold increase in inorganic phosphorus and up to 40% decrease in phytic acid content in selected rice transgenic (T_2) lines, increasing the bioavailability of grain iron. Similarly, up to 60% reduction in phytic acid content was observed in selected transgenic lines (T_2) in soybean.

Molecular Basis of Insect-Plant Interactions in Rice: Rice genotypes, namely TN 1 (susceptible to gall midge and carries no gene for resistance) and Kavya (a resistant genotype but susceptible to new virulent strains and carries a resistance gene *Gm1*), were compared by molecular analysis for their response to gall midge infestation. The study of a selected set of 20 genes related to plant defence system revealed certain distinct variations in early response (24 hours after GMB4M infestation) in Kavya compared to TN 1. Kavya mountedan elevated defence response during early hours (24hours) of virulent gall midge infestation than the other. This induced defence was suppressed during later hours (120 hours) by the virulent insect with the counter defence mechanism and resulted in plant susceptibility.

Nano-fertilizer application: In nano-fertilizers, microorganisms (26 fungi and 1 bacterium) suitable for biosynthesis of nanoparticles of P, Mg, Fe, B, and K were identified, cultured and developed. The biosafety investigations showed no adverse effect of the application of nano-fertilizers on seed germination, soluble seed protein content, microbial diversity in rhizosphere, body weight and consumption rate of mice subjects, or nanoparticle concentration in seeds. Furthermore, Zn and Fe nanoparticles at 1.5-10 ppm expressed up to 98% reduction in superoxide dismutase activity in cluster bean leaves, indicating more tolerant capacity of the plants against drought. For the production of polysaccharide for gum production/soil

binding and moisture retention in arid soils, 12 bacteria and two efficient polysaccharide producing fungi were developed and identified. Application of nanoparticles for fertilizer use in barley, mungbean, mothbean and pearlmillet showed increased nutrient use efficiency by 48-61% and yield by 20-48%. The beneficial effect of nano-P on the pearl millet crop was observed.

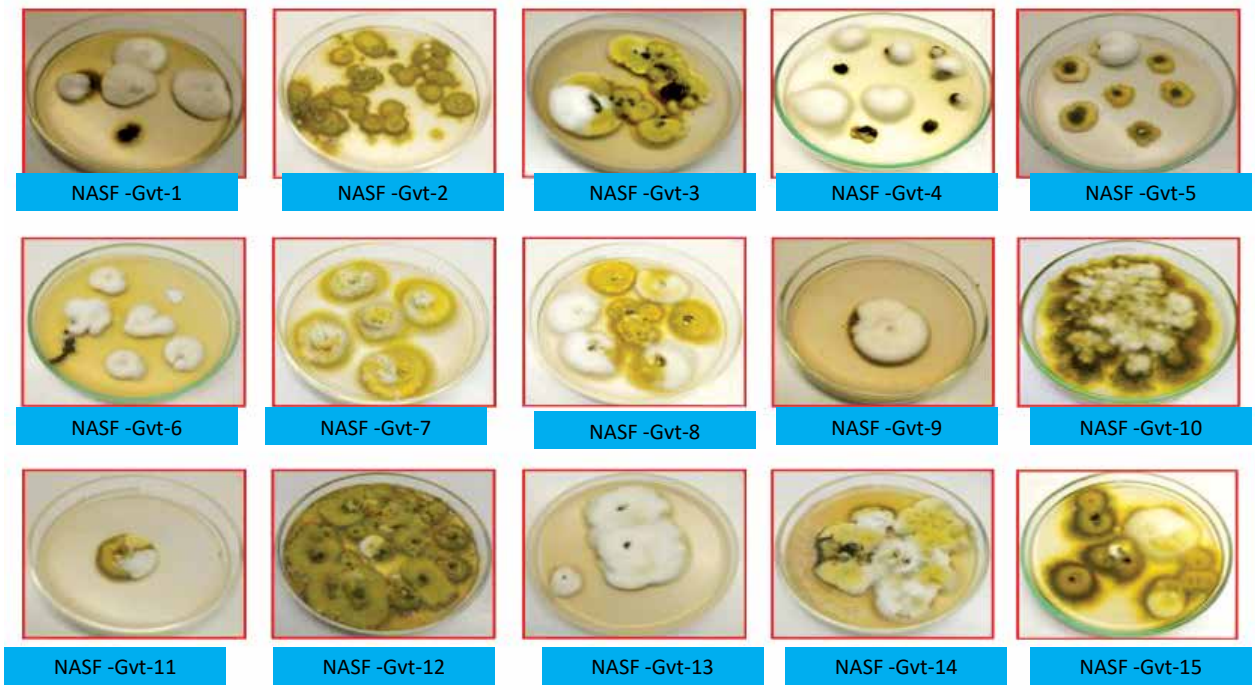
Stem cells in cattle and buffaloes: Germ line cell-specific genes in buffalo embryonic stem cells (ESCs), testis and ovary were identified. DAZL was expressed in ESCs, testis as well as ovary but not in fibroblasts white VASA expression was observed in adult testis and ovary and not in fibroblasts and ESCs. Proliferation of spermatogonial stem cells (SSCs) were significantly higher in the presence of GDNF+EGF+FGF2 than when the medium was supplemented with EGF or FGF2 in combination with GDNF. Media containing GDNF along with adult bull serum resulted in a greater number of spermatogonia ceH colonies and also higher proliferation rate in terms of size of colonies, which was also confirmed by MTT assay. Association of two major alleles of BM861 lod with semen parameters revealed no significant variability in sperm characteristics in relation to bovine growth hormone genotypes. 'Mahima', a female calf weighing 32 kg was born on January 25, 2013 to 'Garima-II' a cloned buffalo, produced by hand-guided cloning using ESCs as donor cells. Garima-II had attained early sexual maturity at 19 months (compared to her contemporary – around 28 months) and was inseminated with frozen-thawed semen of a progeny tested bull on 27th March 2012, which resulted in conception and delivery of 'Mahima' through normal parturition. This was the first calf in the world to be born to a cloned buffalo thus produced.

Cryopreservation of bovine spermatozoa: Buffalo and Karan Fries were differentiated on the basis of distinct localization patterns of vital proteins / enzymes between the two species. Composition of the new soya-based extender was standardized using 25 per cent soya milk in place of egg yolk in tris buffer. The sub-lethal damage observed was less in soya milk extender compared to the egg yolk extender in the buffalo and Karan Fries spermatozoa. Improved *in vitro* fertility assessment in terms of in vitro capacitation and in vitro homologous fertilization was observed in the spermatozoa cryopreserved with additives. *In vivo* fertility trials using cryopreserved semen in both the extenders showed comparable pregnancy rates. Two new soya formulations as extenders were made ready in the concentrated form for further commercial use.

Enhancing the meat production of goat having knocked down myostatin gene: Knockdown efficiency of MSTN gene in case of stable adult fibroblast cell line after 11 " passage was about 90 per cent, compared to mock control. About 15-20 transformed embryos having knock-down MSTN gene were produced and cryopreserved, for further transfer into surrogates. Spermatogonia germ cells culture in serto ii cell feeder layer and *in vitro* transduced with GFP expression vector were also established.

2.2 Abiotic and biotic stresses and, quality traits in plants, animals & fisheries

Identification and characterization of fungal effectors and host factors in rice-false smut pathosystem: Rice false smut samples (174) were collected from different 18 states of rice-growing areas. *Ustilaginoidea virens* was isolated from the yellow-coloured smut balls using potato sucrose agar medium. Around 148 *U. virens* isolates were obtained and the morphological characters viz., colony colour, size, and texture etc., were recorded. During *Kharif* 2023, about 70, 100, and 70 germplasm lines were screened either artificially or under natural conditions. Four genotypes were selected and screened artificially. GNV-10-89 and Co-51 is being used as susceptible line to study the virulence of the collected *U. virens* isolates at Gangavathi and IIRR, respectively. High-quality DNA was isolated from the two highly virulent selected false smut isolates from different geographic regions of India. The DNA was subjected to pre-library quality control on the Femto Pulse system to separate large DNA fragments for PacBio sequencing. The whole genome sequences were caried out on the PacBio Sequel II third-generation sequencing platform and Hi-C (chromatin interaction) sequencing. The time points for the collection of tissues during the rice-false smut interaction for gene expression studies were standardized using the IIRR rice false smut (RFS) isolate in the genotypes showing differential disease reactions.

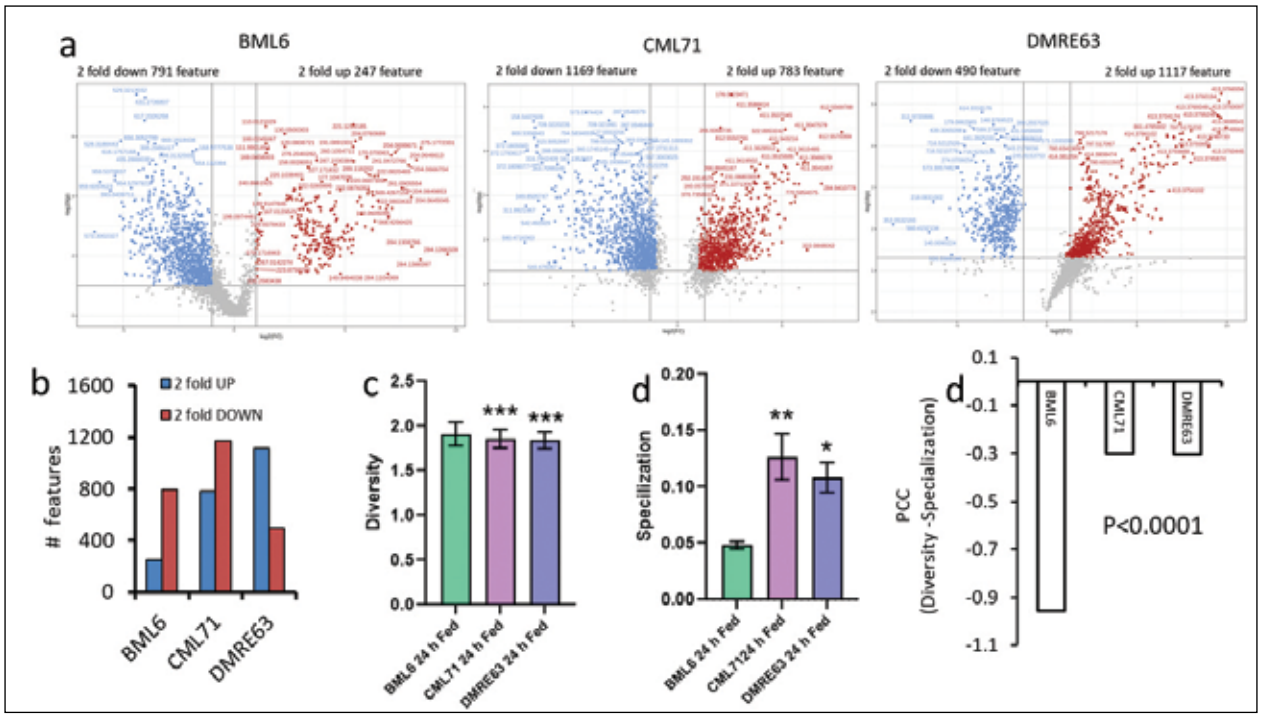


Morphological observation of collected *U. virens* isolates.

Marker assisted stacking of yellow mosaic disease resistance, null Kunitz trypsin inhibitor, null lipoxygenase-2 genes, and broadening the genetic base of soybean: Based on the multilocation evaluation of 322 germplasm accessions and zonal check varieties, diverse parents were identified for hybridization programme under AICRP on soybean. For different agroclimatic zones, hybridizations between the adapted variety of the zone and the diverse germplasm were identified based on the D^2 analysis. A set of 250 inter-specific RILs of soybean (F_{10}) developed at IARI, New Delhi, were grown during kharif 2022.. Wide variations were observed among the RILs for the traits studied. Several lines with a higher number of pods per plant, yield and resistance to yellow mosaic virus were identified for crossing. A total of 10 accessions of landrace (*Glycine max*) and 2 accessions of wild-type soybean (*Glycine soja*) including 4 HYVs were collected and multiplied. About 200 F_1 seeds for various cross combinations were harvested and grown. Hybridity testing confirmed 90 true F_1 plants.

Sustainable management tools for Fall Armyworm *Spodoptera frugiperda* (J.E.Smith) in maize: The maize genotypes *viz*., CML 44 BBB (3.0), DML 163-1 (3.5), and IML 16-248 (4.0) were found promising based on leaf damage rating (1-9) scale for foliar resistance to FAW artificial infestation. The expression study of lipoxygenase and BXs pathway genes and correlation analysis of jasmonate and BXs metabolites indicated that induction of toxic BXs accumulation in resistant genotypes depends on JA signalling pathway. Higher content of threonine (Thr) and arginine (Arg) were found in BML 6 (susceptible line) and was lower in resistant lines (DMRE 63, CML 71). Five geographical populations of FAW were assessed for molecular diversity using Tpi marker to resolve the ambiguity in mtCOI-based strain identification. All were identified as corn strains based on nucleotide variations at positions 168, 180, and 183 of the Tpi exon, where a few individuals also had Corn-Rice inter-strain signatures at certain positions. Also, more than 90% of the FAW population in India is corn strain according to sequenced data and NCBI data.

Exploiting alien genetic resources for developing climate resilient wheat and understanding mechanism of heat tolerance: The germplasm comprising of 400 accessions including wild relatives and progenitors of wheat phenotyped for heat stress tolerance was genotyped using 35K Axiom SNP chip to identify the novel genes/QTLs. Under late sown conditions, the major SNPs for SPAD and CFL were found on 2A, 3A, 11 SNPs for GFD on 3A and 2B, and 5 SNPs for TGW on 2B, 3A, 5D, 6B and 7B and under timely sown conditions



Differentiation of metabolite profile alteration pattern in three maize genotypes upon FAW feeding.

major SNPs for SPAD and CFL were identified on 2B and 7A, for GFD on 1D and 2A, 24 SNPs for TGW on 1B, 5A and 5B. Using a set of 310 *T. durum* / *Ae. speltoides* BILs phenotyped for heat stress tolerance and genotyped by sequencing, 50 QTLs were detected on all the chromosomes except 7B. Consistent QTLs were detected for various heat tolerance traits under OE and HE across the years. Under HE, seven QTLs *QSn.pau-Td-HE-2B*, *QSn.pau-Td-HE-7A*, *QPl.pau-As-HE-3B*, *QGw.pau-Gw-Td-HE-1B*, *QGps.pau-Td-HE-2B*, *QGfd.pau-Td-HE-2A.2* and *QDtm.pau-As-HE-6A* were detected. The QTL for SL QSL.pau-DS-OE-HE-5A on chromosome 5A was detected under both OE and HE. For HTI of the phenotypic traits six QTLs *QHti-Sn.pau-Td-7A*, *QHti-Sl.pau-As-5A*, *QHti-Pl.pau-As-2A*, *QHti-Gfd.pau-As-1B*, *QHti-Gfd.pau-As-6A* and *QHti-Dtm.pau-As-1B* were mapped that were found to be stable across the years.

Super donors and alleles for spikelet fertility and low chalkiness under thermal stress in rice: To identify the rice donors having a higher ability to withstand the challenges posed by high temperatures, 435 *indica* rice accessions were imported from the 3000 sequenced accessions, with an aim to phenotype them under high temperature stress for spikelet fertility and grain chalkiness. A panel of 150 diverse accessions from the 3K rice genome panel of IRRI was assembled, and extensively phenotyped in the Phenomics Facility under well-watered (100% FC) and water limited (60% FC) conditions. The traits showed remarkable consistency across water regimes and seasons indicating a strong genetic control of physiological traits. It was demonstrated that leaf mass area (LMA) was closely related to NAR and was an important determinant of drought resistance. Results of stomatal traits measurements revealed that higher stomatal frequency combined with small size showed higher WUE. Molecular analysis using the large SNP database available for these genotypes led to the identifications of robust QTL associated with these traits by GWAS.

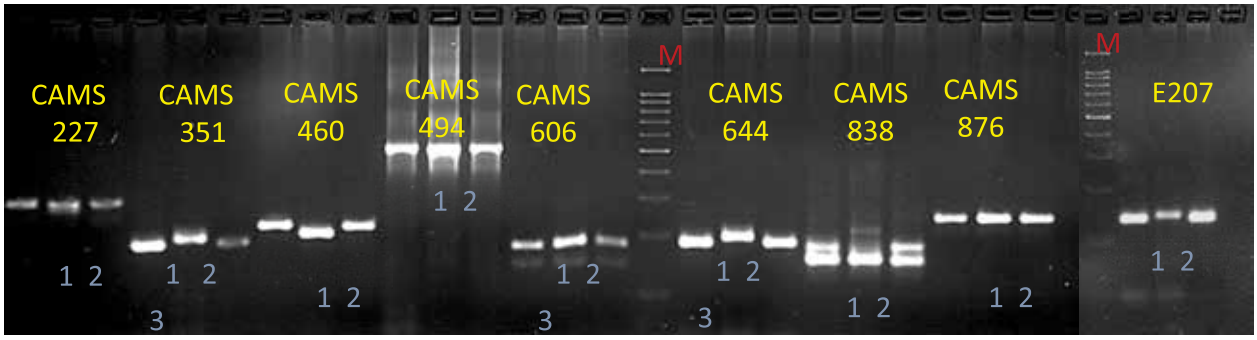
Role of dietary trace minerals in animals under biotic and abiotic stress conditions: Experimental study in rats fed purified diets under heat stress conditions revealed that higher dietary selenium at 300 and 450 ppb levels had positive effects on blood haemoglobin and serum calcium and phosphorus concentrations in rats under heat stress condition. Selenium at 450 ppb level ameliorated heat stress induced harmful effects by improving antioxidant status, regulating thyroid and insulin hormone, reducing inflammatory cytokines and improving humoral immunity indicating higher requirement of dietary selenium under heat stress conditions. higher zinc at 24 and 36 ppm level lowered oxidative stress biomarker in rats. Feeding 36 ppm zinc in the diet reduced hepatic

Metallothionein-1 (MT-1) gene expression irrespective of stress condition, however, endotoxin exposure up-regulated intestinal zinc transporter genes (ZIP-1 and ZnT-1) expression in rats fed diet containing 12 ppm zinc, but higher zinc at 24 and 36 ppm concentration resulted in down-regulation of zinc transporter genes under healthy as well as endotoxin stress conditions.

Potential gene mining from salt tolerant grasses for improvement of salt tolerance in crops: Thirty-four differentially expressed genes (DEGs) from grass halophytes, *Urochondra setulosa* and *Dichanthium annulatum* showing high level of expression during salt stress were compared with DEGs in salt tolerant rice, CSR10, during reproductive stage @12 and 18 dsm^{-1}.The analysis showed two genes involved in trehalose metabolism (*Trehalose 6-P synthase*, *Trehalose 6-P Phosphatase*) were co-expressed both in *Urochondra* and *Dicanthium* at salt stress >18 dsm^{-1}. However, co-expression pattern was not identified in CSR10 @ 18 dsm^{-1} and in contrast *trehalase* gene was differentially expressed in salt stress. Differential co-expression of trehalose biosynthesis genes could be one of the major mechanisms for hypersalinity tolerance in *Urochondra* and *Dicanthium*. Next, *dehydrin* gene from *Urochondra* was cloned in pCAMBIA1304 binary vector and transformed in CSR10.

Molecular mapping and identification of candidate genes for anthracnose fruit rot disease resistance in chilli (*Capsicum annuum* L.): A total of 357 F_2 segregating populations along with contrast parents were genotyped. Based on GBS analysis, aligned with *Capsicum baccatum*_CM008444.1 and *Capsicum baccatum*_PBC81, whole genome sequence data, 8644 SNP markers were identified and consensus linkage map was developed. The distribution of SNPs observed across the 12 chromosomes. The SNPs located on Chr2 and 6 were validated in F_2 and $F_{2:3}$ phenotyped populations using the SSR primers designed specific to the regions where SNPs are present. The candidate genes (2 each located on Chr 2 & 6) linked to anthracnose fruit rot resistance were identified. Through GWAS, two major genomic regions were identified which are located on chr2 and chr6 as candidate resistance loci associated with anthracnose fruit rot in chilli. A total of 19 SNPs (QTNs; Quantitative Trait Nucleotides) were found to be significantly associated with fruit rot resistance (at –log10 (p) value >2.82 for % lesion area), of which five SNPs were located on chr2 (physically positioned at 12666827bp to 141379584bp) and seven SNPs were located on chr6 (physically positioned at 247161384bp to 252255814). Resistance related genes within the candidate genomic regions on chr2 (major locus) were searched on pepper pangenome, which revealed a cluster of nucleotide biding site leucine-rich repeat (NBS-LRR) domain involved in disease resistance in plants. The identified SNPs associated with candidate resistance loci were validated in the segregating populations and could be used in Anthracnose Fruit Rot Resistance (AFRR) breeding program.

Chemotyping of bioactive metabolites in *Hemidesmus indicus* and *Costus speciosus*: The germplasm and rhizospheric soil of 141 samples of *Costus speciosus* (rhizome) and 96 samples of *Hemidesmus indicus* (root) were collected and passport datasheet was prepared and all the GPS coordinates were documented for each collection after mapping and actual field assessment. The collected rhizome/root samples were evaluated for quality parameters as per guidelines of *The Ayurvedic Pharmacopoeia of India*. Diosgenin and Vanillin are the bioactive

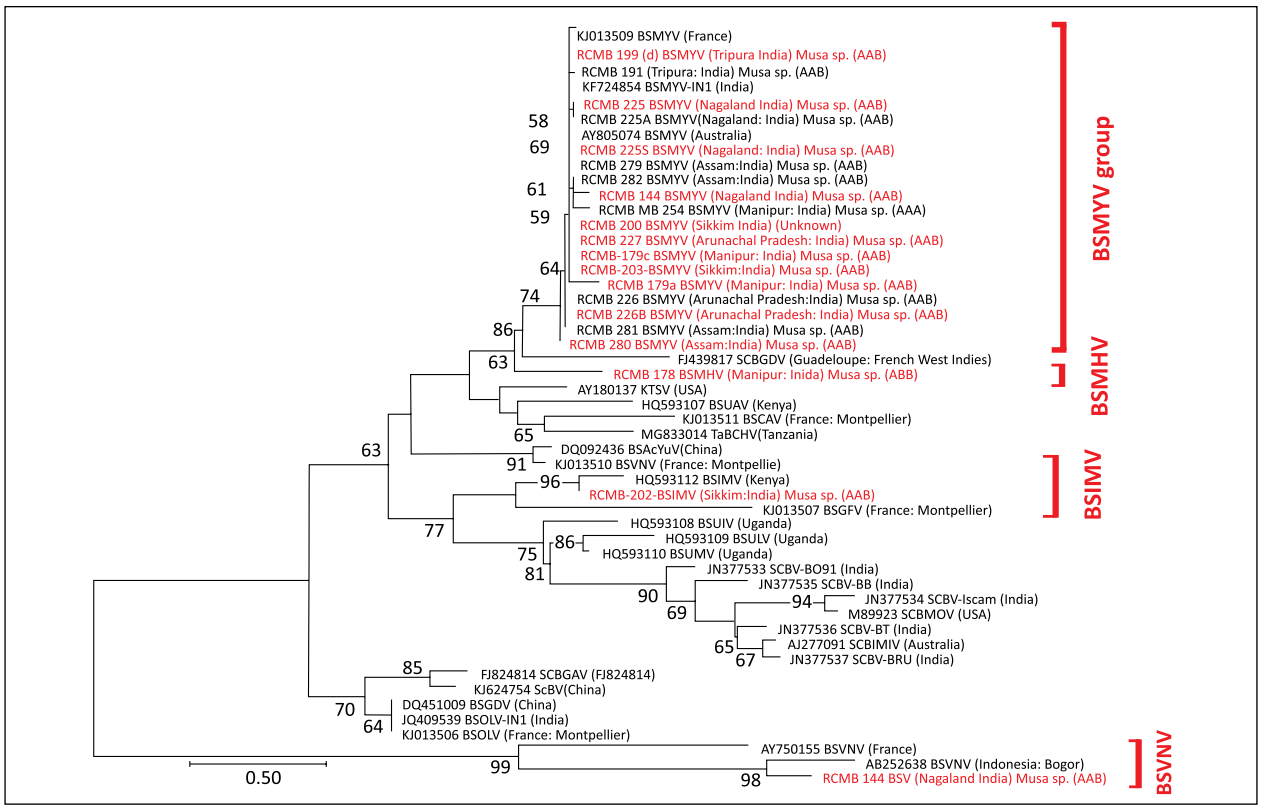


1- Resistant parent 1 (PBC 80); 2 - Susceptible parent (Belly); 3- Resistant parent 2 (PBC81)
Amplification pattern of SSR markers in PBC-80, PBC-81 and Belly type chilli lines.

compounds in *Costus speciosus* and *Hemidesmus indicus*, respectively which have high market potential and industrial demand. These two compounds were quantified in all the collected samples for identifying the elite germplasms. Significant chemical variations were observed among the germplasms within the same phyto-geographical zone as well as within different zones also. Two elite chemotypes were identified *viz.* NBCS-88 with maximum content of Diosgenin (2.405%, on dry weight basis) from *Costus speciosus* and NBH-35 with maximum content of Vanillin (0.0127%, on dry weight) from *Hemidesmus indicus*. Identified elite chemotypes are useful as quality planting material for its commercial cultivation leading to supply of Quality Raw Material (QRM) for herbal drug industries, in turn having huge socioeconomic benefit.

Population diversity of banana streak viruses (BSV) and understanding the mechanisms of resistance to BSV in diploid seedy banana of North East India: Analysis of the genetic diversity of *Musa* species/subspecies from North East India and integrated endogenous *Badnavirus* sequences was carried out in the study. A total of 285 banana mats/genotypes collected from different groves of North Eastern (NE) states were characterized for endogenous banana streak viruses (eBSV), which indicated the prevalence of distinct/novel alleles having similarity to endogenous banana streak OL virus (eBSOLV), banana streak IM virus (eBSIMV), banana streak GF virus (eBSGFV) and *Musa balbisaina* PKW type activable alleles, the allelic positions of which make them activable. Activable eBSV being harbored by banana genotypes of NE India are potential blueprints of episomal BSV diversity. Full-length cloning of 14 episomal BSV isolates (sampled from Manipur, Nagaland, Sikkim, Tripura, Arunachal Pradesh and Assam) and sequencing was done. Whole genome sequence of a new badnavirus banana streak MH virus (BSMHV) associated with streak disease of banana cultivar *Metei Hei* (ABB) grown in Manipur was achieved. Banana streak MY virus (BSMYV) appeared to be the most prevalent episomal badnavirus associated with streak disease of banana genotypes (AAA, AAB, ABB) in NE India.

The *de novo* comparative transcriptome analysis of agroinfected Bhimkol versus mock/healthy samples showed changes in some key mechanism of agroinfected plants. Analysis of

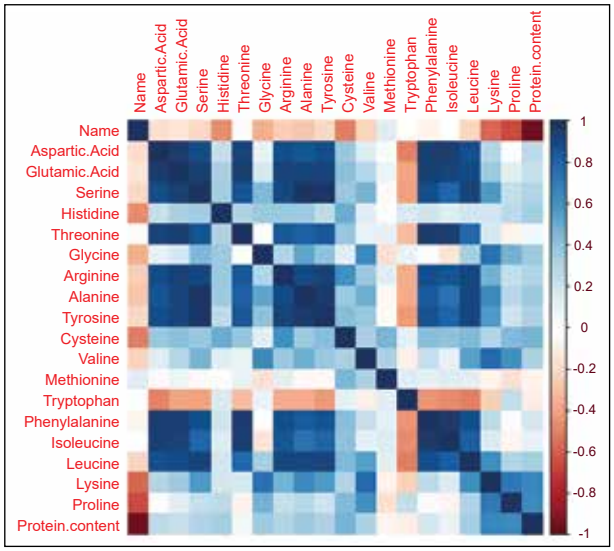


Neighbour joining phylogenetic analysis of characterized episomal BSV isolates from NE India based on conserved RT/RNase H genomic region (580 bp). The isolates highlighted in red are those which were characterized in the present study.

Batch of tissue culture raised *Grand Naine* (AAA) and *Musa balbisiana* (BB) plants agro-inoculated with 1.8-mer dimer (BSMYV) and viral suppressor (Hc-Pro/p19).

the differentially expressed genes (DEGs) in response to BSMYV induced stress between the healthy/mock and the agroinfected Bhimkol sample revealed a total of 1,138 transcripts to be upregulated and 2,036 transcripts downregulated. On the basis of the DEG analysis, virus-host interaction in *Musa balbisiana* was found to bring changes in: (i) cellular signaling machinery, (ii) host gene expression, (iii) hormonal signalling, (iv) cellular metabolism, and (v) host protein degradation pathway.

Mapping and transcriptome analysis of seed protein, β-carotene and mineral contents in chickpea (*Cicer arietinum* L.): Chickpea genotypes were characterized for nutritional traits such as total seed protein, minerals (Zn and Fe content) and β-carotene content. Four hundred four chickpea germplasm were characterized for total seed protein content at ICAR-IARI New Delhi, PAU Ludhiana and ICAR-IIPR Kanpur and for Fe, Zn and β-carotene at ICAR-IARI, New Delhi and PAU, Ludhiana. High yielding cultivars were found to contain higher amounts of seed Zn and Fe. There was negative correlation of phytic acid with Zn & Fe. GNG2171, KWR108, Pusa128, JAKI9218, GBM2 and Phule G 95311 were the HYVs containing high Fe and Zn with low phytic acid (4-5 mg/g). High protein genotypes had higher amounts of essential amino acids. Sulphur amino acids showed negative correlation with protein content. The expression analysis of more than 125 genes (across all the traits) was validated qRT-PCR analysis in mature seeds. Zinc and iron contents ranged from 1.10 – 5.91 mg/100g and 0.50 – 8.54 mg/100g, respectively and were comparable to some of the best bio fortified crops of Harvest Plus target levels. High yielding chickpea cultivars were found to contain higher

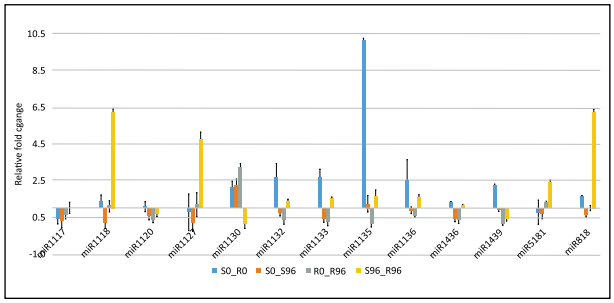


Pearson correlation coefficient among amino acids and protein content of chickpea genotypes.

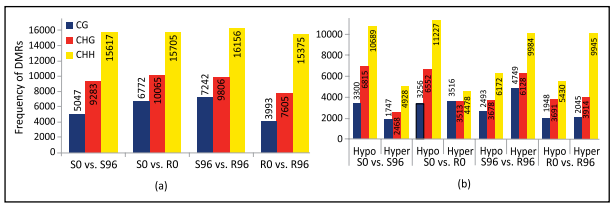
amounts of seed zinc and iron at ICAR-IARI, New Delhi and PAU, Ludhiana. Heera, H82-2 and H214 for Zn; and L550, KGD1168, PG114, JG74 and ICCV6 for Fe are the cultivars identified with higher contents of Zinc (>4 mg/100g) and iron (>6 mg/100g). Analysis of phytic acid in cultivars with higher mineral contents showed negative correlation with zinc and iron. Seed β-carotene content ranged from 248.76 µg/100g (Pusa 72 and ICC 5948) to 538.11 µg/100g (ICC 5002). Transcriptome analysis for seed protein and zinc content using contrasting cultivars identified conserved and novel miRNAs with respect to seed protein content. Large numbers of differentially expressed genes (DEG) were identified with respect to seed protein and zinc contents between contrasting genotypes. Validation of conserved miRNAs in two cultivars revealed presence of miR399 and miR398 exclusively in high seed protein content cultivar i.e. ICC8397. The expression analysis also resulted in differential expression of miRNAs in two contrasting cultivars. Six of the DEG validated in high and low seed protein genotypes through real-time PCR. Target prediction of miRNAs revealed genes encoding seed storage proteins and their sub-classes as important target genes for both conserved and novel miRNAs.

Epigenetic regulation of host-pathogen genetics in leaf rust resistance of wheat: Leaf rust caused by *Puccinia triticina* is a major devastating disease of wheat. This study aimed at unraveling the underlying mechanism of leaf rust disease resistance at the molecular

level. Leaf tissue samples from seedlings raised at National Phytotron Facility, IARI, New Delhi having four treatments (two biological replicates of each treatment) were collected. A total of 50 miRNAs and 1178 lncRNAs were identified through *in silico* analysis of RNA-seq data, of these, 16 miRNAs and 22 lncRNAs were differentially expressed. Expression of 8 miRNAs was induced in resistant NIL which targeted several important genes including disease responsive genes. As many as 49 lncRNAs were found to be the targets for miRNAs; the results were also validated using qRT-PCR analyses. Role of histone modification (H3K4me3 for activation and H3K27me3 for repression) was examined using ChIP-Seq; several differentially binding sites (DBSs) and the associated genes for modified H3 were identified. Next, the role of DNA methylation was examined using bisulfite sequencing and context specific (CG, CHG and CHH) differential methylation was observed during compatible and incompatible interactions. A number of disease response genes undergoing differential methylation were identified including the cross interactions involving histone modifications, gene expression and DNA methylation. The results were validated using qRT-PCR and Chop-PCR. The computational prediction of non-coding(nc) RNAs and effectors was carried out in the available *P. triticina* genome sequences; some of these ncRNAs/effectors were validated using qRT-PCR.

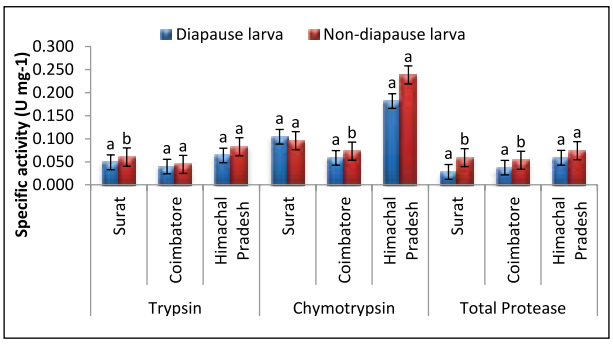


Relative fold change of miRNAs in mock (S0_R0), susceptible (S0_S96), resistant (R0_R96) and susceptible vs resistant treatment 96h after pathogen inoculation (S96_R96).



Distribution of (a) context-wise DMRs and (b) hypo/ hypermethylated DMRs in four pairs of comparisons. Hypo, hypomethylated; Hyper, hypermethylated.

Expression of resistance to diapausing and non-diapausing spotted stem borer (*Chilo partellus*) in sorghum and maize: The genetic and biochemical variation in diapausing and non-diapausing populations of spotted stem borer, *Chilo partellus* in India was studied in this project. The proteolytic activity in diapause (aestivation) and non-diapause larvae of *C. partellus* at different locations showed that trypsin activity was significantly higher in non-diapause larvae (0.060 U mg^{-1}) as compared to aestivation diapause larvae (0.049 U mg^{-1}) of the Surat population. Chymotrypsin activity was significantly higher in non-diapause larvae (0.073 U mg^{-1}) when compared with aestivation diapause larvae (0.059 U mg^{-1}) of the Coimbatore population. Total protease activity was significantly higher in non-diapause larvae (0.059 and 0.053 U mg^{-1}) as compared to aestivation diapause larvae (0.028 and 0.037 U mg^{-1}) of Surat and Coimbatore populations, respectively, while no such significant differences were observed between non-diapause and diapause larvae of Himachal Pradesh population with respect to trypsin, chymotrypsin and total protease activities. Significant differences were observed between the population from different locations (P <0.01) with respect to proteolytic activities in the midgut of *C. partellus* larvae.

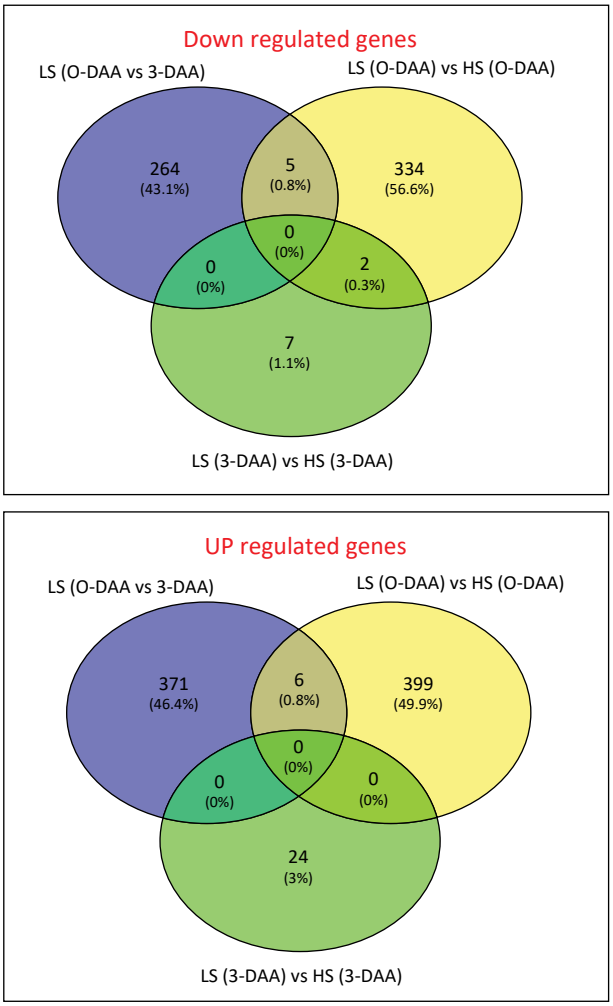


Proteolytic activity in diapause (aestivation) and non-diapause *C. partellus* larvae at different locations.

Role of environmental factors and host plants on induction and termination of diapause in *C. partellus* showed significant differences between the larval populations of *C. partellus* from different locations (Fp <0.001) with respect to induction of diapause at higher temperatures (35^{0}C) when reared on artificial diet. Seven sorghum genotypes comprising two resistant lines (IS 18551, IS 2205), two

susceptible lines (Swarna, DJ 6514) and improved moderately resistant lines (ICSV 1, ICSV 700, ICSV 93046) were evaluated for their reactions at eight locations (Akola, Coimbatore, Indore, Hyderabad, Ludhiana, Palem, Parbhani and Surat) under natural infestation during *Kharif* 2017. Irrespective of sorghum lines, there were significant differences in reaction to stem borer across the locations in terms of leaf damage score (LDS) (1-9), deadhearts (DH) at 45 DAE and number of exit holes/ stalk (EHS). Based on deadhearts percentage, there was significantly more damage at Surat (22.9%) which was not significantly different from Hyderabad (21.8), Indore (18.3%). The damage was low at Parbhani and Ludhiana. These results indicated significant variations in biological parameters on various genotypes, which could be due to genetically diverse *C. partellus* populations in different agro-climatic zones of India.

Low ovule-to-seed ratio in range grasses, genetical and physiochemical basis: The study involved hormonal studies in developing embryo. The influence of exogenous hormonal spray on seed setting was examined by spraying 100 ppm IAA, GA3, kinetin, NAA, cobaltous nitrate and 200-ppm TIBA. The effect of hormones differed in both the lines. In high seed setting line (IG96 593), TIBA was found to enhance both the number of spikelet and seed per spike. However, the seed setting per se was non-significant due to hormonal treatment. In low seed setting line (IG96 124), the kinetin treatment showed significant enhancement in number of spikelet and seeds resulting in no increase in seed setting percentage. Furthermore, pollen viability and stigma receptivity were studied using different pollen staining solutions. The pollen sterility of 4-12% was observed in both the seed setting lines using different staining solutions. Pollen viability was found to reduce with time after dehiscence in both the lines. To identify genes involved in embryogenesis, two cDNA libraries were constructed from tissues of ovules representing pre-fertilization (early stigma emergence or 0-DAA) and early fertilization stage (post stigma emergence or 3-DAA) from low (LS) and high seed setting (HS) genotypes of *Cenchrus ciliaris*. A total of 9,922,396 and 5,831,569 reads were generated from LS from 0-DAA and 3-DAA libraries, respectively. A total of 11,004,158 and 12,676,405 reads were generated from HS from 0-DAA and 3-DAA



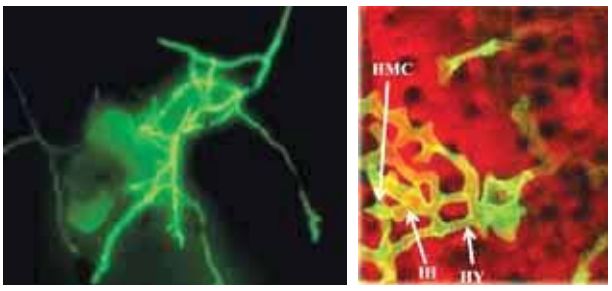
Venn diagram of DEGs based on pairwise comparison of two libraries (0-DAA and 3-DAA) between LS and HS genotypes

libraries, respectively. The expression levels of the assembled transcripts were analysed by using threshold value of false discovery rate (FDR) with adjusted p value ≤ 0.05 and $\log_2$ fold change ≥ 2. The up- and down-regulated transcripts in 0-DAA library between LS and HS were 405 and 341, respectively. While 24 and 9 transcripts were up- and down-regulated in 3-DAA library between LS and HS, respectively. The important genes identified through transcriptomics study were validated based on differential expression of transcripts. A total of 35 primers representing different functional genes were designed and evaluated for amplification.

Molecular cross-talk between defense pathways in rice: Antagonism to synergism: Fourteen key defense genes were previously identified through microarray analysis of global genome expression profiles modulated under combined challenge of BB (bacterial blight) +

GM (gall midge) or BB+BL (fungal blast) in the selected gene pyramided lines. Further, the expression of some key genes like cytochrome P450 family gene, terpene synthase, Bowman-birk type trypsin inhibitor, lipoxyginase, and glucan endo-beta glucosidase was found to be relatively inhibited in plants subjected to combined challenge by either BB+BL or BB+GM as compared to those in plants with single-pest attack. The examination of possible antagonism and their impact on manifestation of resistance showed no adverse effect of pyramiding of the genes on expression of resistance against the target pests.

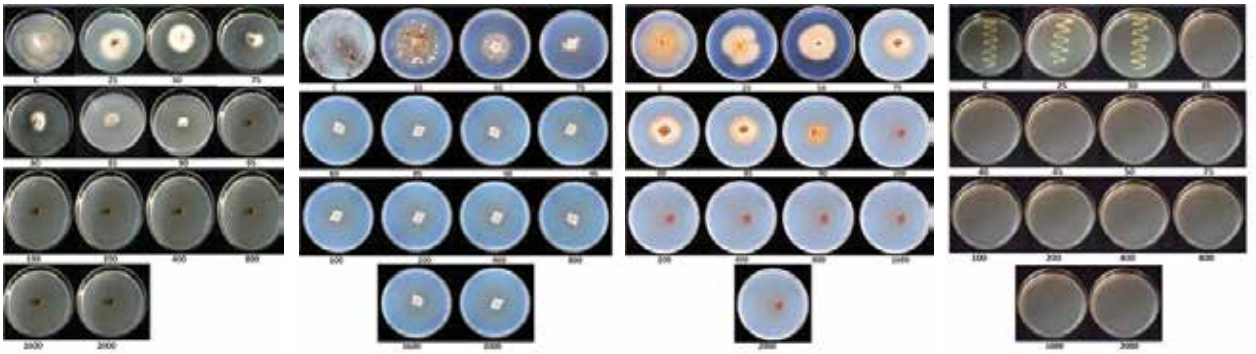
Mechanisms of non-host resistance (NHR) against rust and blast in rice and wheat: The role of three different epigenetic modifications *viz*., sRNA, histone modifications and DNA methylation were investigated. The work on miRNA revealed several conserved sequences. Using qRT-PCR, three miRNAs were also validated. Targets of differentially expressed miRNAs were also identified using degradome data and other *in silico* approaches. Genes encoding effectors and some ncRNAs in *Puccinia triticina* (Pt) genome were also identified from the available transcriptome and EST data using *in silico* approaches. A total of 57 rice accessions including seven cold tolerant varities were screened against non-host pathogen, *Puccinia graminis tritici* 40A. It was observed that *Puccinia graminis tritici* 40A interacts with rice genotypes, albeit without any pustule formation. Not only had the *Puccinia graminis tritici* 40A recognized rice plant, but entered the rice stomata and colonized intercellular spaces of several mesophyll cells with concomitant and spontaneousdefense responses.



Recognition and entry of *Puccinia graminis tritici* 40A into stomata of rice plant.

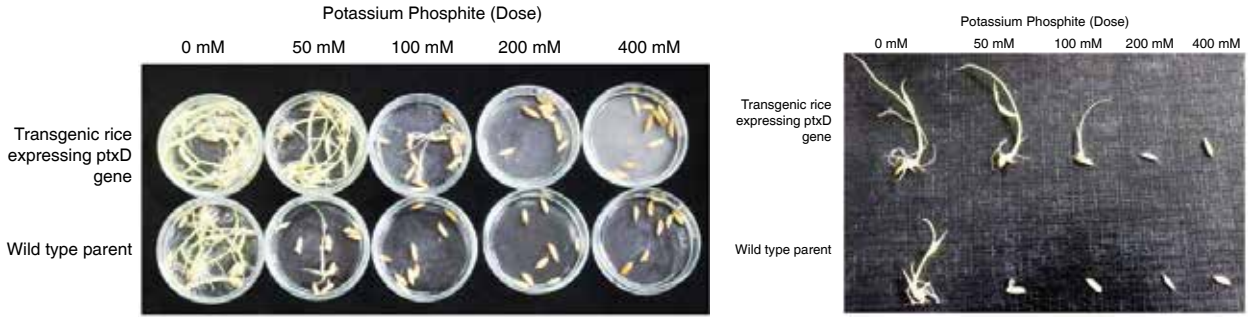
Molecular mechanism of induction of biotic stress tolerance by *Trichoderma* spp. in castor (*Ricinus communis* L.): Early events of colonization of castor roots by *Trichoderma* established that the fungus entered roots through the intercellular spaces and colonized in the apoplastic region of the roots. It was demonstrated that 1-hydroxy-3-methyl anthraquinone (1H3MAQ), present only in the secretome of P+T (plant + Trichoderma) treatment but not in either P or T treatments, suggesting a candidate elicitor triggering the ISR in castor. To study the ability of 1H3MAQ and six analog derivatives were synthesised chemically. These were confirmed with spectral readings and properties. These seven compounds (1H3MAQ and six derivatives) were checked for direct antifungal activity against various plant pathogenic fungi like *Fusarium oxysporum*, *Aspergillus niger*, *Phytophthora infestans* and *Botryytis ricni*. The parent compound demonstrated reduction in fungal growth in comparison to the other analogs.

Double herbicide tolerant transgenic rice: weed management: Potassium phosphite displayed dosage as well as pre-existing PO_4 dependent inhibition of organisms; complete *in vitro* inhibition of fungal pathogens was observed at 80-95 mM on *Magnaporthe oryzae* causing blast disease, *Rhizoctonia solani* causing sheath blight, and *Fusarium fujikuroii* causing bakanae disease. Potassium phosphite was able to completely inhibit *X. oryzae* pv. *oryzae* at 35 mM and above. Potassium phosphite could control rice blast and bacterial blight in rice upon spray at 100-200 mM that revealed its potential as fungicide and bactericide. Potassium phosphite spray at 500-1000 mM on rice grown on P rich soil showed little herbicidal action with phosphate starvation symptoms on weed. Neither potassium phosphite nor the recommended herbicide check, Bispyribac Na showed any carry over herbicidal effect on weeds in next season indicating the potential of phosphite as safe herbicide. While transgenic rice expressing ptxD germinated in the presence of potassium phosphite, the non-transgenic rice showed no germination indicating its pre-emergence effect. NGS based metagenomics and conventional microbiological tool based phyllosphere microbiome analysis revealed no adverse effect of ptxD gene expression on microbiome of rice as both the plants recorded identical phyllosphere microbial communities. Pattern of species distribution and their relative abundance was nearly identical in 45 and 90 days old transgenic and non-transgenic



Effect of potassium phosphite on major rice pathogens

Effect of potassium phosphite on blast incidence in rice on non-transgenic rice



Effect of potassium phosphite on germination of rice

parent rice. Species such as *Rhizobium rhizogen*, *Flavobacterium* sp IGB-4-14, *Herpetosiphon aurantiacus*, uncultured Gram-positive bacterium, *Cellovibrio tontiphilus*, uncultured soil bacterium, *Uncultured Rickettsiales*, *Flavobacterium fontis* and uncultured proteobacterium were found on both rice types. The data revealed potential of potassium phosphite at 200-400 mM as fungicidal and bactericidal compound for use as an agroinput in rice cultivation.

Development of transgenic pigeon pea and chickpea: Event selection trials of transgenic pigeon pea and chickpea were conducted at ICAR-IIPR, Kanpur to identify the best event each in pigeon pea and chickpea, based on trait efficacy (resistance to gram pod borer), expression of Bt protein at various stages and related agronomic characters including yield. PCR analyses with gene-specific primers revealed segregation of transgene in the progenies and presence of vector backbone in few of the events. Expression of the Bt gene was detected in all the positive progenies of the transgenic lines. However, the expression of the gene drastically dipped post-flowering stages. Insect bioassay was conducted both in filed condition and *in vitro* conditions, and mortality of larvae was correlated with protein expression. Event characterization including flanking sequence analyses of two best events (each in chickpea and pigeon pea) were done.

At IIPR, Kanpur, a total of 100 putative chickpea transformants and 51 putative pigeon pea transformants were generated using *Agrobacterium*-mediated genetic transformation. Genetic fidelity of the transgenic chickpea lines derived from DCP92-

Pigeon pea

Chickpea

Event selection trial in chickpea and pigeon pea and chickpea

3 was assessed using SSR markers having genome-wide coverage. Detached leaf bioassay was conducted in T_1 lines derived from two chickpea events using third instar larvae. Based on molecular analyses and insect bioassay data, three promising events each in chickpea and pigeon pea were identified for event selection trial, and application submitted to RCGM, Department of Biotechnology, New Delhi. At AAU, Jorhat, more than 200 transgenic lines were generated in chickpea using different Bt-*Cry* gene constructs harbouring either a *Cry1Ac* or a *Cry2Aa* gene. Of these, 12 lines had high level of Bt toxin (>30 ng/mg FW) and in 9 of these 12 lines, transgene segregated at a ratio of 3:1. Lines with complete protection against *Helicoverpa* were obtained. At UAS, Dharwad, 202 primary transformants for *cry1Ac* and 216 primary transformants for *cry2Aa* in pigeon pea were generated. A total of 53 *cryAc* positive and 20 *cry2Aa* positive plants were selected, and the bioassay of all 53 transformants showed a maximum mortality of about 90.0%. In two events, the progenies showed 15:1 segregation. In the progenies maximum larval mortality observed was about 84.0%.

Agrocin producing *Agrobacterium radiobacter* for biological control of crown gall in stone fruits: A native non-gall forming isolate of the bacterium *Agrobacterium radiobacter*, isolate UHFBA-218 (Cherry 2E-2-2) showed control of crown gall of peach by 92.14% compared to 74.19% by strain K-84 of the bacterium that is used world over as seed treatment on peach. The disease incidence in untreated plants was 84.92%.

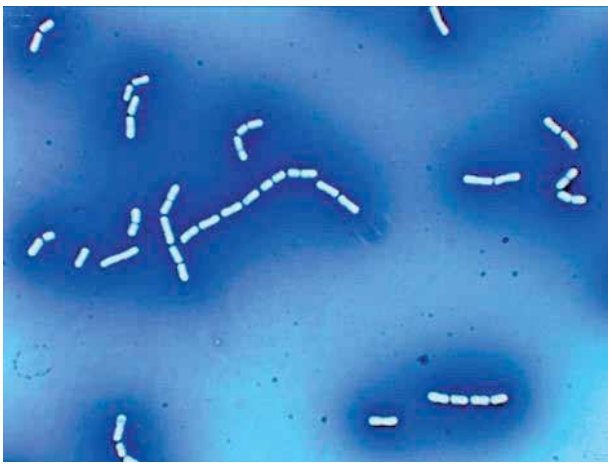
Epidemiology and forewarning system of downey mildew disease of cucurbits to develop appropriate IPM strategy: A rule-based prediction model for predicting onset of downy mildew disease, the most important disease of cucurbits, was developed and validated combining average daily temperature and night leaf wetness duration. The model was validated on three cucurbit crops at the experimental station in 2010 and 2011 with 75% success. The model is now being tested in farmers' fields.

Role of small signal peptides in systemic defense response of Indian mustard *(Brassica juncea)* to aphids *(Lipaphis erysimi)*: The genes like *BjEli1* and *BjEli2* which trigger the defence system of mustard plants to aphids were identified, cloned and validated. The results of fungal bioassay established the capability of *BjEli1* to restrict the disease lesion size and intensity of the alternaria blight fungus, *Alternaria brassicae*. Plants of the mustard cultivar BYSR constitutively expressing *BjEli2* showed higher expression of several defence genes, and in insect bioassay using aphid nymphs showed significant inhibition of growth and multiplication of aphid population.

Development of autotransgenic Asian Catfish *Clarias batrachus* L: Functional autotransgene constructs having Histone 3 and β-actin promoter driving growth hormone gene along with 3´ regulatory sequences for *Clarias batrachus* (Indian catfish magur) were made and gene delivery methods were successfully standardized: microinjection in Zebrafish and in magur embryo and sperm mediated electroporation in magur. Autotransgenic

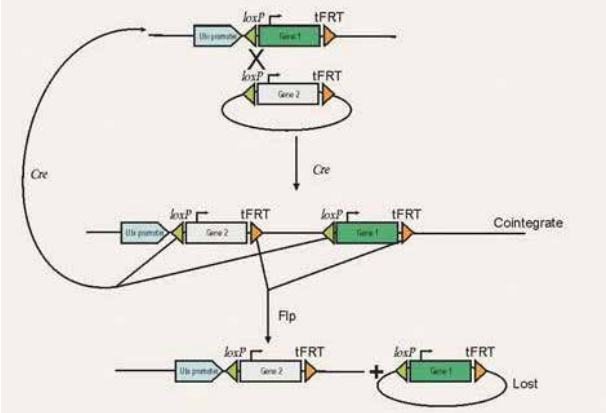
fish could be made with these constructs and confirmed by three independent assays: PCR, sequencing and southern blotting and functionality of the autotransgene was confirmed by western analysis.

Gene-based genetic maps and molecular markers for biotic and abiotic stress tolerance in cultivated groundnut: Among the 52 bacterial and 20 fungal endophytes from the Rann of Kachchh characterized, five fungal and 38 bacterial endophytes were found to tolerate 10% NaCl concentration and 50°C temperature which would be useful in using them to study alleviation of abiotic stress tolerance in groundnut.



Bacillus megaterium RE7: a root endophyte of groundnut

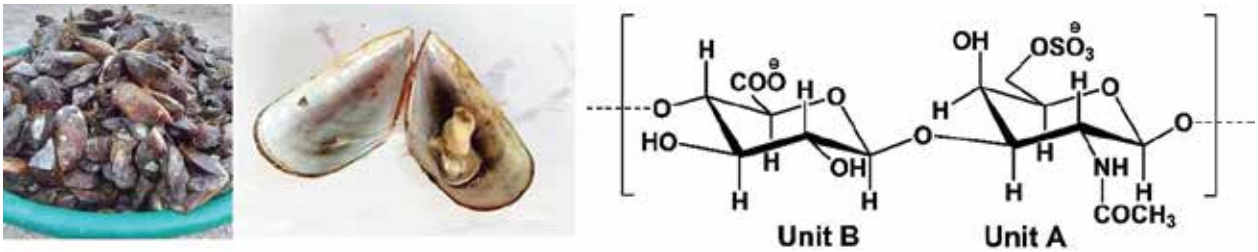
Targeted gene integration in rice and cotton: The available plant transformation methods poses challenges such as random integration, multiple transgene copies and unpredictable transgene into a predetermined locus in the plant genome. Therefore, a technique was developed for gene integration into the desired sites on chromosomes. The efficacy of the method was tested in rice and the success rate was as high as 17%. This technique was, for the first time, applied in transgenic research studies in plants.



Schematic diagram of the target gene integration strategy

Off-season flowering and fruiting in mango: Peclobutrazol (PBZ, early flowering inducer hormone) application to advance the flowering in different agro-climatic zones showed success in off-season mango at temperatures as low as 14'C. Furthermore, lower temperature was a limiting factor for producing off-season mangoes. The application of peclobutrazol during March was successful in producing off-season fruits in mango cv Rumani and Totapari at Chitoor in Andhra Pradesh. Two months early harvest of mango cv Totapari, i.e. during March-April significantly boosted the remunerative value of the variety by Rs. 10-15/ kg in Medak district of Andhra Pradesh. The same treatment on cv Dashehari recorded earliness in flowering by 45 days in Warangal district. Market price of early harvested fruits of Dashehari variety of mango was higher by Rs.40/ kg. Mango fruiting in cv Alphonso grown on lateritic coastal rocky areas of Konkan region could be advanced by two months and a half by the PBZ application between 15" May and 15th June and adopting suitable cultural practices.

Bioactives and Polysaccharides from Marine and Coastal Bivalves to develop Prospective Nutraceutical Products: Samples of marine/estuarine bivalves collected from Vizhinjam. (8° N, 76° E) and Kozhikode (11° N, 75° E) were used to develop extracts/fractions,



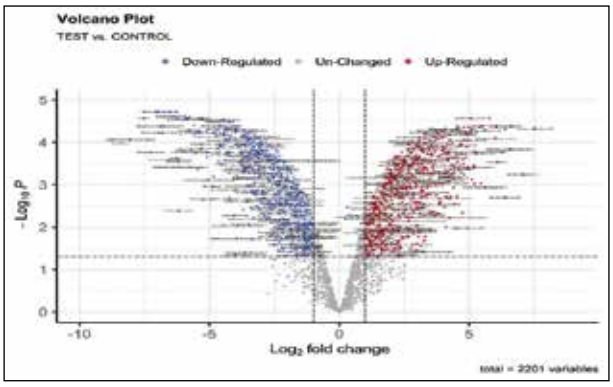
Sulfated glycosaminoglycan (PIP-2) isolated from brown mussel *Perna indica*

which were chromatographically fractionated to obtain oligosaccharide fractions. PIP-2 purified from brown mussel *Perna indica* was exemplified as [→1)-6-O-SO_3-β-GalNAc*p*-(3→1)-β-GlcA*p*-(4→], exhibited an anti-inflammatory effect on lipopolysaccharide (LPS)-induced macrophages. The sulfated glycosaminoglycan at different concentration ranges (10-50 µg/mL), downregulated the secretion of pro-inflammatory cytokines such as IL-1β (1.18-1.46 pg/mL), IL-6 (0.75-1.17 pg/mL), TNF-α (3.9-4.82 pg/mL) in LPS induced RAW 264.7 cells.

Purified polysaccharide (SCP-2) derived from *Saccostrea cucullata* yielded [→4)-β-GlcNS*p*-(1→4)-α-GlcA*p*-(1→3)-β-GlcNS*p*(1→]. SCP-2 downregulated nitric oxide production in LPS-stimulated RAW 264.7 macrophage cells with an IC_{50} of 5.4 µg/mL. A sulfated glycosaminoglycan, PVP-2, purified from the crude polysaccharide extract of *Perna viridis*, was established spectroscopically as [→4)-β-GlcNS*p*-(1→4)-β-GlcNS*p*-{(3→1)-α-GlcA*p*}-(1→]. At 3 µg/mL, PVP-2 effectively restores nitric oxide levels to homeostasis by downregulating excessive production. In further *in vivo* studies, SCP-2 and PVP-2 at 110 and 22 mg/kg body weight, respectively demonstrated a time-dependent escalation in the suppression of carrageenan-induced paw edema and effectively reduced edema by greater than 80% by the end of the 5-hour mark, mirroring the results achieved by the standard drug indomethacin (87%) at a dose of 10 mg/kg body weight.

Novel approaches for disease free health certification in finfish and development of high health shrimp for sustainable aquaculture: For developing MAbs, serum immunoglobulins (sIgs) of three Indian major carps, *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* were purified by affinity chromatography. Healthy fish were immunized with bovine serum albumin (BSA) to induce anti-BSA antibodies. Purified sIgs analysed by SDS-PAGE revealed two bands of ~80 kda and ~27 kDa, corresponding to heavy chains and light chains, respectively. Gel filtration chromatography of the sIgs revealed mixture of tetramers, dimers, monomers and half-mers in the purified preparation. These sIgs was used as an antigen to develop monoclonal antibodies. Effective dosage of prebiotic, inulin was determined for development of high health shrimp providing better growth and disease resistance. A dose of 20g/kg inulin coated on the feed showed 22-32% higher growth and prolonged survival to WSSV challenge than control. Expression of immune and growth genes was higher in experimental group. Metagenome analysis indicated higher bacterial diversity in the gut of experimental animal than in control. *Bacillus subtilis* isolated from the GIT of healthy shrimp was evaluated as probiotic by two methods, either by coating the feed or as one of the feed ingredients. Feed coated with the bacteria showed higher growth and disease resistance.

Vaccine against animal's haemoprotozoan parasites for mitigating biotic stress: Theileriosis is one of the economically important haemoprotozoan diseases of livestock. Proteomic analysis identified 2761 and 1814 specific proteins in *Theileria annulata* and *T. equi* with a total of 330 and 203 unique proteins found on bioinformatic analysis. Volcano plot analysis was performed, and proteins up and down regulated during *T. annulata* and *T. equi* infection were identified. Some merozoite surface proteins were identified which have specific importance during invasion process of the parasites. These were TAMS-1 and EMA-1, EMA-2 for *T. annulata* and *T. equi* respectively. These recombinant proteins were expressed as gst tagged in pGEX-4T 1 vector and purified on glutathione Sepharose beads.

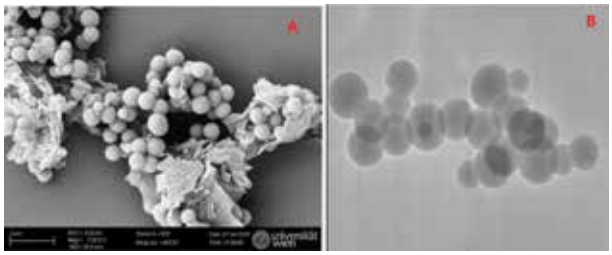


Volcano plot on the proteomic analysis of *Theileria annulata* parasites indicating up and down regulations of protein during infection.

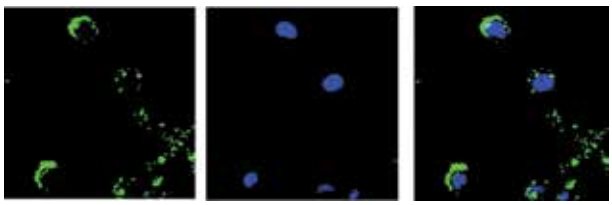
Captive breeding of hilsa, *Tenualosa Ilisha* -Phase II: Developed captive broodstock of hilsa 250 numbers of the size range of 400-600 g, which are being maintained in the freshwater culture facilities at Kolaghat and Rahara; and brackish water systems at Kakdwip of West Bengal. The fishes attained full maturity for the first time in captivity and two breeding attempts were undertaken with captive reared stock but

were unsuccessful at post-fertilization stage. Maintaining a stock of another 20 fishes in RAS system in which the males attained maturity. Non-invasive methods of *in situ* maturity determination technique of both females and males through ultrasonography has been developed for the first time in hilsa. Determined the dose of anesthesia for different life stages and successfully reduced handling stress. Developed feeds for larval, grow-out, and brood stock rearing phases tailoring specific requirements at different growth stages of hilsa. RAS rearing depicted feasibility of complete rearing in controlled facilities. Artificial spawning of hilsa using wild brood stock yielded 95-99 % fertilization and 75-89 % hatching success. The fry to fingerling rearing yielded 85-99 % survival in FRP tanks. A total stock of 800 – 1000 number of juveniles are being maintained in the 3 culture facilities.

Thermostable Peste des Petits Ruminants (PPR) vaccine using spontaneously assembling, biodegradable mesoporous silica nano-scaffolds: PPR, a morbilliviral disease of small ruminants leads to high economic losses. Existing PPR vaccines provide life-long immunity but require cold-chain maintenance from lab to field. To exploit the adjuvant potential of mesoporous silica nanoparticles (MSN) to thermostabilizing PPR vaccine virus (PPRV), four types of MSN were synthesized and characterized. Scanning electron microscopy (SEM) imaging of these nanoparticles on a model substrate demonstrated random particle assembly forming a dense scaffold with inter-particle spaces. The nanoparticles were FITC labelled and analysed by fluorescent microscopy and flow cytometry. Confocal microscopy studies demonstrated the uptake of FITC-labelled particles in Vero cells. Different concentrations of nanoparticles were tested for *in vitro* cytotoxicity in Vero cells. The ability of MSN particles for recruiting host cells was studied in laboratory animals. MSNs were



Characterization of mesoporous silica nanoparticles (MSN) (A) SEM image of hollow mesoporous silica nanoparticles (HMSN), (B) TEM Image of HMSN



Visualization of uptake of FITC-labelled MSN particles in Vero cells (40X magnification) (A) FITC labelled HMSN, (B) DAPI stained nuclei (C) Merged image representing the localization of MSN in the cytoplasm of Vero cells.

evaluated for binding of PPRV and release kinetics was studied. The *in vitro* release of PPRV from MSN was confirmed in Vero cells by visualization of cytopathic effects (CPE) and immuno fluorescence assay using PPRV-specific antibodies. Immunization with antigen-loaded MSN particles demonstrated the formation of the antigen-MSN depot with inter-particle spaces for recruitment of antigen-presenting cells leading to enhanced immune responses in mice model. The experiments demonstrated that sera from mice and rabbits immunized with MSN-encapsulated PPRV were able to generate neutralizing antibodies and generated comparatively higher antibody responses in comparison to animals immunized with naked PPRV.

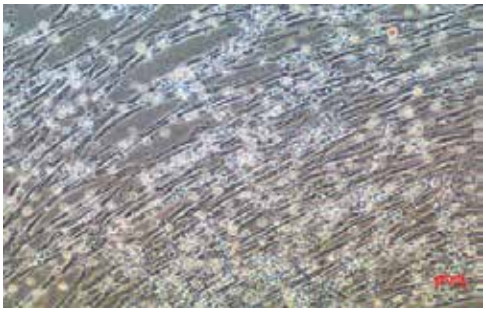
Dendritic cell platforms for *in vitro* and *in vivo* studies of antigen processing and presentation in cattle for combined vaccine antigens using FMD virus and *Pasteurella multocida* as model: Foot-and-mouth disease [FMD] virus and *Pasteurella multocida* are economically important animal pathogens. Available vaccines for both pathogens are inactivated antigens, which induce immunologic response of shorter duration. In this direction, purified 146S antigen of FMDV was characterized by double antibody sandwich ELISA. The estimated concentrations for serotypes A, O and Asia 1 were 82.5 µg/ml 423.3µg/ml and 190.5 µg/ml, respectively. Bacterial ghosts of *P. multocida* were produced using chemical methods and characterized

by electron microscopy (SEM/TEM) and SDS-PAGE. The nano emulsion and PLGA (50:50) nanoparticles were produced and characterized by dynamic light scattering, zeta potential and SEM imaging. Size and potential were found to be <500 nm and -12.5 mV for nano emulsion and <500 nm and -19.9 mV for PLGA nanoparticles, respectively. In order to express cytokines in the laboratory, IL4 and GM-CSF genes were cloned and expressed in human embryonic kidney 293 cell lines. Monocyte derived dendritic cells (MoDCs) generated from bovine PBMCs were stimulated with different combinations of FMD antigens, bacterial ghost, OMVs, nano-emulsion and SLNPs, and subjected to flow cytometry analysis for CD40, CD80, CD86 and MHCII (DC markers) Stimulation of MoDC with combination of PLGA nanoparticles and immunization of guinea pigs with vaccine formulation is underway.

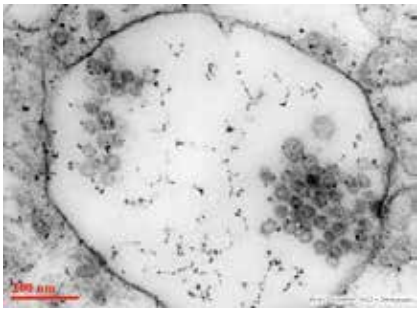
Host-pathogen-environment interaction of tilapia lake virus disease: The Chitralada, GIFT and local strains of Nile Tilapia were evaluated for their susceptibility to Tilapia Lake Virus (TiLV) through experimental infection. All the strains exhibited susceptibility to TiLV, with lower mortalities in Chitralada followed by GIFT and local strain. The expression profiles of MX, IL1β, and HSP70 genes were studied following TiLV infection at different temperatures. Gut microbiome analysis of sub-clinically and clinically infected Nile tilapia revealed significant diversity, suggesting a potential role in TiLV disease development. Screening of wild tilapia populations from reservoirs displaying clinical signs yielded positive results for TiLV in one reservoir, indicating its presence in nature. A sensitive single-step SYBR Green chemistrybased qRT-PCR assay demonstrated excellent reproducibility, with low inter-assay and intra-assay variation. Efforts have been initiated for the commercialization of this diagnostic assay. To identify risk factors associated with TiLV disease in tilapia farms, epidemiological studies were conducted in West Bengal, Kerala, and Maharashtra, covering 69 tilapia farms. A new viral pathogen, Tilapia parvovirus (TiPV) was detected in farmed Nile tilapia from Maharashtra and Uttar Pradesh.

Targeted immobilization of Y-bearing spermatozoa and modulation of oviduct milieu for skewing sex ratio towards female offspring in dairy cattle: The sex specificity of the four identified potential proteins was assessed using FISH and Western Blotting techniques All the proteins were specific to Y-Chromosome bearing spermatozoa. A targeted immobilization method was developed, using iron nano particles conjugated with the developed antibodies (polyclonal), to immobilize the Y-Chromosome bearing spermatozoa. Cattle embryos were produced through *in vitro* fertilization technique using the semen enriched with X-Chromosome bearing spermatozoa (using the developed Y-chromosome bearing sperm immobilizing method) and sex of the embryos was assessed. The developed immobilization technique resulted in production of 72-76% of female embryos. Similarly, a model for assessment of sperm-oviduct binding was developed for cattle and found that incorporation of calcium at 1mM concentration in the media induced 15 times more X-bearing sperm binding to oviduct. Incorporation of magnesium at 3mM concentration resulted in 33 times more Y-bearing sperm binding to oviduct. Collectively, it was inferred that the sex ratio of the embryos was skewed towards females to 3.16:1 (for every three females one male) using the developed targeted immobilization technique. This technique could be used to get male to female ratio 25:75.

Lesions in Nile tilapia co-infected with TiLV and TiPV



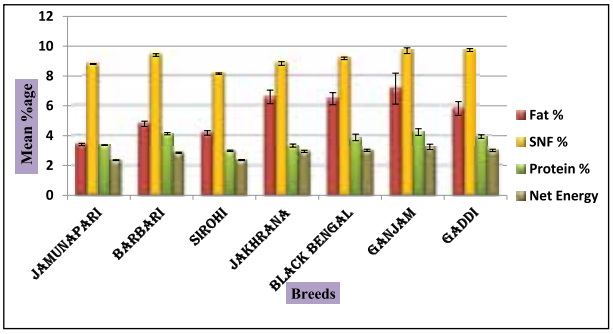
Isolation of TiPV in OnL cell line



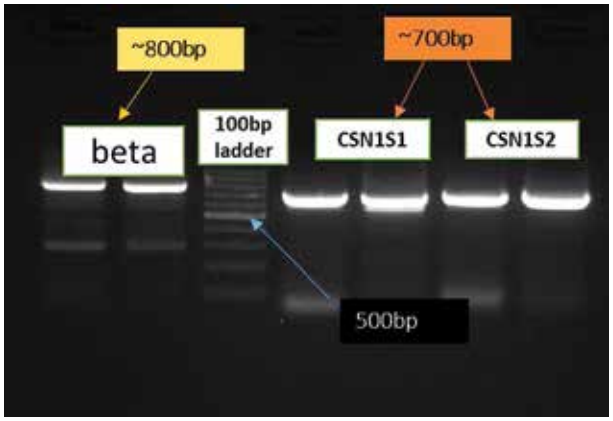
TEM of OnL cells-infected with TiPV showing virus particles in both nucleus and cytoplasm

Resveratrol and catechin-loaded niosomes and nanoparticles as delivery vehicles for fortification of milk and milk products: The process conditions of catechins-loaded niosomes were optimized, and the niosomes were characterized for fortification of milk, curd (*da*hi) and yoghurt. Aqueous solubility of catechin improved after their nanoencapsulation. Free catechins were highly photosensitive to artificial UV light, whereas nano encapsulated forms exhibited good photo stability. The catechins-loaded niosomes exhibited a sustained release under simulated GI conditions. Antioxidant activity of catechins was retained in the niosomes. The niosomes were stable up to 30 and 90 days at 30 and 5°C, respectively. In the second approach, resveratrol and catechins were converted into the dry proniosomes using GRAS encapsulants. The morphological, ultrastructural, entrapment and release properties of resveratrol and catechins-loaded proniosomes were evaluated for fortification in milk. Maltodextrin produced proniosomes with hydrodynamic diameter below 200 nm and entrapment efficiency above 90%. Also, catechins were converted into electro spun nanofibers. The nanofibers had cylindrical and non-porous ultrastructure with continuous three-dimensional network, and mean fiber diameter and encapsulation efficiency less than 100 nm and 92%, respectively.

Proteomic approach for genetic variability of milk protein in Indian goats: In the present study, goat milk samples were collected from seven breeds (Barbari, Jamunapari, Jakhrana, Gaddi, Ganjam, Sirohi and Black Bengal) from different agro-climatic zones. Goat milk proteome analysis identified 1308 proteins in milk samples across 15 Indian goat breeds. These proteins are functional in 237 KEGG pathways including NOD-like receptor signaling pathway, HIF-1 signaling pathway, metabolic pathways, as well as disease pathways such as tuberculosis, malaria, and measles. Majority of identified proteins were localized in nucleus, cytoplasm and extracellular and involved in various biological process having transporter, binding and catalytic activities. *CSN1S1* gene was also characterized in Jamunapari goats and its effect on milk composition traits was observed. Genetic parameter estimates were obtained from 518 records from 48 sires and 131 dams with a pedigree covering over 3



Various Milk composition traits for different Indian breeds.

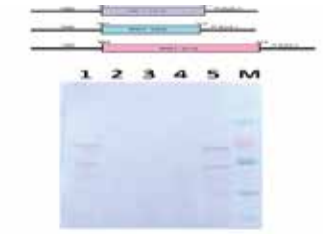


PCR amplification of full-length milk casein genes CSN1S1, CSN1S2 and CSN2.

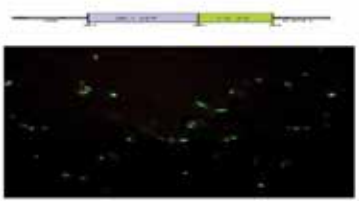
generations. Milk protein variability at protein and DNA level was carried out by SDS-PAGE and PCR-RFLP. The A, B and F alleles were observed in the analyzed population with the allelic frequencies were 0.4566, 0.503 and 0.041, respectively. The direct heritability for protein%, SNF% and lactose% was 0.441, 0.294 and 0.326, respectively.

The genotyping presented αs_1 (CSN1S1), αs_2 (CSN1S2), β-casein (CSN2), κ-casein (CSN3) and whey protein β- LG and α-LA as observed in individual samples in different breeds and indicated the presence or absence of certain genetic variants in different individuals.

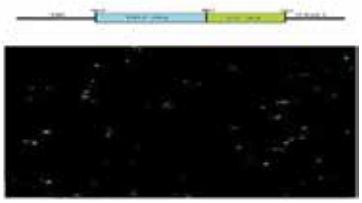
Molecular basis of Peste-des- Petits Ruminants virus (PPRV) mediated host immune modulation for the development of next generation vaccine: Study was undertaken to understand pathophysiology of PPRV and its role in host immunosuppression The complete genome of PPRV was amplified in fragments and cloned in pJET1.2/blunt vector. The Luciferase promoter assay showed that expression of PPRV coded C and V proteins caused suppression of ISRE containing promoter indicating their immunosuppressive nature. In total 12,688



Immunoblot of helper plasmid transfected vero cell lysates probed with anti N (4 G6) Mab
1 & 5-cell lysates transfected with PPRVN helper plasmid
2- cell lysate transfected with control plasmid without insert
3- cell lysate transfected with PPRV P helper plasmid
4- cell lysate transfected with PPRV L helper plasmid
M- Puregene 3 color prestained protein ladder (PG-PMT2922)



Vero cells transfected with PPRV N-GFP constructs showing green fluorescence confirming protein from the helper construct



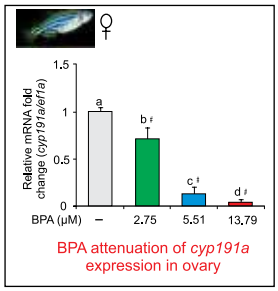
Vero cells transfected with PPRV P-eGFP constructs showing green fluorescence confirming the expression of PPRVP protein from the helper construct

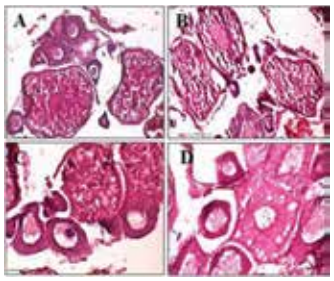
genes were found to be differentially expressed. Of these 684 genes were differentially expressed at significant level, among which 574 were up-regulated in expression while 110 were down-regulated. Identified putative 37 up-regulated and 13 down-regulated genes were found to be associated with innate immune response pathway. A mouse model for PPRV infection was established to study disease pathogenesis mechanistically. The genetically defective mice, developed for interferon response served as an excellent in *vivo* animal model for investigating PPRV pathogenesis. Replicating virus and its antigens were detected in most of the critical organs of infected mice. Innate immune cells such as neutrophils and macrophages likely transported the replicating virus to the central nervous system to cause encephalitis. This established and employed a laboratory animal model for investigating PPRV pathogenesis and protective role of $CD8^+$ T cells of immune system. A viral vector system based on the Indian vaccine strain (Sungri/96) of PPRV, specifically for the development of next generation live attenuated dual/combined vaccines for other viral/ bacterial/ parasitic diseases was also developed.

Biomarkers for early diagnosis of *Mycobacterium avium* subspecies *paratuberculosis* (map) infection and development of DIVA test: Healthy goat and sheep populations (Herds/flocks), belonging to five different farms at ICAR-CIRG Makhdhoom, LUVAS, Hisar, OUAT, Orissa, SKAUST, Jammu, were screened for Johne's diseases by routine diagnostic tests. MAP 2191c or mammalian cell entry protein and *Mod*D secretome protein in the form of peptide were targeted for the development of DIVA ELISA. The inflammatory biomarker IL18 was consistently up-regulated in MAP infected animals as early as 30 days post inoculation of MAP in experimental animals. While, IL1β and IFNγ genes were transcriptionally elevated in chronic cases as well as vaccinated animals beyond >90dpt timeline. Besides, the calcium signaling and MAPK pathways were identified as key mechanisms, which help in the survival of MAP inside the macrophages of host and successful chronic infection, that could be exploited in the nation-wide control programmes on JD. Amongst the acute phase proteins, significantly higher levels of serum albumin (2.86 g/dl) were observed in JD positive animals.

Assessment of amelioration potential of *Ocimum* and *Lucas* in stress-induced impaired homeostasis on growth and reproduction in Zebrafish: In the study, amelioration of stress in zebrafish using plant based preparation of *Ocimum sanctum was* investigated. The organic carbon, microbial biomass carbon and phosphorous availability in soil regulate S-adenosyl-L- methionine (SAM) and Ursolic acid (UA) and exceptionally high concentration of SAM was detected in *Ocimum* and *Lucas*. The exposure to hypoxia, acidic pH stress, density and excess fat (HFD) impair metabolic homeostasis through down regulation of energy sensors (SIRT1, pAMPK and PGC1□) and disruption of mitochondrial ATP production in muscle tissue. It was observed that HPLC-purified SAM could suppress Fetuin A (FetA) and ameliorate impaired energy homeostasis. Additionally, abiotic stress in the form of polluting organic ambience (Bisphenol A, 4-Nonylphenol), at environmentally relevant doses, severely impacted fish health. While elevated follicular death (atresia) and reduced maturational competence lead to reduced fecundity and reproductive fitness in BPA-

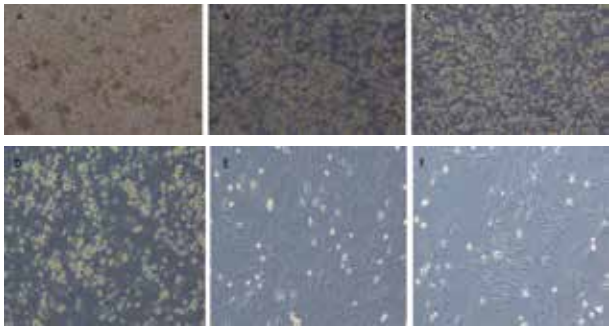
treated females, 4-NP could alter redox balance (oxidative stress), inflammatory response, lipid accumulation (steatosis) and apoptotic index in zebrafish liver. Low dose of SAM, isolated from plant source (*Ocimum* spp), had the potential to induce oocyte maturation and formation of fertilizable female gamete. Observations suggested that plant preparation significantly ameliorated the oxidative stress and rescued the formation of lipid peroxidation (MDA) in oxygen depleted zebrafish. Effect of BPA exposure on reproductive parameters was also studied. BPA exposure attenuated ovarian steroidogenic potential as manifested through dose-dependent decrease in *cyp19a1* expression. The study indicated that congruent with significant increase in oxidative stress response, membrane damage and breakdown of hepatic anti-oxidant defence system, BPA exposure, had wide-spread negative influence on gonadal architecture, development of male and female gametes and attenuation of maturational potential in full grown follicles, thereby reducing the number of fertilizable female gametes.





Effect of graded levels of BPA exposure (14 days) on ovarian cyp19a1 mRNA expression (left panel) and follicular damage as evident in T.S. of ovary (right panel).

Effect of mesenchymal stem cell transplantation on ovarian function and fecundity in goats: To develop infertile rodent models by depleting their follicles and ovarian restoration through the transplantation of allo-genic or auto-genic MSCs, ovarian reserve depletion has been successfully established in rat model. Ovarian morphologic analysis and mating trials were carried out. MSCs attached to the culture flasks sparsely and displayed a fibroblast-like, spindle-shaped morphology during the initial days of incubation. The non-adherent cells were removed on third day after culture, and adherent cells grew as fibroblast-like morphology.



Female Rat Mesenchymal Stem Cells at different time and passages. A: day 1, B: day 3, C: day 5, D: day 7, E: passage 1, F: passage 2 (original magnification 10X).

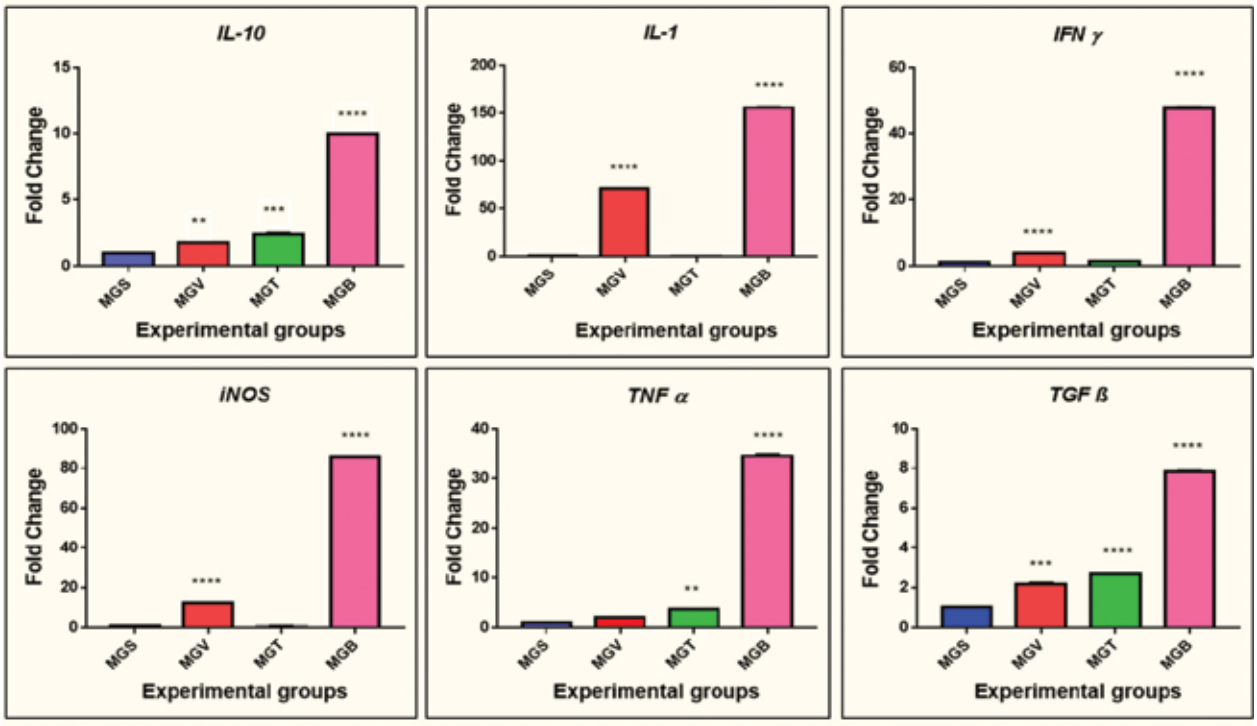
Enrichment of Rat BM-MSCs with a number of surface protein markers were explored. The results indicated a high expression of CD29 (99.42%) and CD54 (97.44%) for the isolated female rat BM-MSCs. A normal diploid karyotype with 42 chromosomes and no abnormal changes in chromosome structure was observed by the analysis of 10 metaphase cells. Immuno-fluorescence analysis was done to check the expression of cell surface markers in rat BM-MSCs. The majority of identified proteins were localized in nucleus, cytoplasm and extracellular and were involved in various biological processes having transporter, binding and catalytic activities. *CSN1S1* gene was also characterized in Jamunapari goats and its effect on milk composition traits was observed. The goats with AB genotype had highest protein content (3.56%) followed by AA (3.50%), BB (3.26%), BF (3.03%) and AF (2.99%) genotypes. Genetic correlation between protein% and SNF% was moderate and positive. Casein genes were amplified from Beetal cross milk somatic cell, subsequently, cloned for their sequencing. Full length kappa casein encoding gene sequence was obtained from one positive clone. The full-length goat kappa casein gene sequence was submitted to GenBank.

Detection of peptide biomarkers and development of synthetic anti-microbial peptide hydrogels for bovine mastitis: The lead antimicrobial peptide (AMP) molecule identified from insect secretions was chemically synthesized and tested for its activity against ESKAPE bacteria to determine the MIC and MBC. Stability at different temperature, in presence of salts and serum, toxicity in Galleria melonella larvae, mammalian cells and haemolytic activity in RBCs of different species were determined *in vitro* prior to therapeutic

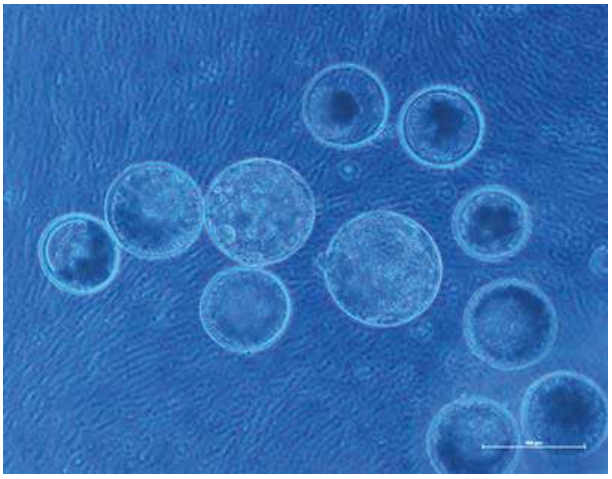
evaluation in lactating Balb-c mice challenged with virulent *S.aureus* isolate. It was observed that there was significant reduction in the bacterial load per gland in the AMP and antibiotic treated groups as compared to infected glands treated with sterile PBS. Further, there was significant reduction in expression of pro-inflammatory cytokines (IL-10, IL-1, IFN-Y, iNOS, TNF-α and TGF-β) in comparison to mouse infected with bacteria and treated with sterile PBS. The results of SAMAMP-1 treatment of infected mouse mammary gland were comparable with the standard antibiotic treatment group. Further, histopathological analyses showed that *S. aureus* - induced inflammatory cell infiltration, mammary alveoli thickening and edema were significantly reduced by treatment of AMP and standard antibiotic. Thus, this lead AMP can be a promising molecule for treatment of bacterial mastitis, especially caused by *S aureus*.

Synthetic Endometrium: A novel model to study early embryonic development and uterine health in ruminants: To develop endometrium-like 3-Dimensional cell culture system in buffalo, buffalo genetalia with ovary bearing CL haemorrhagicum were procured from local slaughter house in HBSS. The primary endometrial epithelial and stromal cells culture [2D- EEC/ ESC culture] systems were established separately using double enzymatic digestion method. The confluent cultures of primary stromal and epithelial cells were achieved by days 7-9 and 10-12 of culture, respectively. Eleven set of experiments revealed that purecol (PC) and its combination in different concentrations with Geltrex (GT)/ matrigel, Gelatin (GL) and Maxgel (MX) showed successful growth potential for both type of cells. Maximum stromal cells growth and attainment of confluency was observed at the earliest in PC +GT followed by PC + GT + MX, PC, GT, GL, MX and control. Co-culturing stromal as well as epithelial cells up to day 28 of culture was successful. Immunocytochemistry of epithelial cells, stromal cells and 3D ECC was conducted. Effect of different extra-cellular matrices on structural and functional characteristics of buffalo epithelial cells using 2D-culture system was studied. Differential gene expression was analyzed. Based on expression of key genes on epithelial cells (Cox-2 and PGFS) and other genes related to cell proliferation (PCNA) and cells receptivity (SSP-1, ITGB3, ITGA3), two matrix material which included Gelatin 0.1% and Geltrex 1:3 was considered best for growth of epithelial cells.

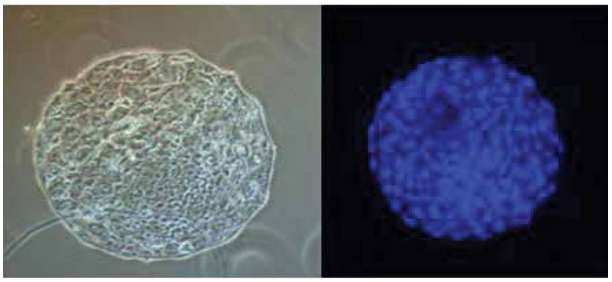
Collection of buffalo oocytes and *in vitro* maturation, fertilization and culture for production of embryos was carried out. Out of 487 cleaved embryos, 125 (25.66%) developed



Expression of pro-inflammatory cytokines (IL-10, IL-1, IFN-Y, iNOS, TNF-α and TGF-β)



Group of buffalo blastocysts



Phase contrast **Hoechst 33342**

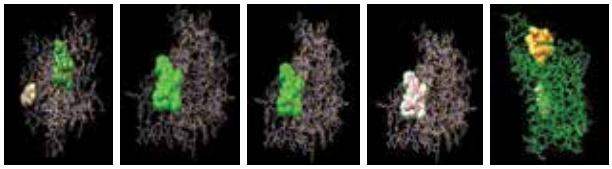
Total cell numbers of hatched blastocyst

to morula, 75 (15.44%) to hatched blastocysts and finally 39 (8.00%) to expanded blastocyst stage. In order to find out health status of the *in vitro* produced buffalo blastocysts, the total cell number (TCN) and apoptotic index was determined after staining with Hoechst 33342 and TUNEL assay, respectively which stains the nuclei. These embryos will be utilized for further studies on endometrium-embryo-pathogen interactions and gene expression.

Delineating beta casein variants in Indian cows and potential health implications of A1A2 milk: The allelic frequencies for the A1/A2 allele of beta casein was estimated in more than 4000 animals including Indian native (30 breeds), crossbred, exotic cattle and semen samples. The analysis revealed that the frequency of A1 allele was highest in exotic cattle (0.31), followed by the semen samples (0.30) and crossbred cattle (0.29). Indian native cattle revealed the minimum frequency of A1 allele (0.05). The genotype A2A2 was predominant in all the analyzed cattle types and ranged from 0.49 (exotic cattle) to 0.90 (Indigenous cattle) with an average frequency of 0.59. The analysis of β-casein mRNA expression data (based on CT values) revealed that in both Sahiwal and Karan

BCM-9 BCM-5 BCM-7

Crystal model structure BCMs



HMOR-1b1 HMOR-1c HMOR-1y2 HMOR-1y3 HOPRM-1

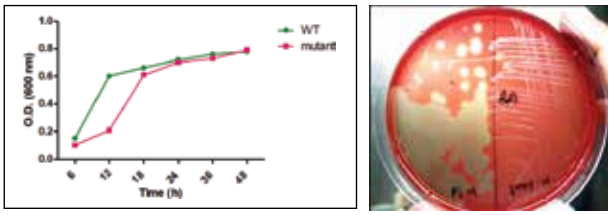
Molecular docking of human mu-opioid receptor with BCM-9

fries, the expression of β-casein was significantly ($P=0.0014$, $P<0.05$) higher in early and peak lactation stage than mid and late stages. Time course and feeding schedule for studies related to association of BCM7/9 with diabetes in mouse model were carried out. Molecular docking studies to understand binding of BCMs with different mu receptors (splice variants) was done. In-silico analysis was carried out to identify genes representing μ-opioid receptors (MOR) in mice and human genome. Different splice variants of MORs were fished out from a much larger pool of sequences available in NCBI databases. The structures of BCMs, mu, kappa and delta receptors were predicted and molecular docking studies were performed.

Molecular docking was carried out between ligands (BCM-5, BCM-7 and BCM-9) and mice MOR receptors. The studies showed that BCMs have highest affinity for MOR and least affinity for kappa 1 opioid receptor. The Tandem Mass Tag (TMT) based comparative proteome profiling of A1A1, A2A2 and A1A2 Beta casein variants of cow milk was carried out. Protein-Protein Interaction (PPI) analysis revealed the association of few differentially expressed proteins such as XDH, LPO, SFRP4, APOE, APOA-1 etc. having role in regulation of lactation, prevention of diabetes, heart diseases, albinism and hindrance of tumor proliferation.

Vaccine potential of cctA and hyaluronidase gene mutants of *Clostridium chauvoei*: Studies indicated that replicon repH of the pMTL007C-E2 was replaced by repL of the pMTL85151 resulting in pMTL007C-E6. pFdx promoter (from *C. sporogenes*) of the

pMTL007C-E6 was replaced by pCc-Fdx promoter (from *C. chauvoei*) to yield pMTL010 vector. The pFdx promoter (from *C. sporogenes*) was replaced with native cc-pFdx promoter from *C. chauvoei* to generate pMTL010: Cch-*cctA*-274a construct, which was transferred into *C. chauvoei* cells by conjugation. This construct could efficiently inactivate the *cctA* gene of *C. chauvoei*, generating Cch-*cctA*274a: CT mutant. For functional characterization, wild type and mutant C. chauvoei cells were grown on sheep blood agar for 48 h under anaerobic conditions. Since cctA is the major haemolysin of C. chauvoei, cctA mutant of C. chauvoei did not haemolyse sheep RBCs, while wildtype C. chauvoei showed extensive haemolysis, thus confirming the inactivation of cctA gene at phenotypic level. Apart from this, cctA and hyaluronidase genes of *C. chauvoei* were characterized by sequencing analysis and expressed in prokaryotic expression system. It was found out that TatD by itself may not be a true DNase, but could be contributing to the DNase activity of *C. chauvoei*. The quorum sensing system in *C. chauvoei* was characterised and it was found that, unlike other *Clostridium spp*, *C. chauvoei* does not possess luxS based quorum sensing system but possesses *agrBD* system of quorum sensing.



Characterization of *C. chauvoei* mutant. A. Growth rate of the cctA mutant of *C. chauvoei*. B. Haemolytic assay shows that the cctA mutant of *C. chauvoei* does not haemolyse sheep RBCs indicating the inactivation of cctA gene.

Leukemia Inhibitory factor (BuLF): Pluripotency in buffalo stem cells: The objectives of the study were to produce BuLIF in different hosts (bacteria, yeast and mammalian cells). The pure recombinant protein (rBuLIF) was successfully produced from bacteria (*E. coli*), yeast (*Pichia pastoris*) and mammalian cells (COS-1) which could be used for various *in vitro* and *in vivo* applications. The molecular signalling triggered by rBuLIF in COS-1 cells has been elucidated, which generated new knowledge in explaining the pleotropic mechanism of this molecule. Glycosylated rBuLIF initiates cell growth arrest in COS-1 cells that is mediated through stat3 activation. In addition, rBuLIF also activates MEK/ERK, Ras, mTOR, Hippo-Taz, and RAP1 signalling.

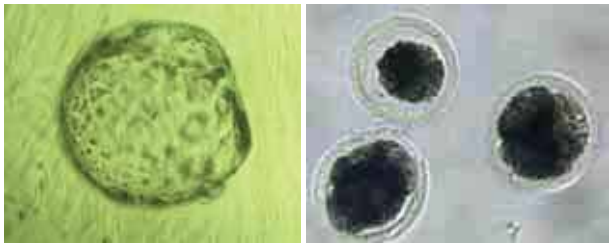
Luteinizing hormone-based sensor for estrus detection in buffaloes: Putative peptide sequences from buffalo LH protein beta subunit were identified, designed and characterized by several bioinformatics analyses in order to develop luteinizing hormone-based sensor for estrus detection in buffaloes. Polyclonal antibodies (Anti-LHP) against those peptides were raised in rabbit. Gold nanoparticles (AuNPs) were conjugated with most specific anti-LHP antibody. It was observed that the AuNP-anti-LHP2 conjugate was specific (antibody against LHP2; Anti- LHP2) for LH and was not found to binds with BSA and other non-specific proteins. Besides crude LH, the conjugate binds to bovine anti-rabbit IgG (secondary antibody), which was also coated on lateral flow strip. Antibody generated against the identified peptide sequence has satisfactory affinity with buffalo and bovine LH.

Chemo-profiling of potential phyto-acaricides and their functional characterization for controlling resistant cattle ticks: A nano formulation showing 80-100% *in vitro* efficacy while 60-70% efficacy in a pilot study using experimentally and naturally infested animals against adult ticks was developed. The discriminating concentration of ivermectin was determined as 93.54 ppm and validated in isolates collected from Bihar, Punjab, and UP. The isolate collected from Punjab was highly resistant. Two formulations (F5 and F10) were found to possess 80-90% efficacy in pilot *in vivo* study. Microarray analysis using lead III compound treated ticks, revealed approximately 300 transcripts differentially expressed in midgut of treated ticks.

In vivo efficacy of F5 and F10 formulation after 7 days of animal treatment.

Diversity and synthesis of immunoglobulins in the Indian major carps: Immunoglobulin IgZ and IgM expression has been analyzed in rohu and catla. TLR4 gene was cloned and characterized in rohu. The expression in various tissues including blood showed wide range of variations among the tested tissues. In response to LPS-stimulation and Gm-negative bacterial infection, activation of TLR-4, the signaling pathway was reported. The B-lymphocyte of rohu was purified from PBMC following panning with rohu specific anti- IgM and anti-IgZ antibody. Study on transcriptomic and proteomic expression profile of TLR2, TLR3, TLR4, TLR5 and downstream signaling molecules (MyD88, ERK, NF-kB, TNFá) and IgM and IgZ, indicated that both IgM and IgZ expression are regulated by PAMPs mediated TLR activation *via* ERK and NF-kB signaling pathway. The ELISA results depicted a dramatic increase in the phospho-ERK (pERK) levels in all the treatment conditions. But there was no changes in the total-ERK levels with respect to the control recorded. Immunoblotting results corroborated with ELISA and qRT-PCR results. The qRT-PCR, ELISA and FACS analysis indicated that PGN and flagellin can potentially activate the ERK- signalling in kidney cells to induce IgM and IgZ synthesis as compared to Poly I:C (7.8-folds; 13.88- folds) and LPS (1.75-folds, 6.48-folds).

Development of parthenogenetic goat from embryonic stem cells: Parthenogenetic *caprine* embryos died after approximately 34 days of gestation, with limited development of extra-embryonic tissues. The main reason for the halted development of asexual embryos is genomic imprinting, a chromosomal modification leading to parental-origin-specific gene expression in somatic cells. Tetraploid ivf embryos and diploid parthenogenetic embryonic stem cells can be aggregated to make chimeras. A protocol was standardized to produce chimeric embryos using tetraploid complementation assay. *In vitro* fertilized embryos were selected at 2 cell stage between 24-30hour post insemination. The chimeric embryos were produced by parthenogenetic embryonic stem cells and fertilized tetraploid embryo complementation. Chimeric embryos produced by aggregation method, were then cultured for the production of blastocyst stage embryos.



Production of chimeric embryos and blastocysts from embryonic stem cells.

Defense genes of tiger shrimp (*Penaeus monodon*) with respect to bacteria (*Vibrio harveyi*) and whitespot virus (WSSV) infection: 2-D gel analysis was carried out with respect to different time point intervals of WSSV infection. Different spots were observed in white spot syndrome virus (WSSV) infected shrimps. The spots were excised and MALDI-TOF analysis revealed differentially expressed proteins. At 72 h post-infection, two of the proteins, viz. Tropomyosin and Arginine Kinase were overexpressed in WSSV infected tissues indicating specific role of these host proteins. Both conventional RT-PCR and real time analysis for differentially expressed genes with respect to WSSV infection were carried out. Expression analysis was carried out for about 22 defense genes. While it was difficult to differentiate the expression pattern by conventional RT-PCR, real time PCR could differentiate clearly the differences at different time point intervals. Immune genes involved in the Toll pathway of shrimp, such as Spatzle (extracellular ligand of Toll), myeloid differentiation factor 88 (MyD88), tumor necrosis factor receptor-associated factor 6 (TRAF6), cactus (mammalian IkB homologue) and dorsal (mammalian NF-kB homologue) were characterized. Full gene sequencing of myeloid differentiation factor 88 (MyD88), tumor necrosis factor receptor-associated factor 6 (TRAF6) and spatzle, and partial gene sequencing of cactus (mammalian IkB homologue) and dorsal (mammalian NF-kB homologue) was done. The akirin gene that showed maximum upregulation during infection was amplified, cloned and expressed. Recombinant clones of akirin (AKN) were sequenced.

Transgenic goat for production of human lactoferrin: The human lactoferrin gene construct was developed with highest promoter activity under 6.5 kb fragment of beta-casein. Simultaneously, goat mammary

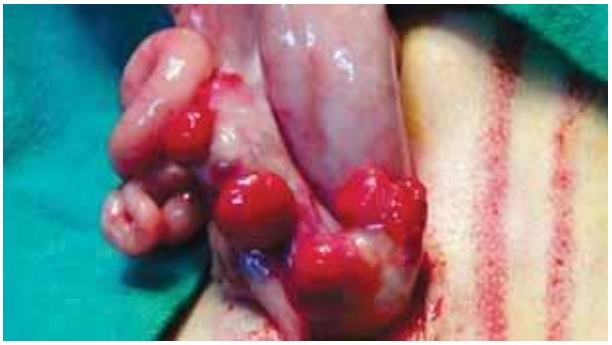
epithelial cell line was established and characterized The prepared construct was subsequently transfected into goat mammary epithelial cell line by nucleofection. The cells were observed for the expression of GFP as the expression vector contains GFP as the reporter marker. Lactoferrin expression in the transgenic cell line was also confirmed by western blotting. The embryos were transferred in the uterine lumen by means of a long micropipette.

Bivalent marker vaccine against bovine herpesvirus-1 and brucella: Genetic analysis showed that the native Malanadugidda breed resistant to FMD is genetically distant from other indigenous breeds and better maintained as pure breed with less gene flow. Thus, these animals may be used in breeding for disease resistance. A positive marker vaccine for FMD virus was prepared by incorporating GFP epitope and tested in 12 crossbred female calves. Competitive ELISA showed the presence of GFP-epitope specific antibodies. This approach can be used to develop marker vaccine for endemic countries like India. A novel FMD virus Asia 1(Indian Vaccine strain) replicon based viral vector for vaccine research and development has been developed.

Genetically engineered vaccines against poultry viral diseases: The IBDV VP2 gene cassette inserted into the final cDNA clone of the NDV virus generated at sites, SacII (position 2354) and AvrII (position 5251). The final clones had expected size of 21,344 bp. Transfection was done using the full-length clone of the virus along with the support plasmids and recombinant virus was rescued. The demonstration of recombinant virus was done by RT-PCR using gene specific primers for both NDV and IBD VP2.The rescued virus was pelleted, run on SDS-PAGE and reacted with NDV and IBDV specific antisera on a western blot. Specific bands in relation to VP2 protein (44 kDa) and NDV proteins were observed in the blot.

Infertility in crossbred bulls and early prediction of fertility: The complete protein profiling of spermatogenic cells derived from indigenous (control) and crossbred males at two age groups (6 and 24 months) were analyzed using bioinformatics and the earlier identified fertility associated proteins in crossbred bull spermatozoa were assessed for their presence in spermatogenic cells. The fertility associated proteins were validated for their efficiency in predicting bull fertility using spermatozoa from large numbers of bulls with known fertility. Four fertility associated sperm proteins (protein A, B, C and D) were identified in 6 and 24 months spermatogenic cells. Hence, the expression of these proteins in spermatogenic cells was compared between indigenous and crossbred males. The proteins A, B, C and D were observed to over-express in spermatozoa from high fertile bulls by 1.93, 2.17, 3.15 and 1.96 folds compared to low fertile bulls, respectively. The expression of these proteins in spermatogenic cells of indigenous males was 1.7, 0.8, 0.74 and 2.03-fold higher, respectively compared to crossbred bulls at 24 months of age. However, at 6 months of age the differential expression was quite impressive; the expression of these proteins in spermatogenic cells of indigenous males was 9.1, 1.8, 8.24 and 1.32-fold higher compared to crossbred bulls at 6 months of age.

Mechanism of aberrant maternal recognition of pregnancy in sheep and buffalo under heat and nutritional stress: A group of 16 adult Malpura ewes were exposed to nutritional and heat stresses. Superovulation was induced by a combination of single injection of 200 IU eCG and multiple injections of Folltropin-V. Combined stress increased respiration rate and rectal temperature and blood urea, whereas decreased average daily gain. The ovarian response, ovulation rate and embryo production decreased; and number of large follicles (anovulation) increased under combined stress. The expression of PGFS mRNA increased significantly on Day 13 of pregnancy but COX-II and PGES mRNA expression decreased significantly following combined stress. Expression of HSP 70 mRNA increased but Integrin and Galactin mRNA decreased on Day 13 of pregnancy in response to combined stress. MRP related genes, viz. COX-II, PGES, PGFS, Galactin, Integrin, Osteopontin, FGF2 and IGF2 cDNA were cloned and characterized in sheep. The nucleotide sequence of COX-II cDNA revealed 84-97% identity with the corresponding mammalian homologs, whereas deduced amino acid sequence exhibited 81-98 % homology. The gene expression study revealed that the most likely cause of oocyte deterioration as a result of heat stress is increased oxidative



Corpus luteum on sheep endometrium.

stress and ATP starvation leadingto apoptosis. The important milestones of embryonic development like maternal to embryonic transition and morula to blastocyst transition were found to be seriously compromised as result of heat stress. Increased oxidative stress and poor mitochondrialmetabolism were detected as key factors responsiblefor adverse effect of heat stress on oocytes and embryos.

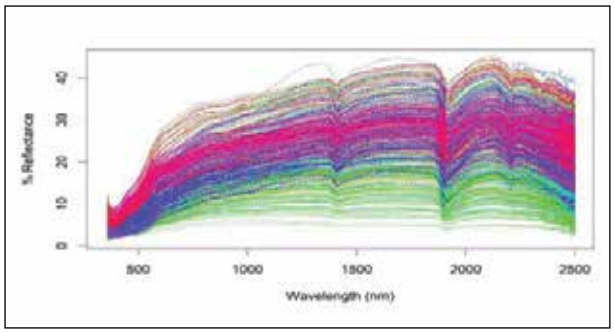
2.3 Precision agriculture and management of natural resources; and application of sensors in crops, animals and fisheries

Artificial Intelligence & IoT based Smart Vet Ecosystem for animal health, patient care & precision livestock farming: Developed the prototypes of Electronic Health Records for Animals (eHRA) and Electronic Veterinary Medical Records (eVMR), and Health and Medical Data Architecture Modules and Data panels QR Code based "Smart Contact" interface was developed and tested for animal owner's usage. It was successfully adopted by 60 to 75% adoption by animal owners. For Animal Medical Data Capture, 5 Medical Information Management Systems were developed and tested. Towards generation of Digital Animal IDs, preliminary works initiated. e-Vaccination Records were evolved and tested for animal owner's usage. "IoT Integrator" for conventional milk testers was developed and further trials commenced for IoT enabled remote quality assessment and monitoring of milk. The conventional milk testers have been successfully integrated with the IoT system, for remote testing and monitoring of milk quality. An APP has been built to act as an interface between testing unit and collection units for reading, transferring and analysing parameters of milk from collection units to research teams. AI tools development works involving prediction of body size measurements, extraction, and

AI &IoT based Smart Vet Ecosystem

quantitative analysis using sheep and goat images with deep learning protocols, were initiated. Face and muzzle point images (300) belonging to 3 breeds -Sahiwal, Tharparkar, Vrindavani were collected and were analysed through a Hybrid Model of Residual Attention Network & Multi -Scale Context Aware Network. The model is being utilized further for classification of animals using digital images and with a plan to use similar model for classification of other breeds & other species.

Hyperspectral reflectance and multi-nutrient extractant based rapid assessment of soil properties for sustainable soil health in India: Optimal sampling design was developed to collect samples representing different agro-ecological sub regions (AESRs) of India by using conditioned Latin hypercube sampling (cLHS) approach. Identified 3410 sampling locations within India representing different AESRs, soil types, landforms, terrain features etc. Results from descriptive analysis revealed a wide variation in soil properties. Hyperspectral signatures of collected soil samples (n=628) from different AESRs were measured using spectroradiometer facility. Variation in spectral signatures of collected soil samples were observed. Overall height of the spectra, absorption features of the spectra and slope of the spectra at different spectral regions depend on the inherent composition of soil and



Hyper-spectral signatures of soil samples collected from different Agro-Ecological Sub-regions of India

thus these spectral signatures act as proxy of different soil properties.

Biosensors for detection of fish pathogenic bacteria and hazardous metalloids in water bodies: Several nanoparticles including gold and silver nanoparticles were synthesized to check their suitability to enhance the signalling efficiency of the developed Molecular Recognition Element (MRE). A sensor has been developed for the efficient detection of Cr (VI) in water with a linearity range 100 ppb to 1 ppm. The UV-Vis absorbance intensities were gradually increased with increasing concentration of Cr (VI). The sensor is able to detect Cr (VI) up to 100ppb which is the permissible limit notified by US EPA. It does not show any cross-reactivity when checked with other heavy metals like Cr (III), Pb, As, Hg, Ba, Cd and ions (SO_4^{2-}, CO_3^{2-}, HCO_3^-). The sensor has been incorporated into a hand-held prototype device. Another aptamer-based biosensor has been developed for the detection of fish pathogenic bacteria *Aeromonas veronii*. The sensor is able to specifically detect *Aeromonas veronii* and shows no cross-reactivity with other bacteria when tested against *A. hydrophila* (AH), *Pseudomonas aeruginosa* (PA) and *Klebsiella pneumoniae* (KP). The sensor is able to detect the bacterial cell up to a concentration of 10^6 CFU/mL.

Bio-waste through microbial consortia for improving soil health: A liquid formulation of microbial consortia (four fungi, four bacteria, two actinobacteria, one yeast, one lactobacillus) was developed for rapid development of compost from bio-wastes. The microbial consortia were demonstrated in a large scale at Sujani, Deoghar (Jharkhand). Compost quality standard has been assessed and it was found that compost is ready for field application after

Customized drum type composting unit for enhance decomposition of organic residues.

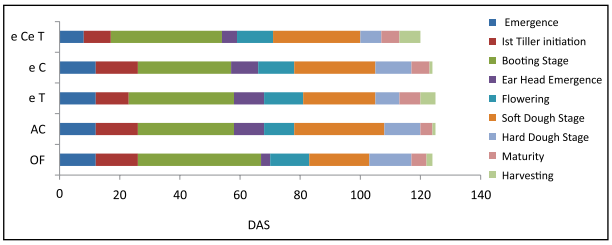
20 days from kitchen and vegetable waste followed by horticultural waste compost (30 days) and farm waste (45 days). The developed biofilters using selective fungi were effective for elicitation of Zn (~ 30%) and Ni (>30), Pb (>40%), Cd (>20%) and therefore improve the quality of compost. The manurial value of compost was enriched by using 0.5% urea-N, 2.5 % P_2O_5 through rock phosphate, 5% pyrites (W/W on materials dry weight basis). The total content of N and P increased from 1.12 to 1.8 % and 3.2 to 4.12 %, respectively in these materials. The varying degree of heavy metals tolerance by microbes was due to presence of functional groups like amide, carboxylate anions, carbonyl groups, and C-f and C-Br groups. The compost prepared from different substrates contained heavy metals, and human pathogens like coliforms and plant pathogen, nematodes, below permissible level and is safe for use in field. Quality compost was prepared from composter with good Germination Index (GI) suitable for the composting of horticultural crop residues. Among all the treatments, horticulture waste compost treated plot showed maximum yield followed by vegetable waste and kitchen waste treatments. Horticulture waste compost treatment plots of maize and soyabean exhibited 1.8 times more yield than control and 1.3 times better than recommended dose of fertilizer.

Biological filter for safe wastewater irrigation exploiting microbial bioremediation trait: For removal of heavy metals and pharmaceutical products, the strains *P.*

aeruginosa, *A. baumannii* and *B. cereus* were found to be effective and the immobilized cells on the filter performed better than the free cells. A novel consortium of immobilized axenic microbial hydrogel beads was used to house the bacterial isolates minimizing the antagonism among strains. The consortia absorbed 43% Cr, 62% Cd and 19% Ni higher than those with axenic beads. Four novel biofilters, namely, i) Biobed, ii) Tunnel, iii) Gabion and iv) Column biofilters were fabricated with packing materials. The biofilters, showed metal-reduction efficiency of 65%, 48% and 43% for Cr, Cd and Ni respectively with synthetic wastewater. Paracetamol and ibuprofen were also reduced by 39% and 25% respectively. The performance of biofilters with factual wastewater was better than synthetic wastewater in reducing pollutants. The reduction of heavy metals, was increased about 10% with the industrial wastewater, and 9 percent for pharmaceuticals in hospital wastewater. Microbial-biofilms were developed in all the filters. In electro-conductive graphite, it was more compact, and resistive to washout at hydraulic pressure. The restricted electron-movement in batch, limits the efficiency of graphite-biofilter, to no better than FRP or gravel. The inoculation of sulphate reducing bacteria (SRB) reduced $SO4^{2-}$ to S^{-} using organics as e-donor. X-Ray Diffraction (XRD) peaks suggested the accumulation of several metal precipitates as crystals on material surfaces. Field Emission Scanning Electron Microscopy (FE-SEM) showed uneven distribution of elements. Energy dispersive X-Ray analysis (EDX) of packing materials showed heavy metal accumulation on biofilms highlighting role of biofilm in metal removal.

Biofilter Prototypes

Effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system: Response of soybean and wheat to climate change variables was seen at different extents. Elevated temperature showed significant reduction or similar grain yield in wheat, whereas significant increase in grain yield was observed in soybean. On an average, 15% yield advantage was observed in wheat as compared to more than 40% in soybean under recommended dose of fertilizer with CO_2 enrichment. This field study clearly showed a conspicuous increase in nutrient uptake and mining from soil under future climate conditions. Elevated CO_2 resulted higher uptake of N by 18–61%, P by 23–62%, and K by 22–62% in soybean. Similarly, additional N uptake to the extent of 15-25 kg N ha $^{-1}$ was observed in wheat. Also, fertilizer-N use was significantly higher with elevation of both CO_2 and temperature than ambient environment. This implies increasing role of fertilizer-N under the future climate conditions. Significantly higher nutrient removal from soil under elevated CO_2 or under co-elevation of both CO_2 and temperature calls for revisiting the fertilizer recommendations for major crops in dominant agro-ecologies of the country. CO_2 fertilization benefit is N-dependent implying that application of N significantly alters the level of CO_2 response. Carbon dioxide elevation enhances use efficiency of applied fertilizer-N. Significantly higher N removal and trend of declining soil mineral N content under elevated CO_2 indicates possible N mining and thus N limitations may constrain the long- term plant response to CO_2 elevation. The post-harvest mineral N content in the surface soil showed a gradual decline under CO_2 elevation treatment. Carbon dioxide elevation significantly enhances profile water storage and water use efficiency (WUE) in soybean and wheat and the benefits in water savings are mostly due to reduced soil



Wheat crop phenology for different growth stages under recommended fertilizer dose (OF:Open field; AC : Ambient chamber; eC: Elevated CO 2, eCeT: Elevation of both CO 2 and temperature; eT:Elevated temperature)

evaporation caused by better canopy and ground cover. The significant reduction in dry gluten content in wheat grain indicated that the protein synthesized is not stored as storage protein i.e. gluten. Different protein synthesized might be involved to sustain the metabolic changes during changed environmental conditions, which may not be stored. Increase in Trypsin inhibitor in soybean grain under changed environmental condition might be regulating the breakdown of protein. Less availability of phosphorus could be one of the reasons for decreased phytic acid in soybean.

Genetic analyses of guggul for the identification of genes governing adventive embryony: The genome of guggul was sequenced, assembled and the transcriptome from different tissues both sexual and apomictic guggul *(Commiphora wightii*) plants which includes ovules, leaf and fruit wall tissue were annotated. Analysis of the assembled contigs reveals that most of the transcripts show very high similarity to apomictic genes from other species. Differentially expressed genes were identified with RNA-Seq by Expectation-Maximization (RSEM), abundance estimation and edge-R analysis. Only 265 transcripts showed expression restricted to the apomictic plants.

Stock characterization, captive breeding, seed production and culture of hilsa (*Tenualosa ilisha*)- Phase I: Hilsa was successfully bred with 98% fertilization. The eggs were incubated in the laboratory in glass aquaria using filtered pond water. Larvae were reared in outdoor FRP tanks. During 46 days of rearing period, larval survival was achieved up to 61.3 % at lowest stocking density (300 m-3). Hilsa was cultured in two ponds of 0.1 ha each at 15,000 and 30,000/ha stocking density, where fish grew to 134.71 mm/ 24.63 g and 119.7 mm/14.64 g from the initial size of 29. mm/0.27 g during 300 days of culture period. Hilsa fry could be weaned to accept artificial feed under pond culture condition. Transportation trial of eggs and larvae of hilsa revealed that the survival of eggs and larvae at 100 and 50 nos./ litre were 80 and 98%, respectively. After 31 months of culture, hilsa attained average growth of 83.80±27.38g/ 339.33±9.68 mm from initial body weight/length of 1.37±0.18 g / 52.97±5.50 mm. Significant number of matured female (358.18g-425.52g/352mm-370mm)

Harvesting of hilsa

with V-stage of oocyte maturation and matured male (139.35g/260 mm) in the cultured pond were found during October-November and January-February after 2 years of culture indicating possibility of brood stock maturation in captivity. The study also revealed that the main reason for decline of hilsa, is increased overfishing and altered flow regime. It was observed that 100 or 110 mm mesh gillnet for hilsa fishing should be followed for harvesting of fishes.

Decision Support System for enhancing water productivity of irrigated rice-wheat cropping system: Four year of experimentation concluded that the System of Rice Intensification (SRI) and Direct Seeded Rice (DSR) methods of rice cultivation resulted in higher grain yield and saving of water as compared to puddled method. Further the crop simulation models, viz. AquaCrop and CERES- rice and wheat modules of DSSAT were calibrated and validated for all experimented rice and wheat cultivars under different rice cultivation methods and irrigation regimes and the water production functions were developed. The data acquired from field experiments were used as background data base for the development of water productivity decision support system for RWCS (WPDSS-RW).The developed DSS was operated with input data of different cultivars, cultivation methods, rainfall depths etc. for different locations to generate scenarios of grain yield under different irrigation depths, water productivity, water saving and consequent increase in the groundwater table information for enhancing water productivity of the study region.

Decision Support System for enhancing productivity of grapes under moisture and temperature stress conditions: *Vitis* Mod, a grape simulation model (beta version) is developed. It is a process based model designed to run at daily step and it can simulate the growth, development and yield of grape. It has a modular structure with modules to simulate phenology, canopy, dry matter partitioning, yield, stress of water and temperature on growth and yield. The phenology module is calibrated, validated and evaluated for its simulation efficiency in farmers' fields. The phenology module is integrated into the web-based DSS. The phenology forecaster module is enabled. This DSS is available to farmers for use and validation.

Variation in status and localization of micronutrients in food crops: Micronutrient efficient and inefficient cultivars of rice, wheat, maize, pigeon pea and chickpea were identified using micronutrient yield and uptake efficiency indices. The efficient cultivars could be grown in micronutrient deficient soils without affecting the yield level. Micronutrient localization studies showed deposition of iron (Fe) and zinc (Zn) in the epidermis of chickpea, and apical cortical regions of pigeon pea stems. In wheat, Zn concentration was more in the aleurone layer and seed embryo. The manganese (Mn) application influenced the vessel size of vascular bundle and enhanced its translocation to the grain. Higher rate of basal dressing of Zn during first year had significant residual effect in second year in terms of grain yield and Zn concentration in wheat; accumulation of Zn in grain occurred mostly through remobilization from vegetative part. However, the contribution from different vegetative parts to grain Zn varied with cultivars. The *rhizobium* isolate R-16 (*Rhizobium pusense*) augmented more Fe whereas rhizobium isolate R-19 is more useful for Zn enhancement in the pigeon pea seeds.

Quality and resilience of soils in diverse agro-ecosystems: Key indicators of soil quality and health were identified for specific locations in the four agro-ecological sub-regions (AESF3) viz., AESR 4.1, AESR 7.2, AESR 10.1 and AESR 15.1 covering the states of Punjab. Andhra Pradesh, Madhya Pradesh and West Bengal. Relative soil quality index (RSQI) was developed based on the 15 known indicators (3 physical, 2 biological and 10 chemical indicators) with assigned weights and marks. On the basis of RSQI values, the soils were classified as poor (value of < 50%), medium (value of 50–70%) and good (value of >70%) quality soils. The soil quality assessment based on RSQI values showed good relationship with crop productivity potential. The SQIC software was developed to calculate the soil quality index. A total of 1,270 soil health cards (SHCs) were distributed to farmers in the four AESRs.

Georeferenced soil information system: The development of SOTER database led to revised Agro-ecological sub-region (AESR) boundaries. With the new data sets, actual available soil water was calculated after the cessation of the rains, and used in revising the length of growing period (LGP) assessment and refining the LGP maps. Similarly, the calculation of hydraulic conductivity (HC) through real time datasets along with those generated through pseudo transfer function (PTF) helped in refining the earlier drainage map. The drainage map was used in identifying the poorly drained and well-drained soils separately and thereby, helping to fine tune the AESR map. This led to revising the number of AESRs from 17 to 29 and from 36 to 54 in the Indo-Gangetic Plain and Black Soil Region, respectively.

Carbon dynamics in soil-plant system: The emission of methane (CH_3) was found significantly higher (26-36 per cent) whereas emission of nitrous oxide (N_2O) was lower by 9 per cent under the rice fish system compared to rice alone. Algal isolates capable of higher biomass yield under elevated CO_2 level were isolated, maintained and further investigated to find significant increase in their biomass content at higher CO_2, levels. At 4 per cent CO_2 level, there was 4.8-fold increase in biomass yield, 172 per cent increase in chlorophyll content and 34 per cent increase in lipid yield. It was estimated that approximately 1,350 tons of CO_2 per ha per year might be fixed by the alga at 4 per cent CO_2 level and thus, indicating its high prospects for carbon trading. The carbon dynamics and greenhouse gases (GHGs) emission in soil-plant system under anticipatory climatic change condition [elevated CO_2, (550 ppm) and temperature (2°C above the ambient temperature)] was quantified in low-land submerged rice ecology in open top chambers. A three-year study in Open Top Chamber (OTC) under elevated CO_2 along

with elevated temperature was conducted. The study showed that the carbon allocation under elevated CO_2 was in the order of panicle > root > stem > leaf. The stimulatory effect on CH_4 and N_2O emission under CEC was linked with relevant factors including the higher iron concentration and increased activities of methanogens and extracellular enzymes. Combined application of chemical and organic nutrients as the INM was able to minimize the adverse effect of the elevated CO_2, on rice grain yield. The grain N use efficiency also decreased by 4-8 per cent in elevated CO_2, as compared to ambient environment under varying nutrient management in OTC experiment.

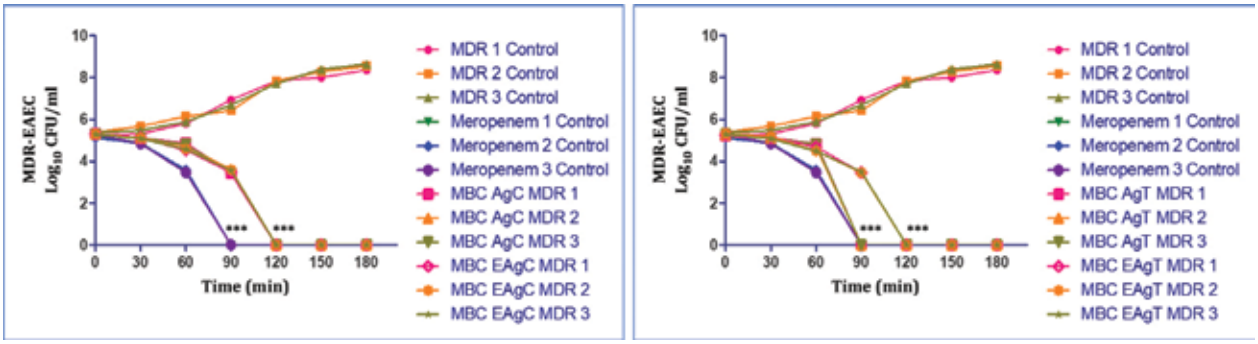
2.4 Nanotechnology in Agriculture

Effect of graded levels of nano selenium supplementation on the performance of broiler chickens: Nano selenium (NSe) was synthesized by chemical method using inorganic sodium selenite as selenium source, GSH as reducing agent and bovine serum albumin (BSA) as stabilizer. The size of the NSe particle was 40–80 nm and shape were spherical with the concentration of 3200 ppm. Also, nano-Se was synthesized by biogenesis and green method by using selenium reducing microorganism isolated from industrial effluents and leaf of spices plants, respectively. Supplementation of 0.15 ppm of nano selenium improves the body weight gain, higher anti-oxidant enzyme status like GPx and SOD activity, both cellular and humoral immunity of the commercial birds. Nano Se concentration in liver, breast muscle, gizzard, kidney and brain are an indicator of Se bioavailability. Se levels in liver, breast muscle, gizzard, kidney and brain in all the Se treated groups were significantly higher but no effect on the organ weight was noticed. At higher level of supplementation i.e. 0.60 and 1.20 ppm levels vacuolar degeneration in liver and degenerative tubular epithelial lining in kidney tissues were observed. Selection of genes for expression analysis related to growth, immunity and stress on the basis of available reported data was done. Designing of primer for the selected genes using available online software's were also done.

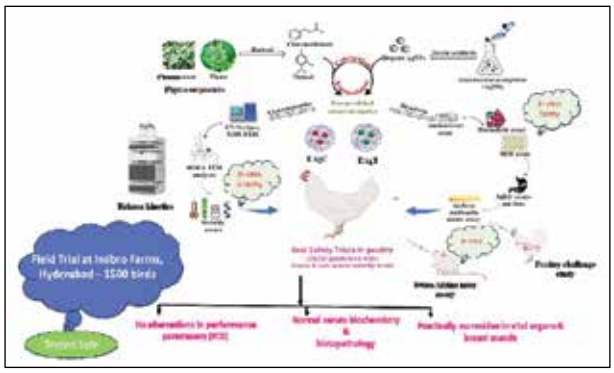
Encapsulated nanoparticle conjugated phytochemicals to combat antimicrobial resistance in poultry: The encapsulated compounds (EAgC, EAgT) derived from the present study were found to inhibit bacterial growth and improve survival rate with minimal toxicity in appropriate *in vitro* assays and *in vivo* *Galleria mellonella* larvae, Swiss albino mice and broiler poultry models, with an improved feed conversion ratio (FCR) in poultry and leaving no residues of the innovated compounds in poultry meat which is crucial for food safety and consumer health. The acute as well as sub-acute toxicity trials performed in poultry as per OECD 425 guidelines revealed that the compounds were safe and left no residues in the meat. No significant changes in the serum biochemical parameters (total protein, blood urea, creatinine, ALT, AST, and ALP) could be observed between the treated as well as control groups. The treated groups retained an optimum FCR, and no silver residues could be detected by atomic absorption spectroscopy (AAS) in the liver, kidney, and breast muscle of broilers suggesting that the encapsulated compounds were safe for therapeutic applications. The innovative product is intended for targeted delivery (released maximum >80% at alkaline pH i.e. in the intestine), hence dose required

Pelleted Feed prepared with nano selenium

Experimental birds fed nano selenium



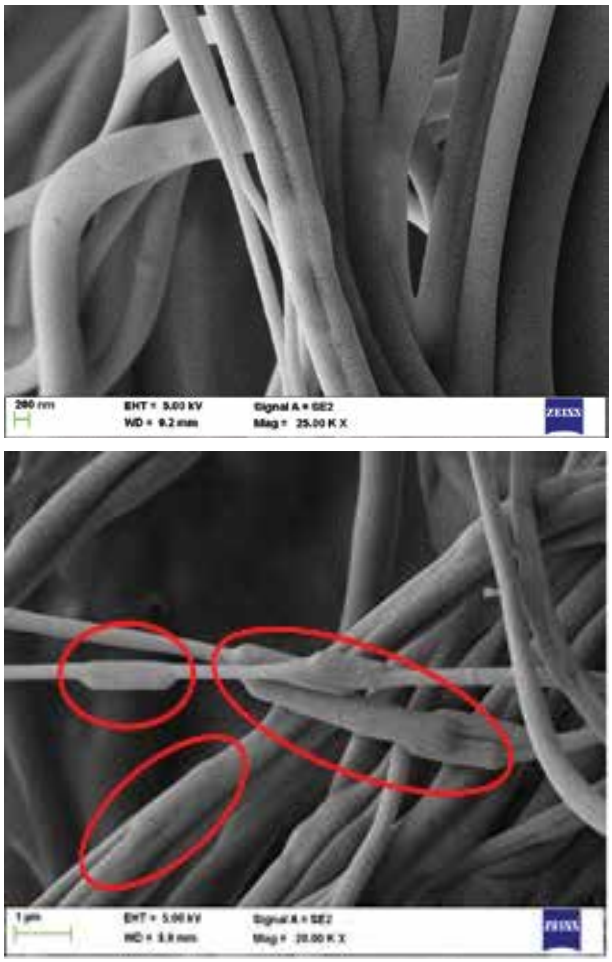
In vitro time and dose dependent killing kinetics of encapsulated nanoparticle- conjugated phytochemicals against MDR- EAEC strains.



Schematic of the Product development.

would be less and also it reduces overall production costs. The microbes may have a very rare or almost negligible chance of developing resistance against the developed product (EAgT and EAgC). The developed product can be used either as a therapeutic as well as from a preventive perspective in the poultry industry. The technology has been commercialised to M/S ITP Special Additives India Private Limited, Mumbai, India.

Nano-micro matrices for the delivery of bioactive, micronutrients and therapeutic: To develop compact core-shell microcapsules "NIMPOD" with *Kluyveromycesmarxianus - lactobacillus casei* probiotic consortium, prebiotic fiber (within dual bio-polymeric layers) and bio actives in nanoliposomes, respectively, were optimized by employing layer-by-layer and coacervation techniques. Curcumin nano emulsion using conjugate (particle size 134.53±1.27 nm & zeta potential -5.28±0.29 mV), under simulated GI conditions, showed slow release of curcumin. Curcumin encapsulation in skim milk using self-assembly approach was also optimized. *Limosilactobacillus reuteri* SW27 and *Ligilactobacillus salivarius* RBL22 of indigenous cattle calf origin were selected and evaluated for *in vitro* and *in vivo* safety after producing spray dried microencapsulated probiotics. Nano ZnO, curcumin and its conjugates were evaluated for their *in vitro* antimicrobial, antioxidant and anti-inflammatory activities. Among the three nanoparticles, nano ZnOcur conjugate showed high antimicrobial activity against *E. coli*, *Staphylococcus* spp and *Salmonella* spp at 300µg/ml. I*n vivo* acute oral toxicity confirms the less toxicity of ZnOcur conjugate with a LD_{50} of 425.4mg/kg bwt vs. nano ZnO (175) and

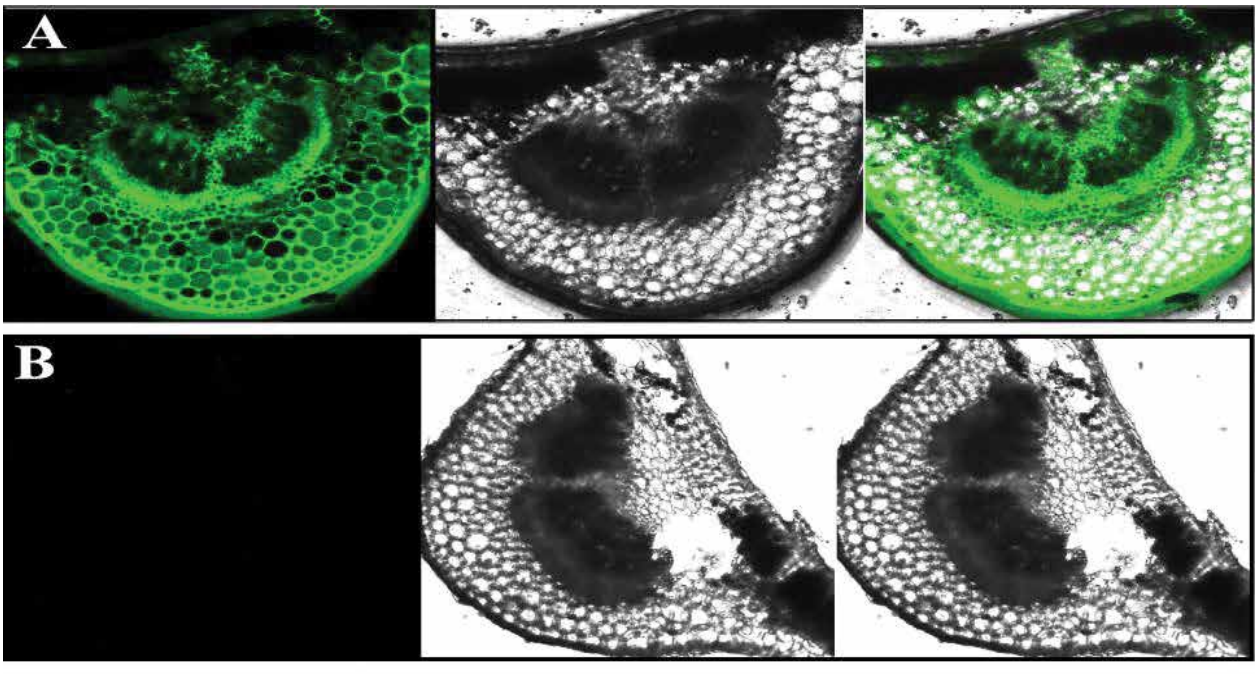


Scanning electron microscopy of *L. reuteri* before and after encapsulation

nano curcumin (311.9). Acute toxicity study was conducted in Wistar Albino rats. LC-MS analysis of buffalo milk isolated exosomes (100nm, zeta potential of -20 mV), protein content of 21 mg/µl, identified approximately 2041 proteins, with 331 being consistently present across all samples. Gene ontology analysis revealed their functioning as immune response proteins.

Genomic approach for risk assessment of metal oxide nanoparticles on soil bacterial communities, soil microbial processes and evaluation of phytotoxicity: In this study, it was observed that ZnO spiked acidic and alkaline soil cause decrease in critical microbial endpoints (soil enzymes, microbial biomass-C,-N & -P and soil respiration) at highest level of 3000 mg Kg^{-1}. In SiO_2 and CaO, all parameters, except soil respiration and biomass carbon decreased at 4000 mg Kg^{-1}. The threshold of nZnO toxicity on beneficial microorganisms (*Bacillus safensis*, *Raoultella terrigena*, *Acinetobacter* sp, *Bacillus amyloliquefaciens* and *Trichoderma asperellum*) varied depending on the bacteria. In general, changes in colony morphology, growth reduction and population reduction were observed at levels greater than10 mg Kg^{-1}. The threshold level of NP toxicity to rice plant (var. Swarna) was identified. Increased plant growth was observed at levels 25 mg Kg^{-1} (ZnO), 250 mg Kg^{-1} (CaO) and 50 mg Kg^{-1} (SiO_2). Higher concentrations of the metal oxides had adverse effect on the growth of rice. Transcriptome analysis of rice grains indicated upregulation of stress response genes *viz*., pentatricopeptide repeat proteins, heavy metal transport/detoxification protein and glycoside hydrolase. Heavy metals differentially affected the expression of dominant starch synthesis genes namely ADP-glucose pyrophosphorylase (Os01g0633100) and granule-bound starch synthase (Os06g0133000). Analysis of key genes involved in biosynthesis of curcumin in turmeric under nZnO and bZnO revealed enhanced curcumin content and expression of pathway genes *viz*., *C4H*, *PAL*, *CURS3* and *CLPKS-11* at 500 mg kg^{-1} nZnO compared to 1000 mg kg^{-1} (except *PAL*). In case of bZnO gene expression was downregulated under both treatments (except *PAL*), with no much difference in curcumin content between treatments.

Effective delivery of nutrients, insecticides and fungicides through nanoparticulates and its effect on uptake and yield in groundnut and chilli: Nanoparticulates (N-ZnO, N-CaO, N-SiO_2) were synthesized using sol-gel method. Protocols were standardized for the synthesis of nanoscale chitosan, nanoscale chitosan encapsulated mancozeb and imidacloprid particles. Seeds treated with 150 ppm and 200



Bright green flouroscence represents Fluorescein isothiocyanate (FITC) tagged N-SiO2.
A) Longitudinal section of groundnut leaf showing transport and accumulation of FITC tagged N-SiO2 in apoplastic space. B) Control leaf showing no flouroscence (dark colour) (confocal microscopy)

ppm nanoscale ZnO recorded significant 100 % germination, while highest seedling vigor index was recorded by treating with 200 ppm of nano ZnO (SVI - 1948) in chilli. Identical structures found on both sides of the leaves, irrespective of the stage of chilli crop. Flexural rigidity (ladder like Si) was observed to be 37 times higher with the application of nanoscale silica compared to the application of potassium orthosilicate (PSi) in chilli. Higher Nanoscale Si spray significantly increased catalase (CAT) activity and superoxide dismutase (SOD) activity in chilli, suggesting the polymerisation as the accumulation of silicon forms a layer beneath the cuticle which acts as chemical barrier by inducing formation of phenols. It was also demonstrated that nanoparticles of zinc, calcium and silicon are entering the leaf through the stomata by following the hydrophilic pathway. After entering the stomata, nanoparticles were found to be translocated by passing through the phloem and reaching the different parts and roots of groundnut plants by following the vascular system–phloem transport pathways in groundnut.

Polymeric nano materials for packaging and efficient delivery of nutraceuticals: Shelf life of guava dices stored in the egg shell could be extended up to 14th day compared to only 6 days in the macro-perforated package. The same for papaya was up to 20th day in the egg shell compared to only 4 days under macro-perforated package. Different modifications of native starch and incorporation of plasticizers and functional compounds were tried to arrive at a suitable biodegradable film for subsequent use. Hydrophilic OH- MMT was prepared by simple ion exchange reaction method between THAC and Na^+-MMT. The good degree of exfoliation achieved can be attributed with the strong interactions between the modified silicate layers and polymer matrix through efficient hydrogen bonding.

Improvement in cotton fabric quality by plasma nano-technology: an eco-friendly approach: Indigenous lab-scale atmospheric pressure cold-plasma reactor, with and without cooling system was designed for environment friendly treatment of cotton-fabrics for effective dyeing and other qualities. Generation of atmospheric pressure cold plasma was also been achieved. An innovative product of commercial significance was developed, validated and licensed in biodegradable composite films using nano-cellulose. Starch (from potato/cassava) nano-cellulose was used as filler to increase the permeability and/or strength of composite films for food packaging and mulching in agricultural fields, respectively. Reduction in energy consumption by 40-50 per cent was achieved in the production of pure nano-fibril with a pre-treatment of cotton fibres/ microcrystalline cellulose with zinc chloride and enzyme.

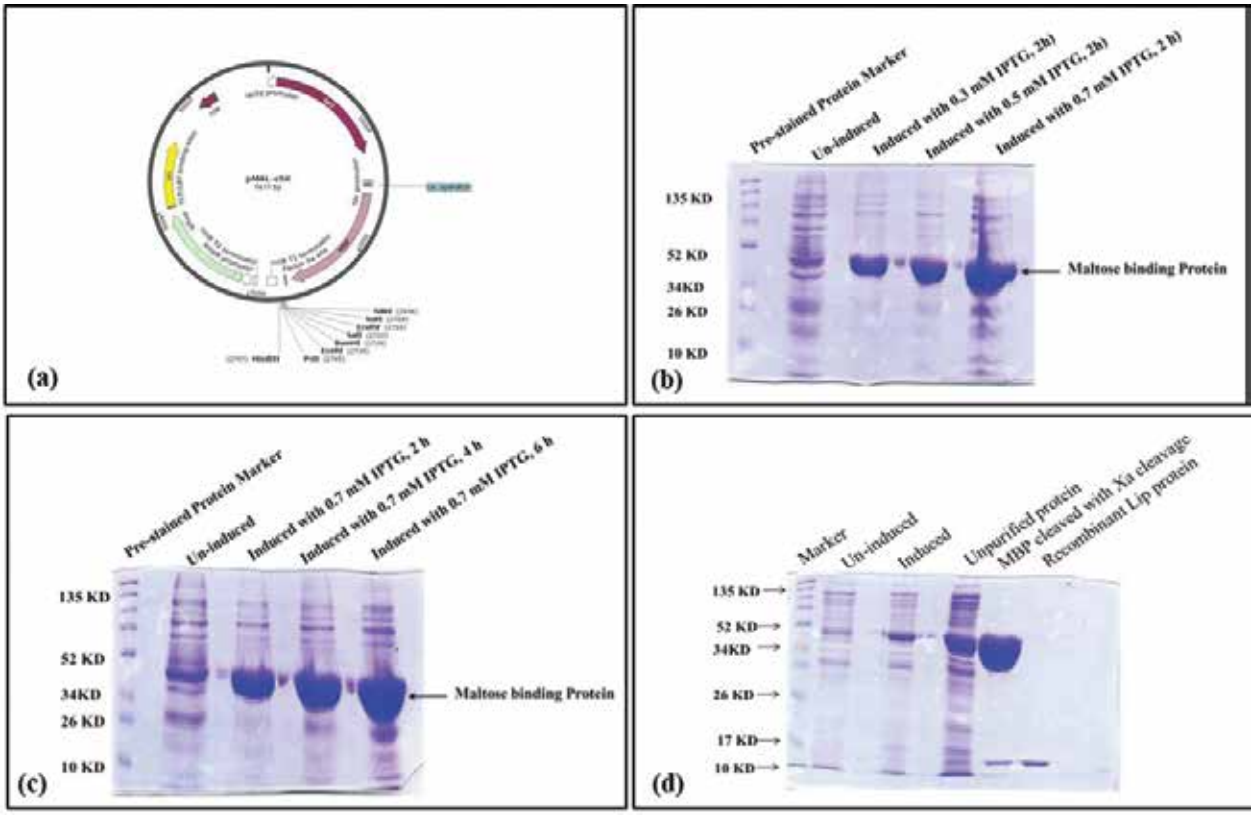
Detection of pathogens and adulterants using chemical biology: Functionalized gold nanoparticles (Fn-GNPs) based sensor systems for on-site detection of urea in milk samples was developed and validated by comparing the detection system with commercially available kits for urea detection. These developed gold nanoparticles (GNPs) based detection systems for on-site detection of urea in milk could be useful at unorganized dairies and small milk plants. The first-generation GNP based system works by giving a “one” or “zero” output. Aptamer-GNPs based nano sensor for the detection of urea in adulterated milk samples was also developed and validated. This sensor could detect urea quantity as well, if coupled to a spectrofluorometer. Presence of common adulterants like NaCI, NaHCO, SDS and glucose in milk was found to cause no interference with the test. Flow injection analysis - Electrochemical quartz crystal nano balance biosensor was also developed, which could facilitate ultrasensitive detection of streptomycin residues in milk up to 1 pg/ ml with a range of 1 pg/ml to 200 pgm/ mi. A simple, economical, and highly stable Flow injection analysis enzyme thermistor (FIA-ET) biosensor for analysis of urea in adulterated milk is successfully demonstrated, first time using this instrument. The developed biosensor can facilitate continuous analysis of milk urea in dairy industry. Another Important feature of the presented biosensor is the lower detection limit and an excellent dynamic range of detection, 1–200 mM urea with a sample throughput of 30 within an hour. Technologies on the detection of harmful bacteria. *Listeria monocytogenes* and *Enterococci* in milk were transferred for commercial use in the first Agri-Investors’ meet organized by NAIP. As part of the integration activity for multi-analyte detection system, the detection of bacteria {Listeria monocytogenes) in milk was achieved by the joint efforts of three

consortium partners, and a kit for the detection of pesticide residues based on nanoparticles was also developed.

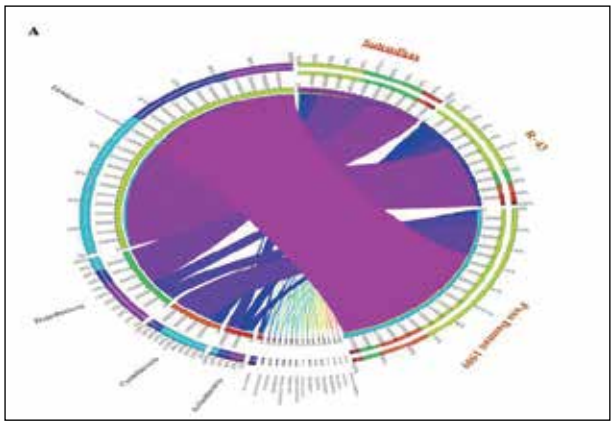
2.5 Metabolomics in Agriculture

Identification and characterization of specific genes/metabolites linked with rancidity and their bioavailability patterns in landraces and elite cultivars of pearl millet for the development of nutri-rich products: To identify the putative genes and reconstruct the pathway linked with flour rancidity, *de novo* transcriptome sequencing of landraces (Damodhar Bajri and Chadhi Bajri), hybrid (Pusa1201) and composite (PC-701) were carried out. In-depth annotation domain search analysis identified and facilitated the cloning of five lipases and two lipoxygenases. The expression analysis of TAG-lipase showed maximum relative fold expression during mealy-ripe stage of endosperm development in diverse genotypes of pearl millet. Similar pattern was observed in case of lipoxygenase (LOX and LOX-6) genes. A direct correlation was observed between the expression and activities of lipase and lipoxygenase in endosperm tissue of pearl millet. The open reading frame of putative TAG-Lipase gene cloned from Pusa1201 was further mobilized in pMal C5x expression vector and was expressed by inducing with 0.8 mM IPTG. The transformed *E. coli* cells were harvested and further recombinant lipase protein of ~14 kDa was purified using anion exchange column and ultra Amicon column.

Rice rhizosphere metabolome - and microbiome functions for improved crop establishment, growth, and yield: The metabolite profiling of seed exudates showed distinct differences among the genotypes tested (cv. Pusa Basmati 1509, cv. R-43, and cv. Sulendhas). The seed microbial diversity differed in these three contrasting rice genotypes, illustrated by the group-specific q-PCR and meta transcriptomic analyses. The number of *Bacterial* 16S rRNA gene copies in cv. R- 43 was significantly higher than other genotypes. The predominant endophytic bacterial morphotypes were isolated and purified from seed husks and grains of different rice cultivars. From a total of 144 isolates, 45 isolates that exhibited an equal or more than 5 bonitur values were chosen for characterizing their environment adaptive functional traits. The metabolite profiles of rice rhizosphere under puddled-transplanted



Heterologous expression of TAG-Lipase gene in E. coli system for the purification of recombinant protein, a) pMal C5x vector, b) Induction of E. coli cells using IPTG, c) Induced MBP with lipase protein, d) Purified recombinant lipase protein.

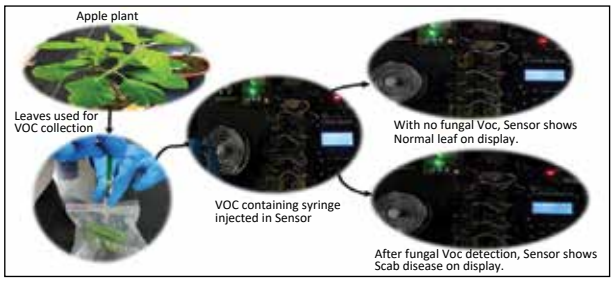


Relative abundance of top microbial phyla, equal or higher than 0.05% in at least one of the genotypes of rice seeds were plotted, var. Pusa Basmati 1509, var. Sulendhas and var. R-43.

and dry direct-seeded experiments showed clear distinctions between the control and modified nitrogen environments by hierarchical clustering. Unique and common microbial genera were involved in carbon (13), nitrogen (150), iron (63), phosphorus (33), and sulfur (231) cycles, analyzed from the transcriptionally active members in the rhizosphere. In addition, the rice rhizosphere metabolites, at seedling stage (15 days), were assessed to identify several sugars, amino acids, and organic acids, besides other metabolites. In another study, the rhizosphere microbial diversity of the scented rice (cv. Kunkuni Joha), characterized using amplicon sequencing analysis, showed that the relative abundance of microbial groups in aerobic and saturated conditions differed distinctly in response to low N and high N doses.

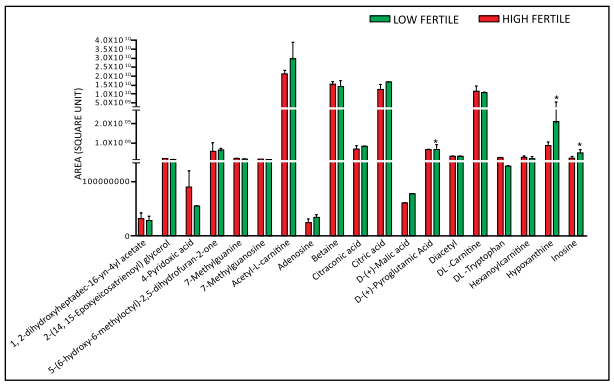
Foodomics study for food authentication and exploration of nutraceutical potential: This experiment was performed to establish the metabolite profile of the new grape variety, Manjari Medika, and differentiated it with its two parents, Flame Seedless and Pusa Navrang. The grape berry samples of these varieties were extracted by methanol. Metabolite profiling was carried out and the data was acquired using the full scan - data dependent MS/MS method of acquisition. The list of identified compounds for the three varieties was prepared, statistically compared and differentiating compounds were identified. The metabolic profile showed significant differences with respect to the number, class and concentration of compounds. Few differentiating compounds, such as epicatechin, trigonelline, kaempferol were identified.

A metabolomics approach for the analyses of scab-disease resistance in apple and development of a metabolite-based non-invasive sensor for early scab-disease diagnosis: The metabolic reprogramming in root tissues of scab-resistant ('Prima') and scab-susceptible ('Red Delicious') apple cultivars was carried out after being infected by *Venturia inaequalis*. Syringic acid, a root-derived metabolite, was identified as a key player in reducing scab fungus growth on aerial parts of plants, revealing a long-distance signalling system between shoot and root. Application of methyl jasmonate (MeJA) for inducing resistance in apple plants was investigated. Exogenous application of MeJA on leaf surfaces showed increased membrane stability and decreased malondialdehyde levels in the scab-susceptible 'Red Delicious', indicating its potential in protecting against oxidative damage. A volatile biomarker(s) was identified for the screening of scab resistant apple germplasm at early stage non-destructively. Based on the biomarker(s), an e-nose sensor prototype was developed for the early non-destructive screening of scab resistance germplasm.



E-nose sensor for scab prediction in apple

Metabolomics fingerprinting of body fluids for development of a metabolite-based novel semen extender for enhancing fertility of bull sperm and diagnostic assays for detection of sub-clinical hemoprotozoan diseases in cattle: Unique metabolites were found only in high fertile bulls as compared to low fertile bulls. Similarly, some unique metabolites were found in low fertile bulls as compared to high fertile bulls, whereas some metabolites were found common both in high fertile as well as in low fertile bulls but concentration of which varied between the groups. Palmitic acid was found significantly higher in seminal plasma of high fertile bulls as compared to low fertile. In contrast, inosine, hypoxanthine and pyro-glutamate were found significantly higher in

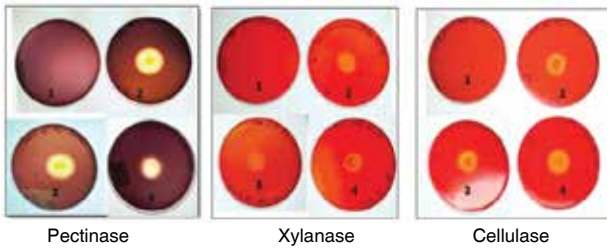


Metabolites identified both in high and low fertile *Holstein Friesian* bull seminal plasma as assessed by HR-MS.

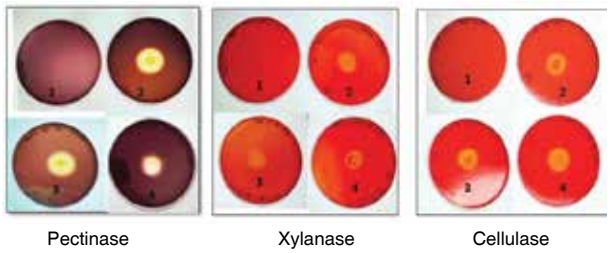
seminal plasma of low fertile bulls as compared to high fertile. L-Arginine was found significantly higher in GF group of bull seminal plasma.

2.6 Farm Mechanization and Energy

Development of a minimal water retting technology of jute: Three bacterial cultures TNA2, TNA 15 (identified in the lab), and ATCC 13542 (procured from ATCC, USA) were used in the study. Qualitatively, all these 3 cultures showed high retting enzyme (pectinase & xylanase) activities. In comparison, cellulase activity was very low in TNA 2 and ATCC 13542 while TNA15 didn't show any detectable cellulase activity. With respect to adaptability to pH, while TNA 2 and TNA 15 showed a slightly narrow range, i. e., from pH 7.0 to 11.0, ATCC 13542 culture showed adaptability to pH from 5.0 to 11.0. Optimum temperature for growth of TNA 15 and ATCC 13542 was found to be 30°C while TNA2 showed maximum growth between 30 to 40°C.



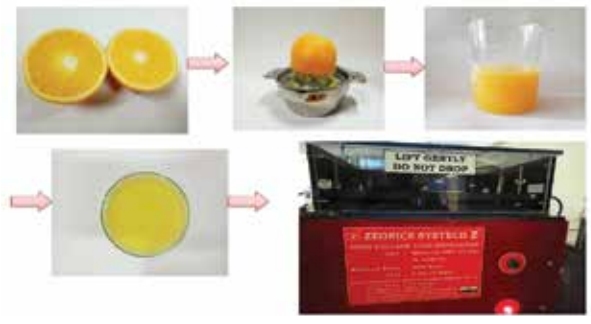
Qualitative Test for retting enzyme activity of three bacterial cultures



Quantitative Test for retting enzyme activity of three bacterial cultures

Retting of mechanical wounded jute stem resulted in reduction of retting duration by at least 2 days. Retting of mechanically wounded jute stems took 6 days to complete the retting process while non-wounded stems took 8 days. A new Green Accelerator (GA) was developed and tested during the preceding season.

Electric Field Based Novel Technologies for Pilot Scale Processing of Juice and Pulp from Potential Fruits of NE Region: A lab scale continuous ohmic heating (COH) system with an isothermal holding section was developed. Experiments were conducted to study the effect of COH on enzyme (polyphenol oxidase, peroxidase and bromelain) and microbial inactivation in pineapple juice. Effect of atmospheric cold plasma (ACP) was studied on fruit juices (orange, kiwi and pineapple) processing with respect to enzyme inactivation, microbial destruction and nutritional properties. Maximum microbial load reduction of 4.32±0.03 log CFU was observed at 90 °C, 35 V/cm and 60 s holding time while processing pineapple juice in lab scale COH. The minimum residual activity of polyphenol oxidase, peroxidase and bromelain enzyme was observed to be 31.8±0.8 %, 17.8±0.4 % and 1.2±0.4 % respectively when pineapple juice was treated at 90°C, 40 V/cm and 60 s holding time. No significant ($p > 0.05$) changes were found for total soluble solids, pH, acidity and the processing did not affect the colour of orange juice. Optimum values of PME enzyme inactivation (54.53 %) and ascorbic acid (31.32 mg/100 ml) were obtained at voltage 20 kV treatment for 2 min and sample thickness of 2 mm for orange processing. A maximum of 87% polyphenol oxidase and 90% peroxidase



Cold Plasma Processing of Orange Juice.

inactivation of pineapple enzymes was achieved by cold plasma treatment. Residual activities of enzymes and ascorbic acid were significantly reduced with the increase in treatment time and voltage while decreasing the sample thickness for all fruit juices in the study.

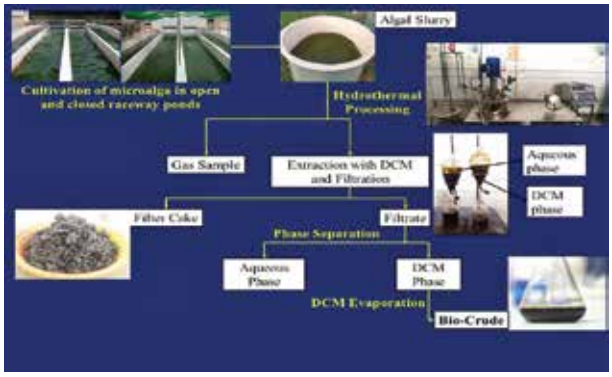
Valorization of industrially produced soybean and groundnut de-oiled meals/cakes by extraction, purification and production of protein isolates: A novel process to produce protein isolates/concentrates from oilseed cakes/meals (example soy meal, groundnut cake) without addition of acid has been developed. The developed process provides about 5% higher yield of protein as compared to the existing chemical process. In selection of biological agents, BBE4 was isolated from dairy products and its 16S rDNA sequence has been registered with NCBI vide GenBank accession number KF974325 and MTCC, IMTECH. The protein produced using ICAR-CIPHET method shows better properties in terms of solubility, wettability, water absorption capacity and degree of hydrolysis. The protein yield is about 35-36% of the total weight of soymeal and 25% of total weight of groundnut cake whereas, in the existing process, maximum 30% protein yield from soymeal can be obtained.

Soy protein isolated through novel method

Groundnut protein isolated through novel method

The developed method comprises novel bacterial strains isolated from a food sample for producing protein from de-oiled meal/flour. The supernatant obtained after precipitation of protein from a particular batch may be used for precipitation of another batch and so on. The protein produced through the new process may find demand at national as well as international level to boost immunity. The plant protein is used in protein supplements, texturized vegetable proteins, imitation dairy products, sea food products, beverage industry, infant food formulations, weaning food formulations, bakery products, meat analogues for various purposes.

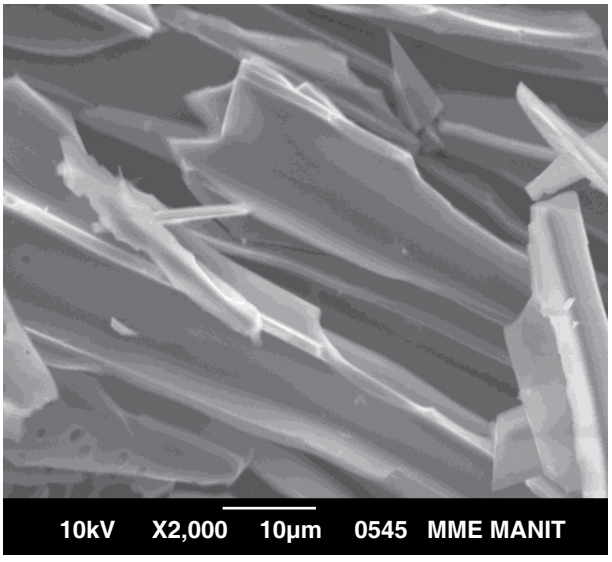
Production and Processing of Microalgal Biomass for Biodiesel and Other Industrially Important Co-products-An Algal Refinery Approach: Growth modelling studies of selected triacylglycerols (TAG)-producing microalgae under unialgal and mixed culture modes were carried out at IIT Kharagpur and IARI, New Delhi. Among different microalgal species *Chlorella minutissima* was a good lipid accumulator. *Anabaena variabilis* is rich in carbohydrate content, whereas *Oscillatoria formosa*, *Calothrix* sp. and *Spirulina subsalsa* are rich in protein + carbohydrate contents. While, *Aulosira fertilissima*, *Calothrix* sp., and *Oscillatoria formosa* are poor lipid accumulators. In the hydrothermal liquefaction (HTL) study, the maximum bio-crude yield (36%) of *C. minutissima* was obtained at 300°C under 200 bar pressure at 60 min retention time without catalyst use. A protocol was standardized for maximum extraction of microalgal protein from *C. minutissima* biomass that can be substituted in the diets of freshwater fishes as a protein supplement. Experiments were conducted to study hydrothermal processing of microalgal biomass for direct conversion to liquid fuel



Hydro thermal processing of micro algal biomass.

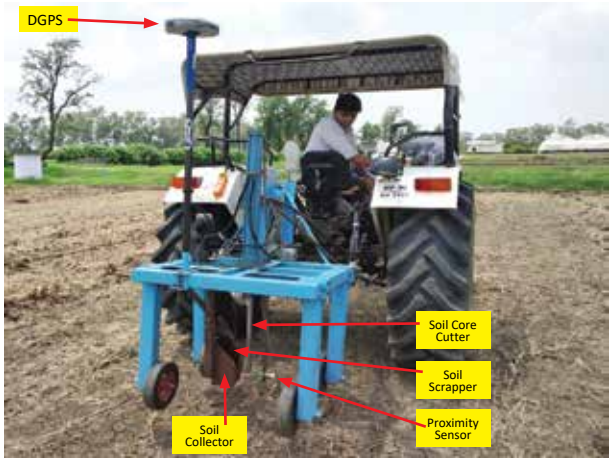
and to explore the algal refinery approach for improving the economics The Cyanobacterium *Leptolyngbya* sp BTA 477 was also explored successfully for biodiesel production. Along with SCC (Sodium Copper Chlorophyllin), protocol was standardized for maximum extraction of micro algal protein from algal biomass that can be substituted in the diets of freshwater fishes as a protein supplement. Standard feed, whole micro algal biomass and extracted micro algal protein diet in the ratio of 25:25:50 was found to be the best diet for maximum growth of the freshwater fish varieties, rohu, mrigal and catla. Crude glycerol (purified up to 92%) was obtained as a by-product of transesterification process.

Thermal degradation of crop residues for kinetics, bio-polymeric transitions and value-added products: The presence of all three bio-polymers: cellulose, hemicellulose and lignin, was remarkably noticed in torrefied biomaterials. During slow pyrolysis, hemi cellulosic and cellulosic bio-polymers almost vanished and lignin bio-polymer dominated the processed bio-product. At high temperature after pyrolysis, only lignin was noticed. Torrefaction and slow pyrolysis increased the total carbon (48 % to 80 %; at 200 to 450 °C). The thermal degradation process was found to impart the changes in the surface morphology of the processed biomaterial and SEM image highlights the formation of micro channels and micro cavities on surface of thermally degraded biomaterial. The iso-conversional FWO model was found better than other models for measuring activation energy for complete range of conversion (from 01. to 0.9). Thermal degradation processes were found to reduce, on an average, the activation energy levels of the lignin segment as the process temperature increased.



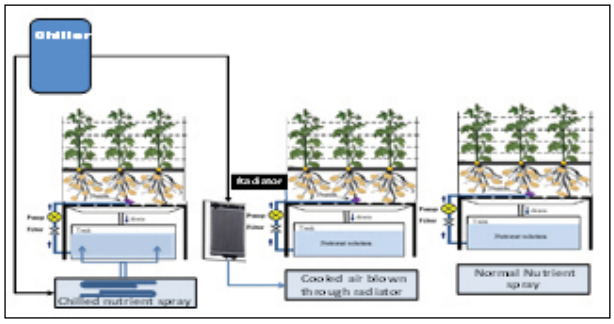
Formation of micro channels and cavities in thermally degraded bio-material.

Development of an Automated Soil Nutrient Sensing System: A hydraulically operated soil sampler equipped with hollow circular core cutter was developed at ICAR-CIAE, Bhopal. In order to decide the soil sampling depth, a proximity sensor-based depth control mechanism was developed and integrated with the soil sampler. The sensor was used to control the sampling depth of 15 cm (adjustable as per requirement) to collect soil samples without having any physical contact. The entire soil sampling unit consists of a hydraulic cylinder, core cutter, soil scrapper, soil collector, proximity sensor, controller, and other components. The hydraulic cylinder works with the help of tractor hydraulic system. The hydraulic cylinder presses the core cutter in the soil, which cuts the soil from ground and then cylinder lifts the core cutter to bring the soil sample up from the ground. A scrapper unit scraps the soil from the core cutter and places it in to the soil collector. A DGPS has been integrated in the developed system so that the tagging of accurate location could be done for the collected soil sample. Identification of the design and operating parameters for soil sample collection was carried out wherein soil properties by electrochemical methods was validated by ICAR-IISS, Bhopal and spectroscopy method by CSIR-CSIO, Chandigarh. Targeted soil nutrients to be measured were soil Nitrogen, Phosphorus, Potassium, soil pH, soil Organic Carbon.



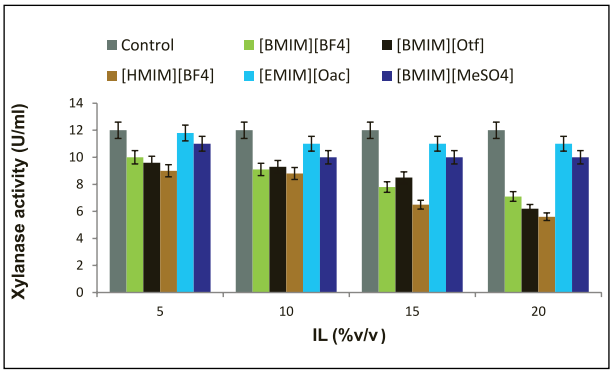
Automated soil sampler in field.

Energy efficient polyhouse and aeroponic system for mini tuber production of tissue cultured potato: A novel and low cost Mini Aeroponic chamber was designed with an objective to standardize the nutrient composition for aeroponic potato cultivation and to optimize the misting cycle for efficient cultivation of potato aeroponically. Dynamic alteration of temperature in the rooting and solonization zone of the plant was studied in the temperature controlled Aeroponic Chambers. Increase in shoot or root zone temperature marginally affected haulm characters but a considerable decrease in tuber number was noticed when the plants were exposed to higher root and shoot zone temperatures under the aeroponic system. The leads of this study indicate that, for every 1°C rise in mean cumulative shoot temperature beyond the threshold of 19.5 °C, there is a reduction of 2.3 tubers per plant. Similarly, 1°C raise in mean cumulative aeroponic chamber (root-zone) temperature beyond 18.4 °C, the tuber number reduced by 3.5. The expression of tuberization signal SP6A and positive regulator BEL5 decreased at high temperature and is correlated with tuber production (number). In poly-house, with the mean maximum temperatures of 32.83 and mean minimum temperatures of 15.09 °C of shoot zone, a significant improvement in mini tuber production was achieved by maintaining optimum aeroponic chamber temperatures (18-20 °C) at Bengaluru. Using LED light panels, the plants, exposed to specific light spectra mainly in the red region achieved substantial reduction in the etiolation under polyhouse conditions with low light intensities. Marginal improvement in tuberization was achieved when plants were exposed to near far-red light (730nm).



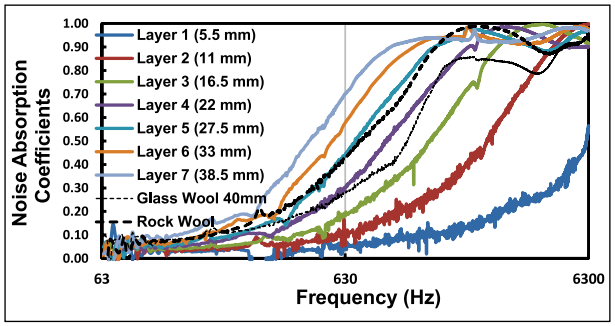
A) Different aeroponic chambers developed B) Different cooling technology of the aeroponic chambers.

Lactic acid bacteria based biorefineries for converting agro and food-based biomass into PLA and high value-added products: An enzymatic process for the production of polylactides was developed for converting agro and food based biomass into PLA and high value-added products. The study was carried out at IIT New Delhi, IIT Kharagpur & IARI, New Delhi. Purified lactic acid (LA) was used for the synthesis of poly-lactic acid (PLA), a biodegradable and biocompatible plastic, by enzymatic method. PLA is a high value-added product synthesized from LA. Effect of ionic liquids on *S. thermophile* xylanase activity was studied. Xylanase activity and stability were evaluated towards five commonly used imidazolium based ILs up to 20%(v/v) concentration for 1h. The xylanase was stable in [BMIM][$MeSO_4$] and [EMIM][OAc]. Further increase in the concentration of these two ILs revealed that the enzyme was stable even up to 50% (v/v) for 72h. Furthermore, foods with improved organoleptic and nutraceuticals properties were prepared by using coproduct polyols, GABA and EPS. Encapsulation of GABA and LAB using exopolysaccharides as a coating agent was carried out and its stability under different process conditions was evaluated. Shelf-stable microcapsules of LAB and GABA containing inulin and dextran as wall materials were prepared using spray drying technology. Spray drying produced a highly stable microcapsule of desirable flowability with higher encapsulation efficiency (99.6%).



Effect of ionic liquids on *S. thermophile* xylanase activity.

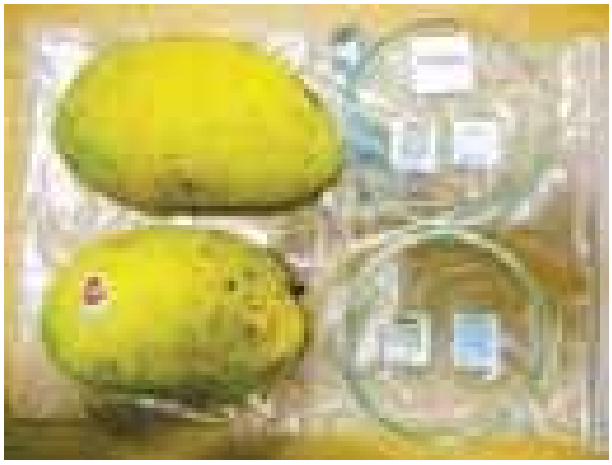
Effect of structure of jute and allied fibre products on sound insulation property: Jute felt of 27.5 mm thickness showed sound absorption property similar to commercially available 40 mm thick sound absorbers viz. glass wool and rock wool. This indicates that thickness of the jute-based sound absorber could be reduced by 12.5 mm.



Frequency dependent sound absorption coefficients of jute felts, glass wool and rock wool of different thicknesses

Seventeen types of jute and allied natural fibers were tested for acoustic properties and compared with the commercial counterparts keeping same densities (g/cc). Jute and some allied fibers showed comparable absorption performance with glass wool and rock wool. Natural fiber extracted from the bast of "Abelmoschus Esculentus", popularly known as "Okra" fiber showed the best noise absorbing (throughout NAC > 0.6) trend. Roselle (*Hibiscus sabdariffa*) fiber showed value similar to jute. It is cheaper than jute fiber. A database of acoustic performances of all the commercially available jute based woven clothes has been prepared. Entire range of commercially available jute woven cloths was tested for the noise absorption property. No conventional woven cloth shows any notable absorption property in the range of audible frequencies. Using jute nonwoven, thickness of absorbers can be reduced significantly; performance of 90 mm conventional material can be achieved by 40 mm thickness only. The acoustic property evaluations of these materials are also in line with the results obtained in "Porometry". As the minimum and mean pore sizes reduce, the absorbing property of felts increases significantly. Jute filled perforated rigid panel absorber can provide transmission loss as well as sound absorption over the complete frequency range. That is, it absorbs the lower frequencies and hinders the transmission in the higher frequencies. Thus, the entire frequency range is insulated by the two mechanisms, viz. Absorption and transmission loss. Specially conceptualized and designed fiber holders have been fabricated to make special type sound insulation products that can act both as effective absorber and barrier depending on the position of its use.

Biodegradable electrospun fibre mat for use in packaging of fresh perishable horticultural produce: Multi-phase electrospinning setup was fabricated for production of electrospun nano fibre mat. The machine has multi-axial arrangements with adjustable nozzle geometry that can orient the needle to desired angle; automated linear motion and multiple parallel needles. The machine has the advantage of forming multi-layer fibre and produce mat with even surface. The parameters for electrospinning process were optimized. The optimized parameters were 25 kV voltage, 15 cm distance, 0.04 ml/min flow rate and 15 min duration. Volatile gas profile of Alphonso mango during the ripening stage was mapped by non-destructive method. Analysis revealed that the major gases being produced from the mango fruit during ripening were 3-methyl furan, α- pinene, α-ocimene, P-mentha-1,4-diene, tetramethyl cyclohexadiene, dimethyl octatriene, ethyl octanoate, ethyl-trans-4-decenoate, ethyl decanoate and caryophyllene.



Colorimetric sensor for mango ripening

Whey to Biofuel: Bioethanol Production by Stress Tolerant and Metabolically Engineered Yeast from Whey: Nine thermo-tolerant yeast (*Klyuveromyces*) isolates were selected from 213, which showed tolerance to 7.5% of ethanol concentration. Among the selected isolates,

6C17 and 6C18 produced up to 8-10% ethanol in 20% sugar concentration broth. Optimum environment for 6C17 to produce ethanol was pH 5, temperature 37°C, lactose 20%, and yeast extract 0.1%. 6C17 yielded 8.0% ethanol with 15% lactose broth and 7.5% with concentrated whey. *Klyuveromyces marxianus* MTCC 1389 produced 10.% ethanol in 15% Yeast Peptone Lactose broth and 7.5% ethanol with concentrated whey.

Spectroscopic Methods for Detection and Quantification of Adulterants and Contaminants in Fruit Juices and Milk: Technology on pesticide residue analysis using biochip was developed with batch fabrication and measurements at different partner locations. Milk samples from field/market were collected and analysed for 3-4 weeks continuously with the developed biochip and the analysis was demonstrated in real time for assessment of the technology. Another optical DNA zyme lead biosensor based on fluorescent dyes and the FRET phenomenon in the presence and absence of Pb+2 ions for chip-based detection of heavy metals was developed. A mobile integrated urea biosensor that provides a decision support system (DSS) in milk supply chain was developed to detect adulterated milk urea samples. Another strip-based detection kit has been developed in which a white strip, on immersion in milk for about 2 minutes, turns blue detecting detergent up to 0.1 per cent. However, this requires optimization to overcome the problem of false positive and sensitivity.

Gossypol-free Lysine-rich Cottonseed cake by Solid State Fermentation: The fungal isolates, LF1-2F1, LF1-5F1 and SV-2F2, reduced gossypol (up to 57%) and improved crude protein (up to 4%) and lysine content (up to 0.32%) in cotton-seed cake and this enhanced its value as a poultry-feed. A solid-state fermentation process has been optimized using a combination of *Pleurotus sajorcaju*, *Saccharomyces cerevisiae*, and *S. cereviseae* + *Candida tropicalis* for maximum detoxification to the extent of 0.04% of free gossypol and total gossypol (0.87%) in cotton-seed cake and improved lysine content within 36 to 48 hours.

Studies on micro-algal triacylglycerols (TAGs) as source of biodiesel: Five green microalgal species, viz. *Scenedesmus obliquus*, *Chlorella vulgaris*, *Chlorella minutissima*, *Scenedesmus accuminatus* and *Scenedesmus armatus* were selected after the screening of fifty oleaginous microalgal strains and were subjected to twelve different culture conditions. N- starved condition showed lipid accumulation by >40% of dry cell wt. in all the chosen species. A schematic model for an algal refinery was developed which demonstrated production of 0.06 g of β-carotene, 380g (0.42 L) of biodiesel, 20 g of omega-3 fatty acids, 30 g (0.024 L) of glycerol, and 170 g (0.19 L) of bioethanol from 1 kg of *S. obliquus* dry biomass. A protein-rich algae meal with the standard (control) + whole microalgal + extracted microalgal protein diet (25:25:50) inducing significant growth stimulation in freshwater fish, was also formulated.

Increasing the efficiency of microbial production of bioethanol from agricultural biomass: Delignification and saccharification of agricultural biomass are important steps for production of bioethanol. A broad database of cellulose and lignin-degrading microbes available in diverse growing conditions has been prepared. Three microbes, *Myrothecium roridum*, *Trametes hirsute* and *Steptomyces griseorubens*, have been found efficient in delignification of paddy-straw, carrot grass etc. *M. roridum* released 408.33 mg/g reducing sugar from bio-pretreated paddy- straw and 376.75 mg/g from sterilized carrot- grass after 32 hr of enzyme action. Fermentation of hydrolysate derived from alkali-treated paddy- straw and carrot-grass with *S. griseorubens* produced ethanol (16.5g/litre) with addition of E- glucosidase. Plant pathogens like *Xanthomonas axonopodis* pv. *punicae* and *Phoma exigua* ITCC 2049 showed saccharification of lignocellulosic biomass.

Investigations on high pressure induced effect on quality characteristics of buffalo milk: Pressure treatment at 400 MPa and above resulted in rapid dissociation of casein micelle. Micellar proteins are fully denatured and serum proteins denatured partially due to pressurization. In buffalo, disruption of casein micelle at 400 MPa or above pressure for 10 minutes indicated that casein fraction was the major site for high pressure induced effect. The change in casein fractions affected viscosity and colour, apart from affecting rennet coagulation time (RCT) and heat coagulation time (HCT) . Shelf- life of high pressured (400

MPa for 10 min) treated samples of both cow and buffalo milk could be stored up to 20 days in refrigeration (5±2°C) without changing functional characteristics and spoilage. Above 400 MPa, the casein protein got denatured.

Extraction and Micro-encapsulation of Nutraceutical for Effective Delivery into Different Food Matrices: An autoclavable microencapsulation system with multistage two fluid nozzle has been developed for microencapsulation of sensitive food components, which are prone to contamination (microorganisms and their products) including bacteriocins. Microencapsulation of probiotic species of yeast, *Lactobacillus casei*, and pediocin, nisin, xylanase, pectinase and amylase has been done. Patent has been filed and technology has been transferred.

Sustainable Biomass Alternative to Fossil Fuel based Urea-Generation of Hydrogen feedstock from Agro residue and Biomass: Delignification of biomass like paddy straw is an essential step for enhanced sugar recovery by enzymatic saccharification for bioenergy. The fungus, *Tremetes hirsuta* MTCC136 showed high ligninase and low cellulase activities. Solid state fermentation of paddy straw with *T. hirsuta* enhanced carbohydrate content by 11.1% within 10 days of incubation. The amount of value-added lignin recovered from the *Tremetes* pretreated paddy straw was higher than controls. Enzymatic hydrolysis of the *Tremetes* pretreated paddy straw yielded more sugars than controls and yields enhanced till 120 hr of incubation.

High clearance multi-utility vehicle for precision farming applications: An improvised high clearance multi-utility vehicle was developed and evaluated for the fertilizer application in rice crop with satellite navigator guided fertilizer spreader. It had 1.37 times more productivity than spreader without the navigator. A yield monitor which could be used for the measurement of wheat yield with high accuracy was developed. A tractor operated pH monitoring system capable of measuring the real-time soil pH and soil mV along with the geo- referenced locations of the points was developed. Independent validation data sets confirmed high correlation values (R2 > 0.7) for predicting the developed spectral models for soil organic carbon (SOC) and available potash (K) in non-saline soils; and for electro-conductivity (ECe), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and chloride (Cl^{-}) in the saturation extract.

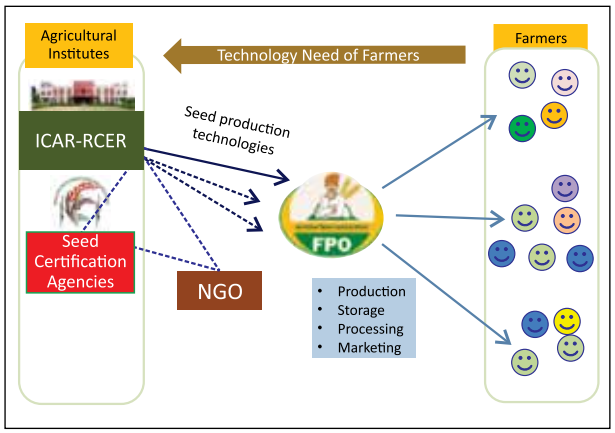
Microprocessor and DSS based precision farming technologies: A sensor controlled five-row seed-cum-fertilizer drill was developed. Sensed by a proximity sensor mounted on the front wheel of the tractor, the required quantity of seed and fertilizer could be dropped by matching with speed of the tractor. Selection of various parameters like speed, quantity/flow, etc. could be done by the user through a keypad provided with up, down, left and right keys. Field validation of the drill along with the software developed was successfully done on the farm using the soybean variety JS 9305 sown at a row-to-row spacing of 35 cm and a given seed/fertilizer application @ 80 and 100 kg/ha.

Decision support system for insect pests: A web enabled decision support system, "Crop Pest DSS", incorporated with predefined pest forecast models for rice and cotton pests was developed and hosted at the website (http://www.crida.in:8080/naipO. Another decision support system (phenology model) for rice leaf folder (Cnaphalocrocis medinalis Guen6e), an important foliage feeder in all rice ecosystems, was developed. Its validation under field conditions showed accurate prediction of second brood of leaf folder development. This DSS would help farmers in a timely and effective management of the pest. Weather based prediction rules for cotton sap feeders' viz., jasstds, thrips and mirids were developed using historical data sets for the period 2001-2008, and validated with independent testing data sets (2009 -2012). Population dynamics of cotton mealybug was assessed during Kharif, 2013 in the Northern and Central cotton growing zones; peak pest incidence coincided with the night and day temperatures in the range of 26 to 36.9'C, and the fields adjacent to infested weeds showed higher severity of mealybug infestation. A new mealybug species, *Rastrococcus ceryoides* (Green), commonly referred to as the mango mealybug, was recorded on cotton in the Central zone; this was earlier recorded in the Southern Zone. Maps with different levels of leaf folder damage are generated from spectral un-mixing analysis based on the spectral characterization of rice leaf folder damage done

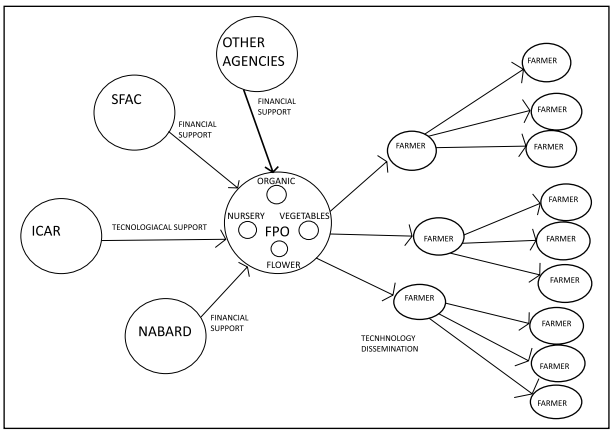
by using Fieldspec-3 hyper-spectral radiometer in several naturally infested farmers' fields at Kaut, Haryana in 2012.

2.7 Social Sciences and Policy in Agriculture

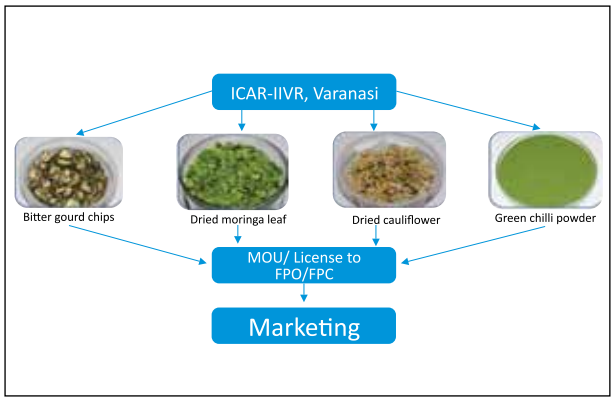
Need Based Technology Delivery Model through Farmers' Producer Organization(FPO) for Eastern Region of India: The four models of technology delivery through FPO have been developed for seed production, vegetable production, organic farming and natural resource management in ICAR-RCER, Patna, ICAR-IIVR, Varanashi, ICAR-RCER, FSRCHPR, Ranchi and UBKV, Cooch Behar respectively. The social network analysis indicated that cohesiveness, sparsity and degree of influence of FPO were better than non-FPO farmers. This technique could also enable to learn that which farmer acts as a leader in influencing the decision making and establishing knowledge network.



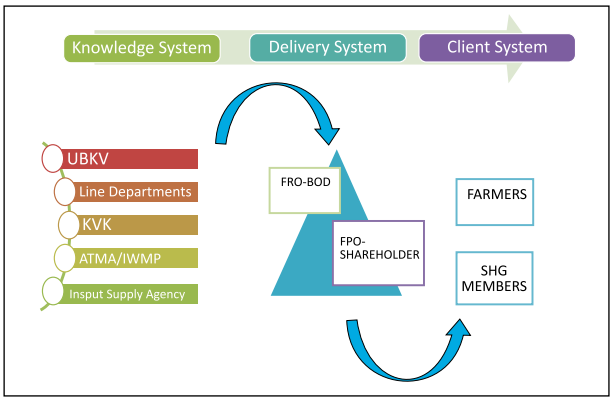
Model 1: FPO based quality seed production and marketing model



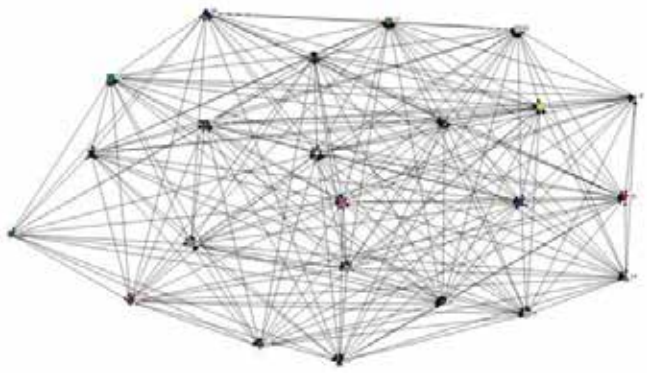
Model 2: FPO based safe food production technology delivery model



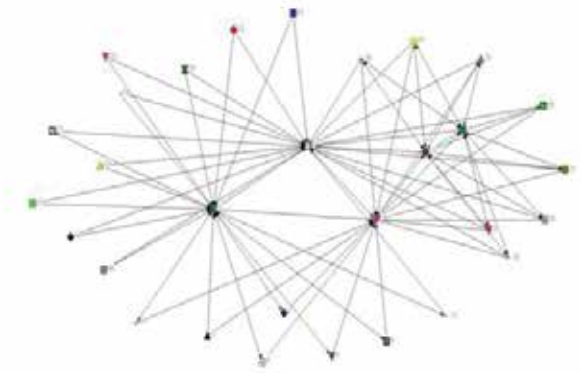
Model 3: FPO based vegetable produce marketing technology delivery model



Model 4: FPO based narural resource farming technology delivery model



Communication Network among FPO members



Communication Network among non- FPO members

Social Network Analysis of FPO and Non FPO farmers' communication.

Women Empowerment and Gender Sensitization – Developing a Model for Bridging Gender Gap: On the basis of the identified critical gender gap indicators, interventions were provided in the Budak village of Hisar district of Haryana under a three-tier 'Gender Sensitive Schematic Extension' model having 'Mass', 'Target group' and 'Focused group'. This was applied to address different issues and conducting action research considering resource endowments and market preferences of the rural community. The drudgery among women was assessed in two seasonal crops (viz. wheat and cotton) for agricultural sector. Based on musculoskeletal problems faced by women in wheat harvesting and cotton picking, they have been provided gender friendly improved sickle, capron and cot bag to improve their work efficiency, reduce their drudgery, and enhance agricultural outcomes. Further, the use of improved sickle decreased grip fatigue by 29.85 percent for the left hand; and 39.18 percent for the right hand. Introduction of bio-fortified rice varieties CR Dhan 311 (*Mukul*) and CR Dhan 315 added an additional protein yield of 3.26 and 3.30 q/ha to the diet of farm families. This could also help in meeting the zinc requirement (20-22 ppm).

Causes and Consequences of e-National Agriculture Market (e-NAM) on the Economic Development of Indian Agriculture – A Case Study: The e-NAM integrated markets were analysed for the performance with respect to cotton, maize, groundnut, turmeric, chilies. In addition to that tomato, onion, potato and red gram reference markets were studied. The key findings suggest that volume and value of trade for chilies, red gram, maize, paddy, onion and tomato increased after the introduction of e-NAM; whereas for cotton, turmeric and groundnut this has been decreased on account of of preference of farmers in direct sale of produce to ginning and pressing mills. In case of turmeric and groundnut, after the introduction of e-NAM, the volume and value of trade drastically decreased due to impact of COVID-19 especially in 2020 and 2021. Seasonal indices are high for commodities like chilies, cotton, groundnut and turmeric for the period from December to March as arrivals are high during this period. In case of perishable commodities, like onion and tomato, no particular pattern could be detected. Cyclical and irregular variations results revealed in both pre and post e-NAM period that cycles are not clearly observed, but random variations in prices are conspicuous for all the selected commodities. Prices are less volatile in post e-NAM period for cotton, groundnut, maize and red gram when compared to pre e-NAM period. This implies that e-NAM has reduced the price volatility among these crops. Further, it was observed that markets were integrated in post e-NAM period when compared to pre-e-NAM period for almost all the commodities.

Entrepreneurship Development through Farmer Led Innovations (FLI)–A Case Study in Plantation Sector: Entrepreneurial Assessment Index and Innovation index were developed to assess the potential of innovators in undertaking entrepreneurial activity based on six identified categories and to analyze novelty, usability and viability of the various FLIs at user level respectively. Two action research were carried out on VINPEPT Black Pepper Thresher and Tractor Operated Farm Waste Shredder for coconut fronds. Validated the augmented FLIs using innovation models/ theories. Identified that Cyclic Model of Innovation is the most suitable model for FLIs in plantation sector. For upscaling of innovations

VINPEPT Black Pepper Thresher

cauterized the potential FLIs into three categories namely, commercialized innovations, potential to commercialize and support required for commercialization. Workshop was conducted for the innovators and assessed their responses for upscaling of innovation. During the workshop, a platform was provided for the FPOs & startups to interact resulting in the way forward for the commercialization of the few innovations. The workshop reported the need for further guidance from scientists of NARES systems for field testing of FLI, assistance in providing roadmap for business plan and funding support.

Smart Aquaculture Model (SAM): Application of ICT and data analytics for sustainable shrimp aquaculture: An android mobile application-CIBA Shrimp Krishi App- was developed and launched for handholding the shrimp farmers to make real-time based informed decisions at farm level. The App is available in four languages viz., English, Hindi, Tamil and Telugu and it is free of cost. Using this interactive mobile application, the farmer can input his or her farm data on day-to-day farming operations/observations from stocking to harvest. Based on the inputs provided and inbuilt decision-making system, the App will display pond-wise status on shrimp survival, biomass, feed conversion ratio, pond water quality, and the expenditure incurred. The expert systems inbuilt in to the App alert the farmer with technical advisories whenever any deviations are noted in day-to-day parameters of water quality, feeding and shrimp health. The app can store the entire crop data in it, and the farmer can retrieve the data for their own long-term decision-making purposes or share it with their resource person for technical advice. The App has a post-your query option through that the end-user can send his queries in text or image format which are answered in two working days. Moreover, it paves the way for accessing real-time bulk data from the remotely located shrimp farms to monitor and extend customized technical advisories. The App is widely being used by the shrimp farmers in India.

Addressing Farmers' Suicide issue through Capacity Building of Farming Families: The project was aimed at providing a sort of Psychological First Aid (PFA) to farmers through the system of peer support and equipping farmers with coping skills to handle stress during agrarian crisis. The project focused on strategies to de-stigmatize mental health issues in the rural areas. The baseline survey of about 1100 distressed farming families across the states of Punjab, Maharashtra and Telangana was carried out. Information about depression, self-esteem, cognitive distortions, resilience, wellbeing, suicidal ideation *etc.* has been collected to know the Cumulative Stress Index (CSI) and Psychological Resources Index (PRI) of these farmers. The basic and advanced trainings were given to Peer Support Volunteers (PSVs) based on six modules. The slogan "*Karoge Baat, Banegi Baat*" (Talk and you will get a solution) got popular with the farmers in three states. PSVs also spread the message to shun conspicuous consumption and cut expenses on social events. Message of the simplicity adopted by Punjab Agricultural University in Kisan Mela snowballed into a state-wide movement with more than 150 village panchayats, mainly in the pockets of suicide, adopted resolutions not to splurge on social ceremonies. A total of nine reasons were short-listed, which included Depression/Mental illness; Family/Marital Dispute; Financial Stress; Health Issues; Land Dispute; Education related problem; Drug Abuse and Others. The stress index and psychological resource index were found to be significant.

Information Dissemination System(s) for Empowering Farming Community of Uttarakhand: The project was implemented with innovative intervention of designing and development of need-based media packages to cater to the information gaps compatible to differing agro-ecological zones. The Participatory Appraisal techniques were applied to generate purposeful linkages with the client in intensive manner in the selected villages of different districts (total 12) of Uttarakhand. The network analysis, that has yielded useful data, will now be utilized in strengthening available information-communication networks in the study villages. The design and development of audio programmes is under process, and targeting to inculcate interests among farmers on a particular field, such as mushroom farming, and its associated benefits. On the other hand, the video programme intends to provide the complete skill-set required to engage in mushroom farming. Finally, the print material serves as a ready reckoner containing detailed

information about mushroom farming, including information about the market, the experts of the field, various government policies and schemes. A pilot test was conducted across the various agro-climatic zones of Uttarakhand (including Tarai region, low hills, mid hills, and high hills) to test the effectiveness of the video programme developed as a part of the media package. A total of 21 video programmes with four in Tarai region, six in low hills, seven in mid hills, and four in high hills were tested.

Development of alternative ICT models: An alternative integrated ICT model–Interactive Information Dissemination System (IIDS) involving toll-free IVRS (interactive voice response), Smart Phone application and Web-based Agri-Advisory System was developed to address farmers' information need on important aspects in location-specific manner. The web and IVRS based applications were made available in three languages – English, Hindi and Telugu. The model was validated through the Annapurna Krishi Prasaar Seva (AKPS) and four Krishi Vigyan Kendras (KVKs) of ANGRAU in Andhra Pradesh. Besides providing expert agro-advisories on agriculture, animal husbandry and fisheries, farmers' training programmes and field diagnostic services and veterinary camps were organized in identified villages. Innovative farmer-to-farmer information sharing meetings were organized, which were attended by ~ 180 farmers. Similarly, thirty three rural youth (project villages) were given a 4-days residential training on operation and benefits of AKPS for undertaking the work as 'Annapurna Volunteer' in the project villages.

Standardization of ethnic foods and beverages: Instant dry idli mix technology was developed using a dry form of patented culture to get soft textured steamed idli. Ready-to-eat (RTE) idli packaging in retort pouch had over three-month shelf-life at atmospheric temperature (28 ± 2°C); it needs to be reheated in micro-oven for 5-10 seconds or steam heated in conventional oven for 2-3 minutes before serving. Dry mix sambar and chutney for the RTE idli packed in high density polyethylene (HDPE) bags also had more than three months' shelf life. and it need to be boiled for 5 -7 minutes before serving. Wet idli batter mixed with preservative could be stored without spoilage for three days at room temperature and five days on refrigeration. Technology details of millet dhokla mix and ready-to-eat dhokla were showcased for technology commercialization; and entrepreneurs showed interest in this technology. Ultrasonication of coconut toddy for 20 minutes with 99% power level was standardized to improve the quality of non-alcoholic (*neera*) toddy for safe consumption up to two months of storage. Presence of health-benefit lactic acid bacteria profile was created in the coconut toddy on storage.

Arsenic in food chain: The study undertaken to overcome the harmful effects of excess arsenic in the soils of West Bengal on the entire food chain including soil, crops, human beings, livestock and fish. This has resulted in: identification of indigenous bacterial strains capable of volatilizing inorganic soil arsenic under aerobic vis-a-vis anaerobic environment. The imposition of intermittent ponding during vegetative phase reduced arsenic content in grain and straw significantly, but non-significant yield reduction in the rice. Varying depths of irrigation water, commensurate with root development, could be adopted for arable crops to reduce arsenic content in edible parts without compromise in yield. Further, retting of jute increased the arsenic content of surface water bodies which ultimately led to increased arsenic content in fish tissues, an unexplored source of arsenic contamination as yet. Interestingly, the vermicompost, as low-cost and eco-friendly, has emerged as the best organic amendment to reduce arsenic availabilities in contaminated soils through greater metal-organic matter complexation. The nitrate restricted the transport of arsenic in both soil and plant systems, and judicious management of nitrogenous fertilizers reduced grain arsenic status in phosphate-rich soil. The rumen bacterial strains were found to be capable of reducing arsenic load in the ruminants; and development of polyherbal product to mitigate the arsenic load in poultry birds was explored. A positive relationship between arsenic content in the diet and arsenic content in human urine could be established in instances where patients were provided with arsenic safe drinking water.

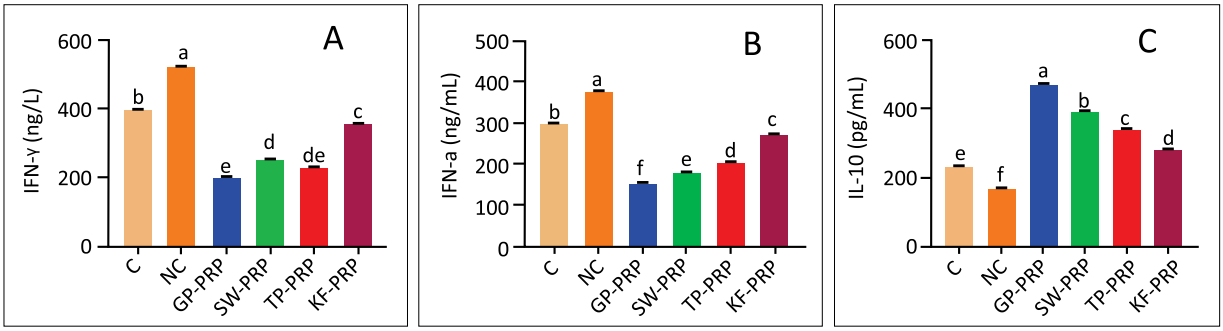
2.8 Scientific Utilization through Research Augmentation- Prime Products/ Panchagavya from Indigenous Cows (SUTRA-PIC)

Unique innate-immunity genomic

signatures identification in Sahiwal, Gir, Tharparkar,Kangayam,KaranFriesandHolstein Friesian cattle using immunoinformatic: The whole genome sequencing of 18 pooled DNA samples identified 3,733 SVs across the breeds. Specifically, Sahiwal (SW) harbored highest number (762) of SVs followed by Karan fries (KF) (731), Tharparker (TP) (718), Kangayam (KG) (580), Holstein Friesian (HF) (578) and Gir (546). Maximum number of SVs belonged to deletion (1650), followed by insertion (1185), inversion (468), break-end (308) and duplications (304). The HF had highest number of breed-specific SV (59) followed by the SW (32), KF (25), TP (17), GIR (7) and KG (4). Maximum number of breed-specific SVs belonged to inversion (58) followed by deletion (48) type. Additionally, to understand the expression profiles of the genes in CNVs, peripheral blood mononucleated cells (PBMC) were isolated from four cattle breeds (SW, TP, Gir and KF), exposed to a bacterial PAMP, LPS (1µg/ml), for four hours in-vitro, and their RNA was sent for custom RNA-seq. Further, an in-house pipeline was developed to identify the innate immune genes related to CNVs using the publicly available genome sequences of Nelore and Hereford cattle. This analysis revealed that 203, 113 and 38 genes had highest number of substitutions, insertions and deletions, respectively. Most of them are related to adaptive immunity. However, innate immune genes such as antimicrobial peptide NK-lysin showed CNVs.

Isolation of proline-rich polypeptides from colostrum of select indigenous cattle breeds and evaluation of their nutraceutical potential: Amino acid profile and sequence of proline-rich polypeptides (PRPs) indicated higher proline content in colostrum of Sahiwal (24.5%) followed by Tharparkar (22.3%), Gir (21.91%), HF (18.25%) and Karan Fries (17.49%). De-nova sequencing of the peptides was done through LC-MS/MS for PRPs isolated from colostrum of Sahiwal and HF and annotated with UNIPORT data base. Total number of peptides identified were 2199 and 2724, respectively in Sahiwal and HF. Out of these 26 and 33 sequences were annotated with UNIPORT data base, having expect (e) value less than 10^{-3}. Most of the annotated sequences located to caseins (69.2% in Sahiwal and 54.5% in HF), especially beta caseins (34.6% in Sahiwal and 36.4% in HF). Immunomodulatory activity of proline-rich polypeptides (PRPs) was studied and *In vitro* analysis indicated higher phagocytic activity and moderate lymphocyte proliferation index of PRPs from Indigenous breeds. Furthermore, immunomodulatory effect of the PRP was evaluated through the *in vivo* studies in mice model. It revealed that serum of mice challenged with *E coli* has higher IgG and IgA concentrations when fed with PRP from indigenous breeds compared to PRPs of Karan Fries. Level of anti-inflammatory cytokines (IL-10) was higher and pro-inflammatory cytokines (TNF-α, IFN-γ) was lower in mice fed with PRPs from indigenous breeds.

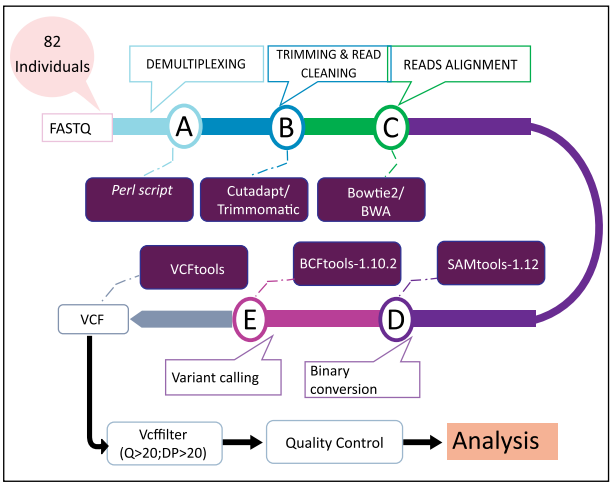
Medicinal and immunomodulatory properties of the urine of indigenous Badri cattle: The immunomodulatory properties of Badri bull urine distillate were studied in Wistar rats. The findings demonstrated that Badri bull urine distillate had immunomodulatory effects on humoral and cell-mediated immunity. In humoral immunity, significant increase in titer of HI antibodies (41.55%) and ELISA values (25.41%) was observed at 90th DPT. Significant increase in Δ OD of the B-lymphocyte proliferation assay (LPA) performed in splenocytes of the test and control rats using lipo-polysaccharide



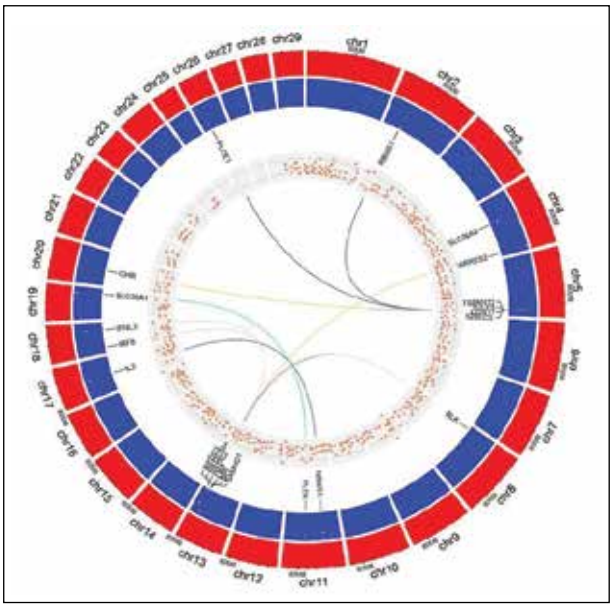
C-Control; NC-Negative Control; GP-PRP from Gir; SW-PRP from Sahiwal; TP-PRP from Tharparkar; KF- PRP from Karan Fries; IFN-γ - Interferon-gamma; TNF-a - Tumour Necrosis Factor - Alpha and IL-10 - Interleukin 10

Effect of PRP supplementation on cytokine profile

(LPS) as mitogen showed 26.69% and 45.85% enhancement of B-lymphocyte proliferation at 60th and 90th DPT, respectively. The results scientifically validate the immunomodulatory effect of Badri bull urine distillate which can be used in Ayurvedic preparations just like cow urine distillate. It was found in the study that all the CUD from Pahari and Jersey cattle had effect against CPV with fall in virus titer and inhibition of CPE, while no antiviral effect of the hexane and butanol fractions could be detected with cells getting infected by virus. Effects of Pahari and Jersey cattle urine (CUD was compared with acyclovir against CPV. It was found that Pahari cattle urine CUD had virus inhibitory effect which was less than acyclovir, but it was better than Jersey cattle urine CUD.



Sequence to variant conversion and Quality Control



Circos plot showing distribution of genes related to production traits

Unique signatures of selective sweeps in indigenous dairy cattle breeds: Samples of Sahiwal cattle (82) were genotyped using by sequencing (72 own data + 10 online data) subjected to quality filtering and the sequence reads were aligned to the *Bos taurus* reference genome assembly (ARS-UCD1.3) for variant calling, employing a range of bioinformatics tools. Several parameters were calculated to evaluate the genetic diversity within the Sahiwal population. Subsequently, a total of 146 regions were identified as undergoing selective sweeps. These regions were associated with improved immune systems and disease resistance, as well as production traits. The gene interleukin 2 (IL2) located on Chr17: 35217075-35223276 was identified as being linked to tick resistance. Additionally, a cluster of genes associated with heat stress was observed. For Tharparkar cattle, several candidate genes that have undergone positive selection were revealed in ~~the analysis~~. These genes were associated with various traits such as milk production, reproductive traits, and health-related characteristics. Furthermore, research was extended to investigate investigation of copy number variations in Tharparkar cattle selection signatures in the MHC region and coat colour across various Indian cattle breeds.

2.9 Extra Mural Research (EMR) Projects

Cultivation and Value Addition of Aromatic Plants for Livelihood Security of Farmers of Uttarakhand Region: The project focused on promotion and expansion of lemon grass (*Cymbopogon flexuous*) and palmarosa (*Cymbopogon martinii*) on an existing degraded land as an alternative crop for livelihood security. Study was conducted in two villages viz. Sadan-kheda and Datanu in remote tribal area of Kalsi block in district Dehradun. Also, at research farm Selaqui of the ICAR-Indian Institute of Soil and Water Conservation, Dehradun wherein 8 different cultivars of aromatic grasses were studied Lemon grass and palmarosa cultivars showed significant variations in growth, biomass and oil yield. Out of evaluated varieties of lemon grass, maximum survival percentage (97%) was recorded in Krishna and minimum survival percentage (92%) was recorded in Praman. Maximum herbal biomass was observed in Praman (3.097 gm/clump). Out of 4 varieties of palmarosa, maximum survival percentage (98%)

was recorded in Tripta and minimum survival percentage (95%) was recorded in Harsh. The maximum and minimum oil % was observed in Tripta (0.41%) and Harsh (0.31%) respectively. Maximum herbal biomass was observed in Tripta (0.820gm/clump). Capacity building of the farmers, field-based training programs were conducted towards cultivation and value addition of lemon grass. They were also trained for making lemon tea and incense stick from lemon grass and mushroom cultivation was done on spent biomass of lemon grass.

Integrated management of Fusarium wilt tropical race 4-A devastating strain of banana: The project carried out the survey for the occurrence of *Foc* TR4 in different banana growing states of India. Development and validation of cheaper and user-friendly diagnostic kit for *Foc*–TR4 detection in plant and/or soil. Identified three different effective consortia of bioagents for the management of Fusarium wilt disease of banana. Soil application of these consortia after planting can be useful to achieve more than 80% reduction in disease incidence even under high inoculum pressure condition. Identified molecular markers specific to Indian Foc of Race 1, TR4, Race 4 and STR4. Identified potential phosphate solubilizing bacteria (PSB), viz., *Enterobacter hormaechii* ssp. *sakuensis* (PSB52) and *Leclercia adecarboxylata* (PSB54) which excellently increased the available P in the soil as well as in the plant and thereby increased the growth and yield parameters significantly compared to control.

Knowledge Management System for Agriculture Extension Services in Indian NARES: In the project design and development of Agricultural Technology Management Portal to Strengthen Agricultural Extension and Knowledge Sharing was carried out. On the portal KVKs have uploaded their Monthly Progress Report (MPR) on key parameters in the system. Dashboard for Krishi Kalyan Abhiyan (KKA-III) has been developed. State level and District level reports have been added in the dashboard. Month wise KVK KPIs data is submitted in National level DARPAN dashboard for the KPIs viz. 'Farmer Training', 'Mobile Agro Advisories' and 'Agriculture Extension Activities'. Master data has been added in the portal for newly formed KVKs. KVK portal has been linked to Kisan Suvidha Portal/App through Web API for displaying the information on basic details of KVKs, facilities available in KVKs, packages and practices developed by KVKs.

Application of next generation breeding, genotyping and digitization approaches for improving the genetic gain in Indian staple crops: A comprehensive breeding programme including measuring genetic gain, development of product profiles, genomic selection modules, breeding data management and breeding pipeline optimizations was designed to increase the rate of genetic gain in stable crops viz. rice, wheat, pearl millet, sorgum, maize, chick pea, pigeon pea, potato etc. Compared the conventional breeding pipeline, the new pipeline included components such as: utilizing only elite lines in the breeding program, no phenotypic selection for quantitative traits during the segregation generation, rapid generation advancement through single-seed-descent (SSD) method, implementing multi-location evaluation, sparse testing and spatial designs for testing the breeding populations, 85 implementation of genomic predictions to estimate breeding values and rapid recycling of elite lines from the breeding program . In wheat developed product profiles targeting seven varieties namely HD2967 and HD3086 for timely sown NWPZ; HD3059 and Sriram 303 for late sown NWPZ; HD2733 and Sriram 303 for timely sown NEPZ. Varietal replacement strategies in HHB 67 and MPMH 17 in pearl millet, CSH 25 and M 35-1 in sorghum, Bio-9544 and Bio-9682 in maize and product profiles formulated based in those crops was carried out. Digitalization of nurseries and trials by design generation, digital data recording and data analysis using Breeding Management System (BMS) in all proposed crops was completed.

Sensor based smart packaging methods for the export of traditional banana varieties and Nano-strip based digital health monitoring of banana: Ripening stage dependent colour chart was developed for Indian banana varieties. Poovan and Rasthali has shown the colour stage development alike Grand Naine. Ney Poovan recorded lower glycemic value and maintained firmness in final stages. Total phenol and flavonoids content enhanced with the progression in stages. A duo of CNN and extreme Gradient Boosting (XgBoost) algorithm (CNN-XgBoost) is introduced for the effective determination of the ripening stage of

banana. In order to eliminate the need to have data augmentation or huge data set, Linear Discriminant Analysis (LDA) is incorporated. Thus, the proposed deep learning approach possess capability to perform classification even with a smaller data set compared to the conventional deep and machine learning techniques. Research study on the effect of various artificial ripening agents on the physico-chemical properties, enzyme activity, secondary metabolites, antioxidant activity and volatile profiling exhibited the elution of acetylene in fruits ripened with calcium carbide. For the fabrication of paper strip device to detect calcium carbide, Ag-ZnO nano composites were developed with microwave technology.

Production and Valorization of Muconic Acid from Agricultural Waste to Produce Adipic Acid Via Combined Fermentation and Chemical Catalytic Process: Revival of *Pseudomonas putida procured* from IMTECH MTCC, Chandigarh and production of muconic acid was carried out from agrowaste. The amount of muconic acid was produced by bacteria which was 10.6g/l during 15th day of incubation. Optimization of muconic acid production with bacterial inoculation along with *Aspergillus clavatus* was carried out. The highest amount of muconic acid was produced by fungus *Aspergillus clavatus* which was 21.6g/l during 9th day of incubation. Compatibility test of *Aspergillus clavatus* and *Pseudomonas putida* on nutrient Agar plates was done on 15 days of incubation at 34-degree Celsius. After compatibility test between *Aspergillus clavatus* and *Pseudomonas putida* treatments were inoculated and successfully extraction was done for HPLC analysis for optimization of muconic acid.

Development of hand-held instrument for non-destructive quality evaluation of mango: An indigenous handheld fruit tester has been developed to acquire, process, view and create library of infra-red spectral data from different fruit samples to determine the quality of fruits like mango, apple and pears, rapidly and non-destructively for various parameters like total soluble solids, titratable acidity, and dry matter content affecting overall maturity of the fruits during harvesting and storage periods. The conceptual design of the instrument was based on NIR models/patent (Patent No. 309407) developed at ICAR-CIPHET, Ludhiana. The handheld instrument with 3-D printed plastic body included a tungsten halogen lamp as the light source, NIR sensor, single porter computer, and batteries. The device was used to acquire the spectral data of different mango varieties (Lagra, Dassehri, Bangan Palli, Neelam, Chausa) collected from ICAR-IARI farm. The analysis with the device was also performed on mango varieties from Punjab, Meerut, Bangalore, Maharashtra and Andhra Pradesh. The developed device has successful applications in determining the quality attributes of several other commodities in food and agriculture sector.

3
Major Outputs

3.1 Technology Developed and Demonstrated

The lead and cooperating centers have availed the handholding and facilitation support from the Project Implementation Unit of NASF. They were also motivated to transfer their lab-scale research findings into validated and/or well demonstrated commercial products. Some of the potential technologies developed or under development are highlighted below:

- 'Mahima', a female calf born on to 'Garima-II' a cloned buffalo, produced by hand-guided cloning using ESCs as donor cells.
- Transgene free genome edited mega rice cultivar MUT1010 with enhanced yield and stress tolerance was developed.
- Highly efficient herbicide-resistant maize line using CRISPR/Cas9-mediated homology donor repair base editing system was developed.
- Production of multiple copies of elite buffalo bulls using animal cloning technology.
- Developed diagnostic kits for detection of Covid-19 infection in animals- SARS-CoV-2 nucleic acid detection LFA kit, SARS-CoV-2 Antibody detection ELISA Kit, Covid-19 Blocking ELISA kit. (commercialized)
- Fine mapping and marker-assisted breeding for alternative dwarfing genes *Rht14* and *Rht18* to develop semi dwarf wheat genotype suitable for conservation agriculture.
- Developed bivalent marker vaccine against bovine herpesvirus-1 and brucella. (commercialized)
- Luteinizing hormone-based sensor developed for estrus detection in buffaloes.
- Phyto-acaricides for controlling resistant cattle ticks developed. (commercialised)
- Developed a metabolite-based non-invasive sensor for early scab-disease diagnosis in apple.
- Developed an Automated Soil Nutrient Sensing System.
- Developed an electronic nose for the optimum harvesting time and fruit quality in Apple and Papaya. (under farmer field trials)
- Biodegradable electro spun fibre mat developed used in packaging of fresh perishable agricultural material.
- A sensing device (IMAGinE) was developed for detection of Chromium (Cr^{6+}) in water.
- Biosensor for analysis of urea in adulterated milk. (commercialized)
- Decision Support System for enhancing productivity of grapes under moisture and temperature stress conditions. (widely used by farmers)
- Developed ShrimpKrishiApp for the shrimp farmers to make real-time based informed decisions. (widely used by shrimp farmers)
- Developed NIR hand-held fruit tester for non-destructive quality evaluation of mango.
- Developed Nano Chitosan encapsulated green technology to combat antimicrobial resistance in poultry. (commercialised)

3.2 Infrastructure Developed (Mega Facilities)

Apart from the support of many sophisticated instruments and equipments for enriching the laboratories, few mega facilities have been created in ICAR with the funding of NASF.

- A state-of-the-art automated high throughput plant phenomics facility for non-destructive and accurate characterization of large number of germplasm and recombinant inbred lines under defined environmental treatment conditions was established at IARI, New Delhi. The facility named as Nanaji Deshmukh Plant Phenomics facility was inaugurated by Honourable Prime Minister of India on 11th October 2017. The facility consists of Hi-tech climate controlled green houses, moving field for handling of 1200 plants within the green house and

to transport them to imaging stations, different imaging platforms viz IR Thermal, Chlorophyll florescence, Visual RGB, NIR root, NIR Shoot, VNIR Hyperspectral and SWIR Hyperspectral sensors for assessing drought and input use efficiency. Many high-profile dignitaries including Dr. M.S.Swaminathan, Dr. Bill Gates, Sh.P.K. Misra, Principal Secretary, PMO have visited the phenomics facility.

- The designing, fabrication and construction of the 19.75m energy efficient fishing vessel, christened as 'FV Sagar Harita' made at the Goa Shipyard Ltd. The ship could conduct Long line and Gillnet multiday fishing operations for 4-5 days in the depth of 1,500-1,900 m. Operations have been conducted from 24 stations for high sea gill netting and 6 stations for long lining. The solar energy was used inmeeting 20% of the energy needs, onboard. Average diesel consumption was 42 litres/hr in deep seaexperimental fishing operations. Low drag shrimp trawls (33 m head rope length) and fish trawls (27 m head rope length) were developed by optimizing the cutting rate which helped in the reduction of drag. The same operations in the commercial trawlers operated at Munambam and Vypeen of Kerala showed a reduction of fuel by 2.5%.

Hon. Prime Minister of India Sh. Narendra Modi inaugurating the phenomics facility

Dr. M.S.Swaminathan, Dr. Bill Gates at the Phenomics facility

Sagar Harita in deep Sea

- A solar-biogas thermal energy based cold storage facility at Anand in Gujarat and solar PV power based cold storage facility at Bhopal has been developed. The facility for storage of about nine tones of the horticultural produce for a period up to six weeks has been developed. The facility may operate in either stand-alone or grid connected mode. So, it can be set-up in the production catchments which are not covered by the grid power supply. The facility has a "vapour absorption machine (lithium bromide water)", which uses hot water at 80-90°C as main source as against the electricity in the common cold storages. A small PV power plant has been set-up to meet the auxiliary electricity requirements for operating water pumps and the fans. The cattle dung based low-cost water requirement biogas plant of innovative design for supply of thermal energy during the non-sunshine hours has been designed.

3.3 IP Filed/Registered/Granted

Patenting is the process to protect technologies from being copied by others and providing the rights for licensing to industries for further distribution in the society. Through NASF supported projects, many technologies have been protected via product as well as process patents. About 32 patents have been

Solar refrigeration & PV power facility

filed, few have been granted and many more are in the active mode of filing. One international application (PCT for Microbial process for Production of Protein isolate / concentrate from de-oiled cakes / meals) has been granted. The list of patents (up to Dec. 2023) is presented below

- Buffalo embryonic stem cell derived teratomas for the assessment of pluripotency.
- A novel foot and mouth disease virus Asia (Indian vaccine strain) replicon based viral vector for vaccine research and development.
- A peptide elicitor of NPR1 and PR proteins mediated pathogen defense in Indian mustard (*Brassica juncea L.*).
- Fermentation vessel for conducting gas production studies (*in vitro*: Fabrication, protocol and uses).
- An autoclavable microencapsulation system with multistage break up two fluid nozzles.
- Microbial Consortium for nitrate and phosphate sequestration for environmental sustenance.
- Method of improving elemental and nutritional content of plant seeds using Bacillus Strain MCC0008 as a biofertilizer.
- Method of generating glyphosate tolerant transgenic plants, reagents and uses thereof.
- A rapid, sensitive and user-friendly visual LAMP-based assay for detection of infectious bovine rhinotracheitis (IBR) virus in bovine semen.
- Construction of glycoprotein E (gE) gene-deleted mutant of infectious bovine rhinotracheitis (IBR) virus Indian strain for DIVA-based marker vaccine.
- A novel process for gossypol reduction and nutritive quality improvement of cottonseed cake for its use in non-ruminant's feed.
- A process for coating metal nano particles on surface of jute fibre /textiles for enhancing functionality of jute fibre/fabric and jute-polymer resin bio composite sheet obtained thereof.
- A process for surface modification of jute fibre / fabric for improved interfacial adhesion characteristics and bio composites obtained thereof.
- Jute bio composite comprising compatibilizer treated jute fibrous material with induced hydrophobicity and a method of manufacture.
- Chemoattractant based upstream migration of amphihaline migratory fish.
- A peptide sequence and polyclonal antibodies against identified peptide for the detection of cow and buffalo luteinizing hormone.
- A novel method for preparation of green gold nanoparticle developed.
- Peptide elicitor of insect, and pathogen defence in brassica.
- Bi-axial electrospinning setup for production of nano fibre mat.
- CRISPR/Cas9 edited maize for glyphosate tolerance.
- An immunosensor for ultra-low detection of total pesticide concentration in vegetable extract.
- Rapid and direct electrochemical growth of multi-coloured electrochromic film of zinc naphthalene metal organic framework (MOF) for display devices.
- Anti-tick phyto-molecule for the management of acaricide-resistant ticks infesting livestock.

3.4 Publications

More than 950 research papers (up to December 2023) have been published in peer reviewed journals by the researchers out of the NASF projects. It is worthwhile to note that about 787 papers have been published with NAAS rating >6.0. The number of papers published in various years and during different calls are shown in Fig. 9 and Fig. 10, respectively. Apart from these many articles have been published in scientific magazines and reports.

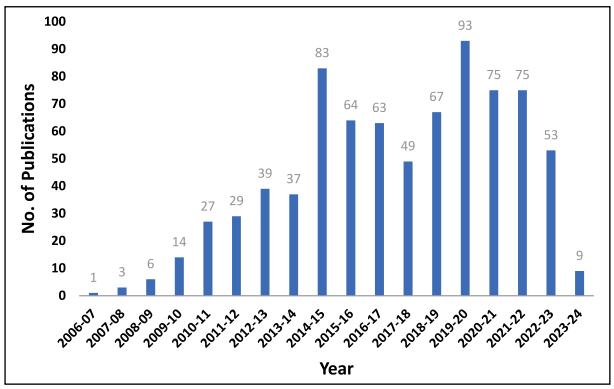


Figure 9: No. of papers published under NASF supported projects

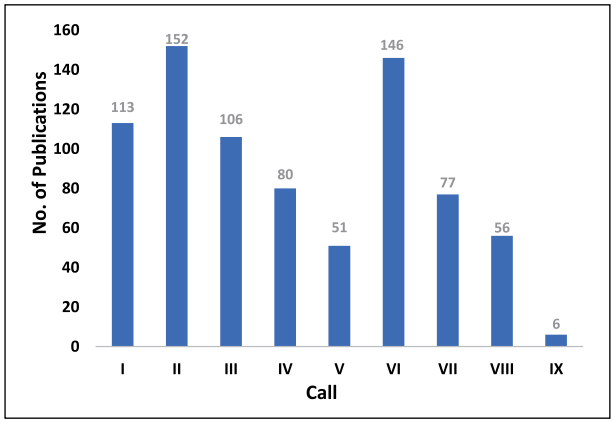


Figure 10: Call wise number of publications

3.5 Training & Workshops

NASF has also supported few workshops in the frontier areas to identify potential projects. Some of these workshops are as shown below

- **"Precision Agriculture in India- Way Forward"** held at NASC Complex, New Delhi on August 27, 2018.
- **"Hilsa Breeding and Management: Way Forward"** held at ICAR-Central Inland Fisheries Research Institute, Barrackpore from October 24-26, 2017.
- **"Transgenic chickpea and pigeon pea"** held at NASC Complex, New Delhi on April 22, 2017.
- **"GM Crops in India-Way forward"** held at NASC Complex New Delhi on May 17, 2016 in New Delhi.
- **"Animal-Human conflict in Agro-pastoral contexts"** held at National Bureau of Agricultural Insect Resources, Bengaluru from December 11-12, 2015.

4
Prominent Success Stories

(i) **Development of diagnostic kits for detection of Covid-19 infection in animals:** Outbreak of novel coronavirus pandemic (Covid-19) caused by SARS-CoV-2 was reported in Wuhan China during Nov/ Dec 2019. SARS-CoV-2 can infect multiple animal species including pet (Dogs and Cats) and wild animals (Tiger, Lion, Minks and Ferrets). To detect SARS-CoV-2 antigen in animals, a RPA-CRISPR based point-of–care kit 'SARS-CoV-2 nucleic acid detection LFA kit' has been developed for detection of SARS-CoV-2 antigen in clinical samples by ICAR-IVRI, Izatnagar. The test can be performed within 1 hour using a thermal block and results can be obtained using lateral flow strips. The kit is being validated using clinical samples. Further, to detect SARS-CoV-2 antibodies in pet animals (dogs and cats), an indirect ELISA kit 'SARS-CoV-2 Antibody detection ELISA Kit' has been developed. The kit is being validated using dog and cat sera. Similarly, a blocking ELISA kit 'Covid-19 Blocking ELISA' has been developed to detect SARS-CoV-2 antibodies in multi-species (dog, cat, lion and tiger). Using this kit, number of serum samples collected from Covid-19 affected (RT-PCR positive) lions and tigers from Arignar Anna Zoological Park, Chennai during 2021 were found positive. The kit is being validated using serum samples collected from different species.

(ii) **Animal cloning technology:** India created a history in the field of animal cloning research by the birth of world's first cloned riverine buffalo using an economical and simple animal cloning technique called handmade cloning at ICAR-NDRI Karnal. Using simplified buffalo cloning technology, several cloned buffaloes were produced in the country using different types of somatic cells. The technology developed is less demanding in terms of equipment, skill and time. Seven clones from a single superior bull, named 'M-29', were produced and birth of first re-cloned calf of a cloned bull, named 'Hisar-Gaurav' was successfully achieved. It has already produced 15,000 doses of semen. These semen doses have been used at ICAR-CIRB as well as at farmers herds to produce 62 pregnancies which are growing normally, similar to progenies of bulls born conventionally. The semen of the cloned bulls has fertility attributes equal to those of normal bulls.

(iii) **Chemical, structural and functional characterization of identified anti-tick lead phytochemicals and optimization of delivery matrix for effective application of natural formulation for the control of acaricide resistant ticks:** Safe, stable and characterized flowable (F10) and natural cream formulations were developed to tackle the resistant tick problem.

SARS-CoV-2 nucleic acid detection LFA kit

SARS-CoV-2 Antibody detection ELISA Kit

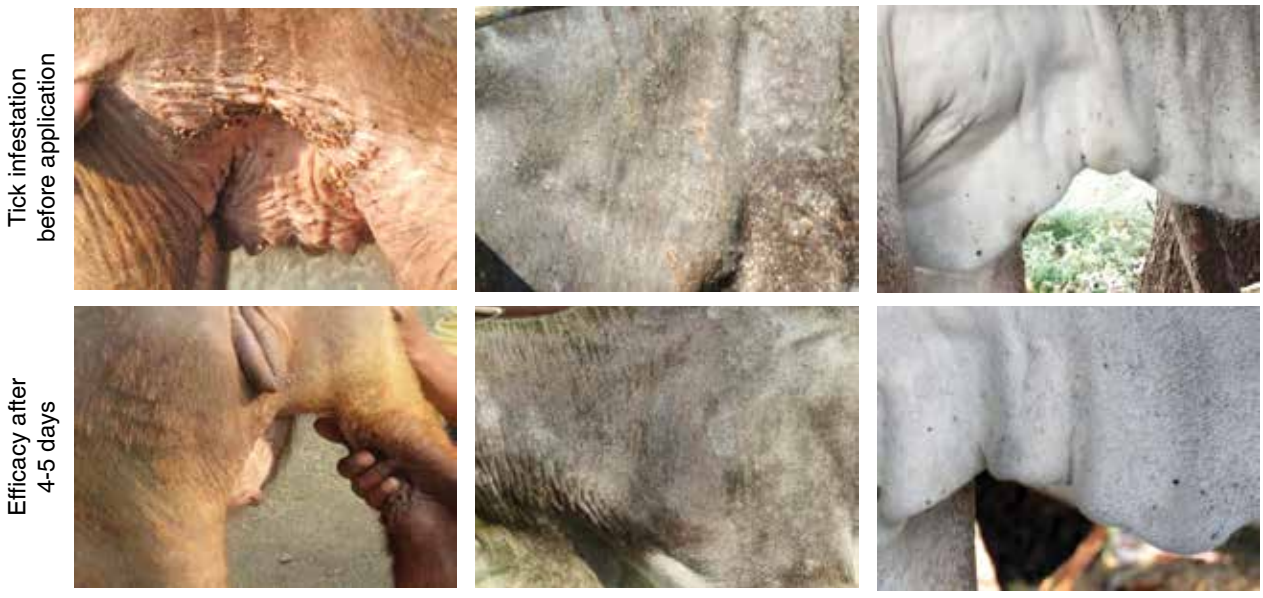
Covid-19 Blocking ELISA kit

Seven clones (left to right) of a superior breeding bull (M-29) of Murrah breed and a re-cloned calf (rightmost) of cloned bull (Hisar-Gaurav)

Identification and quantification of five active compounds in the formulation were validated. Both the formulations were 80-90% effective under *in vitro* model and 60-90% effective against ivermectin resistant ticks. Both the formulations were evaluated against experimental challenge infestations and 70-90% efficacy was recorded. The efficacy of anti-tick natural formulations (F10 and cream) was validated on more than 100 animals at different locations of Parbhani district of Maharashtra and reported to be more than 80%. Field trials of the formulation were also done in Uttarakhand and Maharashtra. The first-generation anti-tick technology was transferred to Ajay Bio-tech India Ltd, Pune.

(iv) Traceable value chain for safe pork in the North Eastern region of India: A protocol was made after standardizing all the features related to capturing the facial image of the animals. Facial images of pigs from different pig breeds of different age groups after weaning were captured. Algorithms was developed to amplify certain hidden features in the face. The features-based image recognition algorithms like Local Binary Patterns Histograms (LBPH), Histogram of Oriented Gradients (HOG), Principal Component Analysis (PCA) and Support Vector Machine (SVM) was applied for individual pig recognition. Machine learning algorithms was applied to same-breed image sets and the Support Vector Machine (SVM) give better prediction accuracy (97%) compared to others. Faster R-CNN was applied on the same image sets for prediction of breeds which produced 91% accuracy with a 94% confidence level. A total of 105 diseases of pigs with typical lesions was tabulated for the antemortem exam (AM) of pigs and 83 diseases of pigs of either sex with typical lesions was tabulated for the Post-mortem exam (PM) of pigs for the Decision Support System (DSS) for pig slaughtering.

(v) Rubber check-dam for watersheds: Flexi-composite rubber check-dam technology was developed and demonstrated in different agro-ecological and geo-hydrological regions. Hydrologic and agricultural data were regularly obtained at four rubber check-dam sites in the Orissa state. During monsoon, immediately after heavy rains, water kept flowing above the crest at up to one meter height. During dry periods, the dam remained full up to the crest height.



Efficacy of the anti tick formulations obtained in field trial in Maharashtra

A flexible rubber dam for water harvesting in watershed

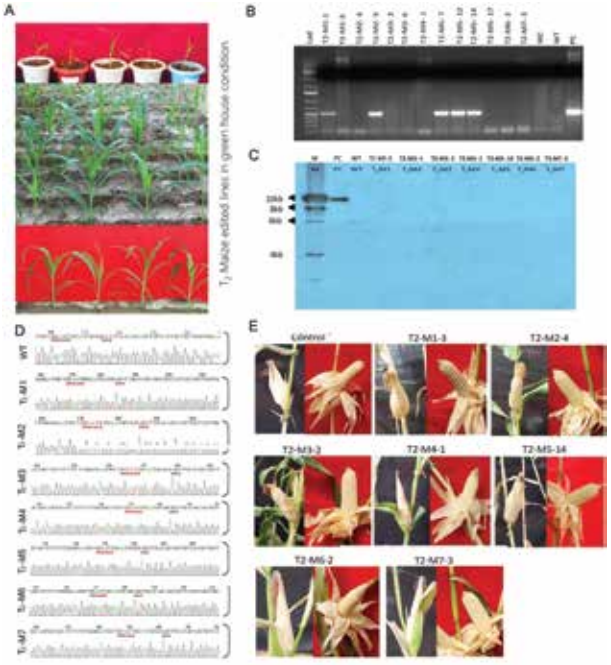
The water was stored upstream up to a length of 0.8 to 1.7 km at various locations. The additional volume of water stored in the upstream due to the installation of rubber dam varied between 4,800 and 10,000 cu.m at any point of time during the monsoon. At the rubber dam installation sites, water was available up to the maximum capacity of the rubber dam since the fourth week of June 2012. The stored water in the rubber dam helped in timely transplanting of rice and irrigating 12-16 ha of rice fields as per need. There was yield enhancement of rice by 16-25 per cent during the Kharif season. Farmers close to the rubber dam sites grew vegetable crops like watermelon, cowpea, cucumber, tomato, ladyfinger, etc. during the summer 2013 in 5.0 ha area which otherwise would have remained fallow. Besides, the rubber dam was instrumental in augmenting groundwater recharge in the project site. Demonstration of rubber dams for watersheds was extended to many states and agro-ecological regions.

(vi) **Development of an electronic nose for the optimum harvesting time and fruit quality in apple and papaya:** A low-cost non-invasive sensor system for determining the correct fruit ripening stages of apple and papaya for harvesting and extended post-harvest storage. Five non-invasive signature VOCs have been identified for tracking the ripening stage and post-harvest nutritional quality in apples. Signature volatile metabolites emitting from apple whose level can specifically tell the ripening stages and nutritional quality of apples was identified. Based on those signature volatiles, a low-cost metal oxide transducer-based sensor to sense ripening stages and nutritional quality of apples was developed. Three different cultivars of apple (*Malus domestica*) namely Shireen (S.H), Golden delicious (G.D) and Red delicious (R.D) at three different maturity stages from CITH (Srinagar, J&K) were used. Development of an electronic circuit for the volatile sensing conducted showed a sharp increase in ethylene during fruit apple ripening. A series of metal oxide (MOS) semiconductor thin layer was used, and metal oxide X and Y (molecular details undisclosed) were highly sensitive towards detection of ethylene up to 5 ppm level. The developed sensor has significant response time and sensor outputs were calculated by using ATMEGA328P-PU based processor. A patent has been filed for the prototype developed. Based on signature VOCs, a metal oxide hybrid transducer-based E-nose sensor prototype was developed at IIT Roorkee to sense these ripening stages. The E-nose senor can work independently with its own display or can be integrated with any Android mobile phone using SMART-Nose app. In addition to ripening stage, this E-nose sensor can also predict sugar, protein and polyphenol contents non-invasively under post-harvest storage conditions. Sensors are ready for field trials by the apple farmers.

Smart Fruit Nose

(vii) **Revolutionizing maize agriculture through CRISPR/Cas9-mediated herbicide resistance:** A highly efficient herbicide-resistant maize line, using CRISPR/Cas9-mediated homology donor repair

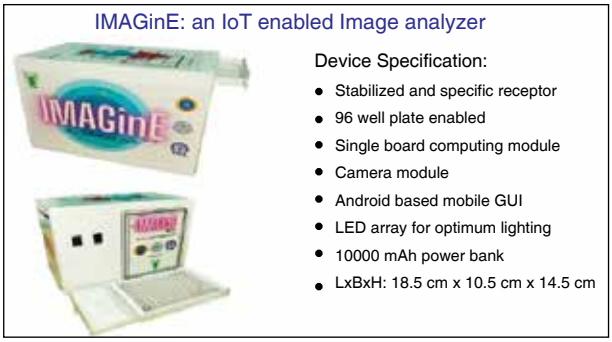
base editing system, was developed by International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi. This breakthrough promises to address the global challenge of weed infestation and significantly enhance crop yield.Weed infestation poses a global threat to crop yields, and the widely used herbicide glyphosate has been acornerstone in weed control. In this study, CRISPR/Cas9 gene-editing technology was used to introduce specific modifications in the maize EPSPS gene, a crucial enzyme in the shikimic acid pathway targeted by glyphosate. A robust CRISPR/Cas9 vector system, employing maize codon-optimized SpCas9, to precisely edit the *ZmEPSPS* gene was developed. A homology donor repair vector encoding a mutated *mZmEPSPS* sequence with triple amino acid substitutions (G163A, T164I, and P168S) was created. Biolistic-mediated transformation successfully integrated the CRISPR/Cas9 expression cassette and the HDR-*mZmEPSPS* template into maize cultivars, resulting in the generation of tailored maize plants. Rigorous screening confirmed the successful integration of the desired genetic modifications in edited plants through PCR and Sanger sequencing. Southern blot analysis confirmed the presence of the Cas9 gene in various copies at random locations in the transformed maize lines. Transgene-free progeny was obtained, ensuring that the desirable traits could pass on without the presence of foreign genetic material. Functional validation of foliar spray experiments substantiated the enhanced glyphosate tolerance in edited maize lines, The edited maize lines exhibited high tolerance to glyphosate (3 ml/L Roundup-Ready), with no discernible yield penalty. The edited plant seeds were subjected to glyphosate-containing media, and the edited lines displayed normal growth in the presence of glyphosate, showing their enhanced tolerance. The edited lines also outperformed control plants in physiological parameters such as net photosynthesis rate and Photosystem II efficiency under glyphosate stress. Further analyses revealed reduced damage and higher chlorophyll content in edited lines as compared to control plants when exposed to various doses of glyphosate. The edited lines were self-crossed to achieve homozygosity, and the Cas9 gene was successfully removed, resulting in “Cas9 gene-free” edited maize lines with no phenotypic abnormalities. The transformative potential of CRISPR/Cas9-mediated genome editing in developing herbicide-resistant crops has been highlighted. It not only addresses the critical issue of weed infestation but also



Molecular and morphological validation of T2 generation maize plants. (A) T2 edited maize plants healthy grown in the field and under greenhouse conditions. (B) The negative Cas9 T2 edited lines confirmed by PCR analysis. Molecular weight marker 1kb was loaded in lane L. Lanes that contain edited lines are lane T2-M1-1 to T2-M7-3 with comparison to plasmid pCris-TK1 act as a positive control in lane PC, wild type in lane WT and water as a control in lane WC. (C) Southern blot analysis for the identification of T-DNA free segregants. In lanes S1-S7 no signal was detected, confirms the presence of T-DNA-free T2 segregants. M- Marker, PC- positive control (Cas9), WT- wild type plant. (D) T2 maize lines Sanger sequencing - chromatograms of the desired HDR obtained from the modified EPSPS gene (glycine (GGA) to alanine (GCA), tryptophan (ACT) to isoleucine (ATT) and proline (CCA) to serine (AGC)) from edited lines. (E) Morphological variations between maize cobs obtained from edited crops generated from glyphosate resistant maize lines (T2). The cobs collected revealed no defects in size of the kernel, no edge dislocation and no abnormality in cob ears. Further, the collected cobs did not show any missed kernels all through the imaged ears. Maize corns comparison with control and edited lines. The cobs collected from the untransformed control plants (WT) and the ones from the edited lines showed no developmental defects and had yielded kernels of the viviparous white colour.

opens avenues for the development of elite maize varieties with enhanced glyphosate resistance. This research represents a significant stride towards sustainable and resilient agriculture, paving the way for future innovations in crop improvement.

(viii) Development of biosensors for detection of fish pathogenic bacteria and hazardous metalloids in selected water bodies: A sensing device (IMAGinE) was developed at ICAR- CIFRI, Barrackpore for detection of Chromium (Cr^{6+}) in water with very trace level detection limit. Different image parameter values, such as R, G, B and S were extracted from the Cr-Detector system of IMAGinE for data analysis. The developed Cr^{6+} sensing device IMAGinE was found to very precise and robust with very low values of limit of detection (LOD) and limit of quantitation (LOQ), 0.0037 ppm and 0.0112 ppm, respectively.



IoT enabled Image analyzer for Cr^{6+} detection

(ix) SMART sensor for non-destructive detection of apple scab disease at asymptomatic stage: Apple scab disease can be detected early, when plants are asymptomatic, using this low-cost handheld sensor developed by IIT Roorkee and ICAR-CITH. Apple scab, caused by the fungus V. inaequalis, is a serious apple disease, causing 50-60% damage to apples. Multiple sprays of fungicides are currently used to control the disease, which is costly and toxic to the environment and health. An early asymptomatic detection of scab disease will allow for proper control measures to be implemented in a localized area, thereby reducing fungicide usage and disease spread. A metal-oxide and nanomaterial-based sensor was developed to detect scab

Sensor for apple scab disease

disease by sensing signature volatile organic compounds (VOCs). During detection, an AI-enabled algorithm is used to minimize error. The sensor shows a 90% accuracy in predicting scab in susceptible apple cultivars under greenhouse conditions. The device is being validated in the apple orchards. Due to the low buyer cost of the technology farmers can afford this sensor thus have huge economic significance. In India, this sensor is expected to have a significant impact on the horticulture industry.

(x) Early detection bovine pregnancy diagnosis kits: India's first-ever cow-side pregnancy diagnosis kits, Lateral Flow Assay (LFA) against Pregnancy Associated Glycoprotein (PAG) and metabolite-based pregnancy diagnosis kit known as Preg-D, specifically designed for bovines was developed at ICAR-CIRB, Hisar. The first scientific evidence that PAG-7 isoform is the most abundant isoform among all the known isoforms of PAGs followed by PAG-18 and PAG-2 in buffalo was reported. Through successful cloning and expression of these PAG isoforms in E. coli, purified recombinant PAG-7, PAG-18 and PAG-2 were obtained which were instrumental in antibody generation. Monoclonal antibodies were developed based on predicted epitopes from the sequences of PAG-7 and PAG-18. These antibodies demonstrated proof of concept, indicating their utility in developing immunodiagnostic methods for detecting and quantifying PAGs in various biological samples. Subsequently, PAG-7,

Preg- D bovine pregnancy diagnosis kit

PAG-18 and PAG-2 were utilized as key resources in developing ELISA and Lateral Flow Immunoassay-based kits for point-of-care pregnancy diagnosis. An Indian patent No.202011026145 has been filed based on these results.

5
Summary & Way Forward

NASF has been successful in fostering the basic, strategic & translational research in agriculture and allied areas in the country. The existing infrastructure of NARS has been strengthened through the funding support. The support has led to procurement of many sophisticated analytical instruments equipping the laboratories of multiple research institutions and universities for conduct of major long-term research capacity development activity. Global state-of-the art research facilities created through NASF support is an asset and will pave the way for the new path breaking research in the future. Many innovative products and diagnostics and vaccines have been developed, patented and commercialised. New research methodologies have been developed leading to many new varieties in crop. A large number of scientists from various institutions have worked in multidisciplinary areas through multi-institutional projects. They have developed and sharpened their knowledge and skills in frontier areas of science and also availed overseas training in cutting edge areas. All these activities not only upgraded the knowledge and skills but also enabled them to build professional contact with other scientific institutions working in their areas of interest. The scientists have also received many awards and brought laurels to their respective institutions through the projects. In addition to the results in terms of high impact publications, patents and technologies, a strong and sustainable platform for developing scientific capacity and culture that encompasses the extended NARS is being established. Besides this, capacity building of quality human resources has been achieved by enriching the knowledge of >1200 students/ SRF/RA/project staff. This will ensure continuous flow of knowledge, ideas and cohesive working among different stakeholders in the basic, strategic and frontier application research for solving problems in agriculture and also forming policies in agriculture.

List of total projects funded by National Agricultural Science Fund

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
1	1001	Molecular basis of insect-plant interactions in rice	Dr. J.S. Bentur	ICAR-IIRR, Hyderabad	2.19	Dec 2006	March 2012
			Dr. J. Nagaraju	CDFD, Hyderabad		Dec 2006	March 2012
2	1002	Targeted gene integration in rice and cotton	Dr. P. Anand Kumar	ICAR-NRCPB, New Delhi	2.01	Dec 2006	March 2013
			Prof. S.K. Sen	IIT, Kharagpur		Dec 2006	March 2013
			Dr. I.S. Katageri	UAS, Dharwad		Dec 2006	March 2013
3	1003	Transcriptional level of developmentally important genes in buffalo pre implantation embryos	Dr. G. Taru Sharma	ICAR-IVRI, Izatnagar	2.02	Dec 2006	March 2012
			Dr. A. Palanisamy	Madras Veterinary College, TANUVAS, Chennai		Dec 2006	March 2012
			Dr. Shiv Prasad	GBPUA&T, Pantnagar		Dec 2006	March 2012
4	1004	Application of reverse genetics: a novel approach for studying the molecular basis of immune response in Indian cattle breed	Dr.V.V.S. Suryanarayana	ICAR-IVRI, Bangalore	1.98	Dec 2006	Nov 2011
			Prof. M.S. Shaila	IISc, Bengaluru		Dec 2006	Nov 2011
			Dr. M.K. Rao	ICAR-NDRI, Bangalore		Dec 2006	Nov 2011
5	1005	Gene-based genetic maps and molecular markers for biotic and abiotic stress tolerance in cultivated groundnut	Dr. R.K. Varshney	ICRISAT, Hyderabad	1.85	Dec 2006	Nov 2011
			Dr. T. Radhakrishnan	ICAR-DGR, Junagarh		Dec 2006	Nov 2011
			Dr. M.V.C. Gowda	UAS, Dharwad		Dec 2006	Nov 2011
6	1006	Endocrine profiles and characterization of candidate genes influencing prolificacy in black Bengal goat	Dr. Avijit Haldar	ICAR-RC for NEH Region, Tripura	2.89	Feb 2007	March 2012
			Dr. Abhijit Mitra	ICAR-IVRI, Izatnagar		Feb 2007	March 2012
			Dr. Chanchal Kanti Biswas	BCKV, Mohanpur		Feb 2007	March 2012
			Dr. S. Pan	WBUAFS, Kolkata		Feb 2007	March 2012

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
7	1007	Antiluteolytic strategies - a novel approach to enhance fertility in buffalo	Dr. S.K. Agarwal	ICAR-IVRI Izatnagar	3.04	Feb 2007	Jan 2012
			Dr. S. Selvaraju	ICAR-NIANP, Bengaluru		Feb 2007	Jan 2012
			Dr. R. Medhamurthy	IISc, Bengaluru		Feb 2007	Jan 2012
			Dr. Shiv Prasad	GBPUA&T, Pantnagar		Feb 2007	Jan 2012
			Dr. G.S. Dhaliwal	GADVASU, Ludhiana		Feb 2007	Jan 2012
8	1008	Development of molecular probes for diagnosis of different virulent and anastomosis groups of *Rhizoctonia solani* infecting leguminous crops	Dr. S.C. Dubey	ICAR-IARI, New Delhi	1.11	Feb 2007	March 2012
			Dr. H.C. Lal	BAU, Ranchi		Feb 2007	March 2012
9	1009	Electro-magnetic energies for biostimulation and post harvest conservation of seeds, and agri-products	Dr. Shantha Nagarajan	ICAR-IARI, New Delhi	1.60	Feb 2007	March 2011
			Dr. Amaresh Chandra	ICAR-IGFRI, Jhansi		Feb 2007	March 2011
			Dr. K.P. Ray	SAMEER, Mumbai		Feb 2007	March 2011
			Dr. K.N. Guruprasad	DAVV, Indore		Feb 2007	March 2011
10	1010	Rumen microbial manipulations for mitigation of methane emission and productivity enhancement in dairy animals	Dr. S.K. Sirohi	ICAR-NDRI, Karnal	2.74	Feb 2007	Jan 2012
			Dr. M. Chandrasekharaiah	ICAR-NIANP, Bengaluru		Feb 2007	Jan 2012
			Dr. L.C.Chaudhary	ICAR-IVRI, Izatnagar		Feb 2007	Jan 2012
			Dr. A.Santra	ICAR-NDRI, Karnal		Feb 2007	Jan 2012
11	1011	Development of autotransgenic Asian Catfish *Clarias batrachus* L	Dr. K.C. Majumdar	CCMB, Hyderabad	1.80	Feb 2007	Jan 2012
			Dr. G. Vanugopal	ICAR-CIFE, Mumbai		Feb 2007	Jan 2012
12	1012	Induction of apomixis in sorghum by down-regulation of somatic –embryogenesis-receptor-kinase	Dr. B. Venkatesh Bhat	ICAR-NRCS, Hyderabad	2.50	Feb 2007	Jan 2012
			Dr. Imran Siddique	CCMB, Hyderabad		Feb 2007	Jan 2012
			Dr. Vishnu Bhat	DU, Delhi		Feb 2007	Jan 2012
13	1013	Role of small signal peptides in systemic defense response of Indian mustard (*Brassica juncea*) to aphids (*Lipaphiserysimi*)	Dr. R.C. Bhattacharya	ICAR-NRCPB, New Delhi	1.38	Feb 2007	Jan 2012
			Dr. Prem Dureja	ICAR-IARI, New Delhi		Feb 2007	Jan 2012

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
14	1014	Evaluating candidate genes towards enhancement of drought tolerance in chickpea (*Cicer arietinum*)	Dr. Srinivasan	ICAR-NRCPB, New Delhi	3.45	Feb 2007	Jan 2012
			Dr. R.K. Varshney	ICRISAT, Hyderabad		Feb 2007	Jan 2012
			Dr. Jitendra Kumar	ICAR-IARI, New Delhi		Feb 2007	Jan 2012
			Dr. Rajendra Kumar	SVBPUAT, Meerut		Feb 2007	Jan 2012
15	1015	Increasing nutrient availability from roughage based rations through enhancing rumen efficiency or reducing enteric methane production by use of secondary plant metabolites	Dr Ramesh C. Jakhmola	ICAR-CSWRI- Arid Region Campus, Bikaner	1.31	Dec 2007	Jan 2012
			Dr. M.K. Tripathi	ICAR-CSWRI, Avikanagar		Dec 2007	Jan 2012
			Dr. Tribhuvan Sharma	Rajasthan Agricultural University, Bikaner		Dec 2007	Jan 2012
16	1016	Molecular diagnosis of fungal diseases of Cassava, Taro, Amorphophallus and Yam.	Dr. (Mrs). M. L. Jeeva	ICAR-CTCRI, Sreekariya, Thiruvananthapuram	0.79	Dec 2007	Jan 2012
17	1017	Epidemiology and forewarning system of Downey mildew disease of cucurbits to develop appropriate IPM Strategy.	Dr. Indrabrata Bhattacharya	BCKV, Mohanpur	0.73	Dec 2007	Jan 2012
			Dr. S. Kumar	Research Complex for the Eastern Region, Ranchi		Dec 2007	Jan 2012
18	1018	Molecular analysis of agrocin producing *Agrobacterium radiobacter* for biological control of crown gall in stone fruits.	Dr. A. K. Gupta	Dr.YSPUH&F, Nauni, Solan (H.P.)	0.87	Dec 2007	Jan 2012
			Prof. Rup Lal	DU, Delhi		Dec 2007	Jan 2012
			Dr. K.P. Singh	GBPUA&T, Ranichauri, Pantnagar		Dec 2007	Jan 2012
19	1019	Evaluation of groundnut germplasm for morphological, physiological and molecular characters/ traits associated with drought tolerance for enhancing productivity in rain-dependent system.	Dr P.C. Nautiyal	ICAR-DGR, Junagadh	1.35	Dec 2007	Jan 2012
			Dr. M.S. Sheshshayee	UAS, Bengaluru		Dec 2007	Jan 2012

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
20	1020	A comprehensive study on argulosis: host-parasite interaction with respect to modulation of innate and specific immune responses, and development of preventive or control measures.	Dr. P.K. Sahoo	ICAR-CIFA, Bhubaneshwar	1.04	Dec 2007	Jan 2012
21	1021	Sustainable biomass alternative to fossil fuel based urea-generation of hydrogen feedstock from agro residue and biomass.	Prof. M.S. Hegde	IISc, Bengaluru	0.97	Dec 2007	Jan 2010
22	2001	The nature of impact of abiotic stresses on three diverse freshwater species of fishes	Prof. Rina Chakrabarti	DU, Delhi	2.29	Jan 2011	June 2014
			Dr. B. P. Mohanty	ICAR-CIFRI, Barrackpore		Jan 2011	June 2014
			Dr. Mrinal Samanta	ICAR-CIFA, Bhubaneshwar		Jan 2011	June 2014
			Dr. Sasmita Mohanty	KIIT University, Bhubaneswar		Jan 2011	June 2014
23	2002	Deciphering the mechanism of aberrant maternal recognition of pregnancy (MRP) events in sheep and buffalo under heat and nutritional stress	Dr. Sukanta Mondal	ICAR-NIANP, Bengaluru	2.41	Jan 2011	Dec 2015
			Dr. Davendra Kumar	ICAR-CSWRI, Avikanagar		Jan 2011	Dec 2015
			Dr. T.K.Datta	ICAR-NDRI, Karnal		Jan 2011	Dec 2015
24	2003	Micro-encapsulation methods for bacteriocins for their controlled release	Dr. K. Narsaiah	ICAR-CIPHET, Ludhiana	1.92	Jan 2011	March 2014
			Dr. R.K. Malik	ICAR-NDRI, Karnal		Jan 2011	March 2014
25	2004	Extraction and micro-encapsulation of nutraceutical for effective delivery into different food matrices	Dr. Abhjit Kar	ICAR-IARI, New Delhi	5.26	Jan 2011	Dec 2015
			Dr. Manjoosha Srivastava	NBRI, Lucknow		Jan 2011	Dec 2015
			Dr. Gargi Ghoshal	Punjab University, Chandigarh		Jan 2011	Dec 2015
26	2005	Investigations on high pressure induced effect on quality characteristics of buffalo milk	Dr. A. Kumar Singh	ICAR-NDRI, Karnal	0.66	Jan 2011	Dec 2012
27	2006	Increasing the efficiency of microbial production of bioethanol from agricultural biomass	Dr. Lata	ICAR-IARI, New Delhi	2.31	Jan 2011	Dec 2015
			Dr. B.S. Chadha	GNDU, Amritsar		Jan 2011	Dec 2015

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
28	2007	Studies on microalgal triacylglycerols (TAGs) as a source of biodiesel	Dr. Nirupama Mallick	IIT, Kharagpur	1.70	Jan 2011	March 2016
29	2008	Studies on sucrose accumulation for efficient ethanol production from sweet sorghum	Dr. C.V. Ratnavathi	ICAR-DSR, Hyderabad	1.96	Jan 2011	March 2016
			Dr. S.R.Gadakh	MPKV, Rahuri		Jan 2011	March 2016
30	2009	Isolation of *Clostridium* strains and a two phase digestion system for efficient butanol production	Dr.Geeta G. Shirnalli	UAS, Dharwad	1.46	Jan 2011	March 2016
			Dr. S. Karthikeyan	TNAU, Coimbatore		Jan 2011	March 2016
31	2010	Development of pod borer resistant transgenic pigeonpea and chickpea	Dr. N. P.Singh	ICAR-IIPR, Kanpur	18.87	Jan 2011	March 2017
			Dr. Rohini Sreevathsa	ICAR-NRCPB, New Delhi		Jan 2011	March 2017
			Dr. Sumangala Bhatt	UAS, Dharwad		Jan 2011	March 2017
			Dr. Bidyut K. Sarmah	AAU, Jorhat		Jan 2011	March 2017
			Dr. Sudip K.Ghosh	IIT, Kharagpur		Jan 2011	March 2017
			Dr. S. Das	Bose Institute, Kolkata		Jan 2011	March 2017
			Dr. W. Tyagi	CAU, Shillong		Jan 2011	March 2017
			Dr. D. Chakraborty	St. Xavier College, Kolkata		Jan 2011	March 2017
32	2011	Use of RNAi technology in developing low phytate soybean and rice	Dr. Archana Sachdev	ICAR-IARI, New Delhi	2.50	June 2011	May 2015
			Dr. Karabi Datta	CU, Kolkata		June 2011	May 2015
			Dr. Anita Rani	ICAR-IISR, Indore		June 2011	May 2015
33	2012	Identification of nucleopolyhedrousvirus (NPV) encoded proteins and small RNAs and feasibility of their expression in plant to control predation by Helicoverpa armigera	Dr. Raj K. Bhatnagar	ICGEB, New Delhi	3.58	Jan 2011	March 2016
			Dr. S.K. Jalali	ICAR-NBAIR, Bengaluru		Jan 2011	March 2016
34	2013	Regulation of fatty acid synthesis by RNA interference in pig	Dr. Sujoy Kumar Dhara	ICAR-IVRI, Izatnagar	2.45	Jan 2011	March 2016
			Dr. Soumen Naskar	ICAR-NRCP, Guwahati		Jan 2011	March 2016

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
35	2014	RNAi mediated comparative functional analysis of immune response genes in ruminants and fish against *Mycobacterium avium* ssp. paratuberculosis and *M. fortuitum*	Dr. Abhijit Mitra	ICAR-IVRI, Izatnagar	3.80	Jan 2011	March 2015
			Dr. S. Mazumdar	DU, Delhi		Jan 2011	March 2015
			Dr. Dhirendra Singh	ICAR-CSWRI, Avikanagar		Jan 2011	March 2015
36	2015	Phenomics of moisture deficit and low temperature stress tolerance in rice	Dr. Viswanathan Chinnusamy	ICAR-IARI, New Delhi	69.71	Feb 2011	March 2016
			Dr. P.K.Mondal	ICAR-NRCPB, New Delhi		Feb 2011	March 2016
			Dr. S. Chaudhury	IIT, New Delhi		Feb 2011	March 2016
			Dr. J. P. Khurana	DU, Delhi		Feb 2011	March 2016
			Dr. S.K.Dash	ICAR-CRRI, Cuttack		Feb 2011	March 2016
			Dr. G. Chandel	IGKV, Raipur		Feb 2011	March 2016
			Dr. Wricha Tyagi	CAU, Imphal		Feb 2011	March 2016
			Dr. A. Pattanaik	ICAR-RC for NEH, Barapani		Feb 2011	March 2016
			Dr. Sudeep Marwaha	ICAR-IASRI, New Delhi		Feb 2011	March 2016
37	2016	Unravelling biochemical and molecular basis of bacterial and fungal endo-symbiosis for management of abiotic stresses in plants	Dr. K. K. Pal	ICAR-DGR, Junagarh	2.55	June 2011	May 2016
			Dr. Ajit Varma	Amity University, Noida		June 2011	May 2016
			Dr. Devidayal	ICAR-CAZRI, Jodhpur		June 2011	May 2016
38	2017	Improvement in cotton fabric quality by plasma nano-technology: An eco-friendly approach	Dr. Kartick Kumar Samanta	ICAR-CIRCOT, Mumbai	1.95	June 2011	May 2014
39	2018	Genomics for augmenting fibre quality improvement in jute	Dr. D. Sarkar	ICAR-CRIJAF, Barrackpore	4.13	June 2011	May 2016
			Dr. N.K. Singh	ICAR-NRCPB, New Delhi		June 2011	May 2016
40	2019	Genetic manipulation based enhancement of microbial phosphate and nitrate remediation for waste water treatment	Dr. Shaon Ray Chaudhuri	West Bengal University of Technology, Kolkata	1.93	June 2011	May 2014
			Dr. Arunava Goswami	ISI, Kolkata		June 2011	May 2014
			Dr. Krishna Ray	West Bengal State University		June 2011	May 2014

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
41	2020	Molecular characterization and validation of fiber strength genes with fiber specific promoter for improvement in cotton	Dr. Balasubramani	ICAR-CICR, Nagpur	2.10	Aug 2011	July 2016
			Dr B.R.Patil	UAS, Dharwad		Aug 2011	July 2016
42	2021	Mitigating abiotic stresses and enhancing resource-use efficiency in pulses in rice fallows through innovative resource conservation practices	Dr. S.S. Singh	ICAR-IIPR, Kanpur	2.44	June 2011	May 2016
			Dr.R.N. Singh	ICAR-IGKV, Raipur		June 2011	May 2016
			Dr. P.K. Bandyopadhyay	BCKV, Mohanpur		June 2011	May 2016
			Dr. P. Parasuraman	TNAU-Tamil Nadu Rice Research Institute, Adhuturai		June 2011	May 2016
			Dr. Anup Das	RC for NEH Region, Meghalaya		June 2011	May 2016
43	2022	Capture and removal of ammonia from fish processing waste water using Archaea	Dr. B.B. Nayak	ICAR-CIFE, Mumbai	2.28	June 2011	May 2016
			Dr. S.K.Girisha	CoF, Mangalore		June 2011	May 2016
44	2023	Bioremediation of agrochemicals and heavy metals present in Yamuna and drainage water used for irrigation in urban and peri-urban agricultural areas	Dr. Dileep Kumar Singh	DU, Delhi	2.10	June 2011	May 2016
			Dr. Anushree Malik	IIT, New Delhi		June 2011	May 2016
			Dr. (Ms.) Neelam Patel	ICAR-IARI, New Delhi		June 2011	May 2016
45	2024	Crop simulation studies to understand the effect of moisture and temperature stress on growth and yield of wheat	Dr. P. Krishnan	ICAR-IARI, New Delhi	2.02	June 2012	May 2015
			Dr R. K. Sharma	ICAR-IIWBR, Karnal		June 2012	May 2015
46	2025	Decision support system for enhancing water productivity of irrigated rice-wheat cropping system	Dr. A. Sarangi	ICAR-IARI, New Delhi	1.44	June 2012	May 2016
			Dr. Ranu Rani Sethi	ICAR-IIWM, Bhubaneswar		June 2012	May 2016
47	2026	Decision support system for enhancing productivity of grapes under moisture and temperature stress conditions	Dr. A.K.Upadhyay	ICAR-NRC for Grapes, Pune	1.97	June 2012	May 2016
			Dr. S. Naresh Kumar	ICAR-IARI, New Delhi		June 2012	May 2016
			Dr. Sanjay Borkar	Shivrai Technologies Pvt. Ltd. (STPL), Pune		June 2012	May 2016
48	3001	Role of Archaebacteriain alleviation of salinity and moisture stress in plants	Dr. A. K. Saxena	ICAR-IARI, New Delhi	2.65	Aug 2012	July 2015
			Dr. Rinku Day	ICAR-DGR, Junagarh		Aug 2012	July 2015

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
49	3002	State of diversity of commercially important seaweeds along the West Coast of India	Dr. Monica G. Kavale	ICS College, University of Mumbai	1.26	June 2012	May 2015
			Dr. V.V.Singh	ICAR-CMFRI, Mumbai		June 2012	May 2015
50	3006	Double herbicide tolerant transgenic rice: weed management	Dr. M.K.Reddy	ICGEB, New Delhi	2.47	June 2012	March 2017
			Dr. C. Parameswaran Rajesh	ICAR-IIRR, Hyderabad		June 2012	March 2017
			Dr. M. Sheshu Madhav	ICAR-NRRI, Cuttack		June 2012	March 2017
51	3007	Deciphering molecular mechanism of induction of biotic stress tolerance by *Trichoderma* spp. in castor (*Ricinus communis* L.)	Dr. V. Dinesh Kumar	ICAR-DOR, Hyderabad	2.56	June 2012	March 2017
			Dr. Ragiba Makandar	University of Hyderabad, Hyderabad		June 2012	March 2017
52	3008	Reduction of crop loss by birds using bio-acoustics	Dr. S.S.Mahesh	VLS, Bengaluru	1.29	June 2012	May 2015
			Dr. V. Vasudeva Rao	ANGRAU, AINP on Ornithology, Hyderabad		June 2012	May 2015
53	3009	Infertility in crossbred bulls: Search for spermatogenic cell markers for early prediction of fertility	Dr. A. Kumaresan	ICAR-NDRI, Karnal	2.82	June 2012	March 2017
			Dr. Savita Yadav	AIIMS, New Delhi		June 2012	March 2017
54	3010	Development of genetically engineered vaccines against economically important poultry viral diseases	Dr. Sohini Dey	ICAR-IVRI, Izatnagar	1.93	June 2012	May 2016
			Dr. Bikash Mondal	ICAR-IARI, New Delhi		June 2012	May 2016
55	3011	Development of a bivalent marker vaccine against bovine herpesvirus-1 and brucella	Dr. Praveen Gupta	ICAR-IVRI, Izatnagar	1.15	June 2012	May 2015
56	3012	Development of live vaccine targeting the protein repair system(s) of *Salmonella*	Dr. Manish Mahawar	ICAR-IVRI, Izatnagar	1.37	June 2012	Nov 2015
57	3013	Phytoplasma diseases of coconut and arecanut: Development of molecular diagnostics	Dr. Vinayak Hegde	ICAR-CPCRI, Kasaragod	0.65	June 2012	May 2015

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
58	3014	Early detection of pregnancy in cow and buffalo by pregnancy associated proteins (PAPs)	Dr. A.K. Mohanty	ICAR-NDRI, Karnal	2.00	June 2012	May 2015
			Dr. Ashok K. Balhare	ICAR-CIRB, Hisar		June 2012	May 2015
59	3015	Development of transgenic goat for production of human lactoferrin	Dr. M.S. Chauhan	ICAR-NDRI, Karnal	2.78	June 2012	May 2016
60	3016	Defense genes of tiger shrimp (*Penaeus monodon*) with respect to bacteria (*Vibrio harveyi*) and whitespot virus (WSSV) infection	Dr.S. Kumar Otta	ICAR-CIBA, Chennai	2.53	June 2012	May 2016
			Dr. M.N. Venugopal	KVAFSU, Mangalore		June 2012	May 2016
			Dr.K.V.Rajendran	ICAR-CIFE, Mumbai		June 2012	May 2016
61	3017	Development of a protocol for targeted integration of genes in Catla (*Catla catla*)	Dr. Hirak Kumar Barman	ICAR-CIFA, Bhubaneshwar	1.48	June 2012	May 2015
62	3019	Countering gastrointestinal tract pathogens by adhesion-promoting probiotic surface proteins	Dr. Jai Kaushik	ICAR-NDRI, Karnal	1.24	June 2012	May 2015
63	3021	Stock characterization, captive breeding, seed production and culture of hilsa (*Tenualosa ilisha*)	Dr. V.R. Suresh	ICAR-CIFRI, Barrackpore	14.46	Nov 2012	Nov 2017
			Dr. Das Gupta	ICAR-CIFE, Kolkata		Nov 2012	Nov 2017
			Dr. Debasis Dey	ICAR-CIBA, RC, Kakdwip, WB		Nov 2012	Nov 2017
			Dr. Shubhadeep Ghosh	ICAR-CMFRI, Vishakhapattanam		Nov 2012	Nov 2017
			Dr. Mrs. Vindhya Mohindra	ICAR-NBFGR, Lucknow		Nov 2012	Nov 2017
			Dr. Sameer Bhattacharya	Vishwa Bharti University, West Bengal		Nov 2012	Nov 2017
			Dr. Debnarayan Chattopadhyay	ICAR-CIFA, RS, Kolkata		Nov 2012	Nov 2017

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64	3022	Understanding plant-nematode interaction: Identification of plant and nematode genes involved in disease development	Dr. K.Subramaniam	IIT, Kanpur	2.77	June 2012	May 2015
			Dr Amar Kumar	DU, Delhi		June 2012	May 2015
			Dr Anil Sirohi	ICAR-IARI, New Delhi		June 2012	May 2015
			Dr Pradeep Kr. Jain	ICAR-NRCPB, New Delhi		June 2012	May 2015
			Shri Ravi Shankar	ICAR-IHBT, Palampur		June 2012	May 2015
65	3023	Enhancing use efficiency of micronutrients: Novel delivery systems	Dr S.P. Dutta	ICAR-IARI, New Delhi	2.25	June 2012	May 2017
			Dr. Kishore M. Paknikar	ARI, Pune		June 2012	May 2017
66	3024	Use of Machine-Vision for distinguishing among crop varieties	Dr. Nachiket Kotwaliwale	ICAR-CIAE, Bhopal	2.37	July 2012	Sep 2015
			Dr. Monika Joshi	ICAR-IARI, New Delhi		July 2012	Sep 2015
			Dr. K. K. Gangopadhyay	ICAR-NBPGR, New Delhi		July 2012	Sep 2015
			Dr. Nabarum Bhattacharya	C-DAC, Kolkatta		July 2012	Sep 2015
67	3025	Green fishing systems for tropical seas	Dr. Leela Edwin	ICAR-CIFT, Cochin	14.49	June 2012	May 2017
			Shri R. Singh	Goa Shipyard Ltd, Vasco Da Gama, Goa		June 2012	May 2017
68	3026	Development of gossypol-free lysine-rich cottonseed cake by solid state fermentation	Dr.V. Mageshwaran	ICAR-CIRCOT, Mumbai	0.77	June 2012	May 2014
			Dr. S.B.Majee	Bombay Vet. College, Mumbai		June 2012	May 2014
69	3027	Development of spectroscopic methods for detection and quantification of adulterants and contaminants in fruit juices and milk	Dr. S. N. Jha	ICAR-CIPHET, Ludhiana	2.73	June 2012	May 2015
			Dr. K.K. Mondal	ICAR-IARI, New Delhi		June 2012	May 2015
70	3028	Development of multiplex microarray system for detection of food borne and shrimp pathogens	Dr. Owais Mohammad	AMU, Aligarh	2.33	June 2012	May 2015
			Dr. Tom Joseph	ICAR-CIFT, Cochin		June 2012	May 2015
71	3029	Jute based biocomposites for industry	Dr. L.Ammayappan	ICAR-NIRJAFT, Kolkata	2.32	June 2012	May 2015
			Er. S.K. Pandey	ICAR-IINRG, Ranchi		June 2012	May 2015
			Mr. Manik Bhowmick	ICAR-CIRCOT, Mumbai		June 2012	May 2015

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72	3030	Understanding genetics and biosynthesis of gum in ramie (*Boehmeria nivea* L. Gaud.) for developing low-gum genotypes	Dr. P. Satya	ICAR-CRIJAF, Barrackpore	1.24	June 2012	May 2016
			Dr. D.P. Ray	ICAR-NIRJAFT, Kolkata		June 2012	May 2016
73	3032	Bioremediation of contaminants in polluted sites: use of weedy plants	Dr. P. J. Khankhane	ICAR-DWSR, Jabalpur	2.06	April 2013	March 2017
			Dr. Ravinder Kaur	ICAR-IARI, New Delhi		April 2013	March 2017
			Dr. D. K. Singh	DU, Delhi		April 2013	March 2017
74	3033	Study of demonstration traits of two weed species	Dr. Bhumesh Kumar	ICAR-DWSR, Jabalpur	1.20	April 2013	March 2016
			Dr. I. C. Barua	AAU, Jorhat		April 2013	March 2016
			Dr. M. T. Sanjay	UAS, Bengaluru		April 2013	March 2016
			Dr. S. K. Guru	GBPUA&T, Pantnagar		April 2013	March 2016
75	3034	Establishment of association of begomovirus species with yellow vein mosaic disease (YVMD) in wild and cultivated species of okra and Identification of source of resistance to the most predominant virus	Dr. M.K. Reddy	ICAR-IIHR, Bengaluru	1.30	April 2013	March 2015
			Dr. V. Venkataravanappa	ICAR-IIVR, Varanasi		April 2013	March 2015
76	3035	Development of solar-hybrid refrigeration technology for on-farm (or in production catchment) safe transient storage of horticultural produce	Er. V.S.Reddy	SPRERI, Gujarat	5.41	May 2013	March 2017
			Dr. Panna Lal Singh	ICAR-CIAE, Bhopal		May 2013	March 2016
			Dr. R. F. Sutar	AAU, Anand, Gujarat		May 2013	March 2017
77	4001	Whey to Biofuel: Bioethanol production by stress tolerant and metabolically engineered yeast from whey	Dr. Shilpa Vij	ICAR-NDRI, Karnal	1.43	April 2013	March 2015
78	4002	Development of parthenogenetic goat from embryonic stem cells	Dr. S. D. Kharche	ICAR-CIRG, Makhdoom	2.68	April 2013	March 2017
			Dr. M. K. Singh	ICAR-NDRI, Karnal		April 2013	March 2017

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79	4003	Diversity and synthesis of immunoglobulins in the Indian major carps	Dr. Mrinal Samanta	ICAR-CIFA, Bhubaneshwar	1.96	April 2013	March 2017
			Dr. Surajit Das	NIT, Rourkela, Odisha		April 2013	March 2017
80	4004	Chemo-profiling of potential phyto-acaricides and their functional characterization for controlling resistant cattle ticks	Dr. Srikanta Ghosh	ICAR-IVRI, Izatnagar	2.26	April 2013	March 2016
			Dr. A.K.Rawat	NBRI, Lucknow		April 2013	March 2016
			Dr. Rajesh Kumar	ICAR-IARI, New Delhi		April 2013	March 2016
			Dr. Sanis Julliet	COVAS, Pookode, Kerala		April 2013	March 2016
81	4005	Enhancing development competence of oocytes for better in vitro fertilizing ability	Dr. T.K. Dutta	ICAR-NDRI, Karnal	1.89	April 2013	March 2016
			Dr. Arindam Dhali	ICAR-NIANP, Bengaluru		April 2013	March 2016
82	4006	Luteinizing hormone based sensors for estrus detection in buffaloes	Dr. Dheer Singh	ICAR-NDRI, Karnal	1.55	April 2013	March 2016
			Dr. Govindaraju Archunan	Bharathidasan University		April 2013	March 2016
83	4007	Imprinted polymers for sensing and removal of selected antibiotic and pesticide residues	Dr. Sunil Bhand	BITS, Pilani, Goa	1.55	April 2013	March 2015
			Dr. Y.S. Rajput	ICAR-NDRI, Karnal		April 2013	March 2015
			Prof. Sudhir Chandra	IIT, New Delhi		April 2013	March 2015
84	4008	Polymeric nano materials for packaging and efficient delivery of nutraceuticals	Dr. Najam Shakil	ICAR-IARI, New Delhi	2.43	April 2013	March 2016
85	4009	Modeling network of gene responses to abiotic stress in rice	Mr. Sanjeev Kumar	ICAR-IASRI, New Delhi	2.85	April 2013	March 2017
			Dr. Kishore Gaikwad	ICAR-NRCPB, New Delhi		April 2013	March 2017
			Dr. D. Subramanyam	ICAR-IIRR, Hyderabad		April 2013	March 2017
			Dr. Ramaeshware Singh	ICAR-DKMA, New Delhi		April 2013	March 2017
			Dr Rajendra Joshi	C-DAC, Pune		April 2013	March 2017
86	4010	The relationships of Phytoplasma with its host plants and insect vectors	Dr. Suman Lakhanpaul	DU, Delhi	2.26	April 2013	March 2016
			Dr. Naresh M. Meshram	ICAR-IARI, New Delhi		April 2013	March 2016

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87	4011	Relationship between *Sclerotium rolfsii*, Rhizoctonia solani, the soil and climatic variables in three major cropping system in the country and identification of markers for resistance to *Sclerotium rolfsii*.	Dr. A.L. RathnaKumar	ICAR-DGR, Junagarh	2.76	April 2013	March 2017
			Dr. Subrata Dutta	BCKV, Mohanpur		April 2013	March 2017
			Dr. Bishnu Maya	ICAR-IARI, New Delhi		April 2013	March 2017
88	4012	The role of bacterial endosymbionts in shaping the insect-virus relationship in *Bemisia tabaci*	Dr. Rajagopal Raman	DU, Delhi	1.53	April 2013	March 2016
			Dr. S. Subramanian	ICAR-IARI, New Delhi		April 2013	March 2016
89	4013	Common basis of defense induction in rice and mustard against sucking and gall insect pests	Dr. Padmakumari	ICAR-IIRR, Hyderabad	2.79	April 2013	March 2017
			Dr. Suresh Nair	ICGEB, New Delhi		April 2013	March 2017
			Dr. R. C. Bhattacharya	ICAR-NRCPB, New Delhi		April 2013	March 2017
			Dr. S. Subramanian	ICAR-IARI, New Delhi		April 2013	March 2017
90	4014	Understanding the adaptation mechanism of wild forage halophytes in the extreme saline-sodic Kachchh plains for enhancing feed resources	Dr. Devi Dayal	ICAR-CAZRI, RRS-Bhuj	2.45	April 2013	March 2016
			Dr. Ashwani Kumar	ICAR-CSSRI, Karnal		April 2013	March 2016
			Dr. J. P. Singh	ICAR-IGFRI, Jhansi		April 2013	March 2016
91	4015	Development of sucrose sensor for phenotyping of soil moisture-deficit stress tolerance in rice	Dr. Prakash C. Nautiyal	ICAR-IARI, New Delhi	2.20	April 2013	March 2016
			Dr. Aruanav Goswami	ISI, Kolkata		April 2013	March 2016
			Dr. S.K. Malik	ICAR-NBPGR, New Delhi		April 2013	March 2016
			Dr. Rajib Bandyopadhyay	Jadavpur University, Kolkata		April 2013	March 2016
92	4016	Understanding the mechanisms of Non Host Resistance (NHR) against rust and blast in rice and wheat	Dr. Aundy Kumar	ICAR-IARI, New Delhi	2.28	April 2013	March 2016
			Dr. Shree Prakash Pandey	Indian Institute of Science Education & Research (IISER), Kolkata		April 2013	March 2016
93	4017	Biodegradable electrospun fibre mat for use in packaging of fresh perishable agricultural material	Mr. G.T.V. Prabu	ICAR-CIRCOT, Mumbai	1.32	April 2013	Sep 2015

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94	4018	Production of phytochemicals from best chemotypes of some threatened medicinal plants through modified cultivation and in-vitro production technologies	Dr. Sharad Srivastava	NBRI, Lucknow	2.56	April 2013	March 2017
			Dr. Amita Bhattacharya	ICAR-IHBT, Palampur		April 2013	March 2017
			Dr. K. S. Negi	ICAR-NBPGR, Bhowali		April 2013	March 2017
95	4019	Molecular and genetic analyses of guggul for the identification of genes governing adventive embryony	Dr. S. R. Bhat	ICAR-NRCPB, New Delhi	2.73	April 2013	March 2017
			Dr. K.A. Geetha	ICAR-DMAPR, Anand		April 2013	March 2017
96	4020	Evaluation of the applicability of a dominant nuclear male sterility system in rice for hybrid seed production	Dr. O.N.Singh	ICAR-CRRI, Cuttack	4.31	April 2013	March 2017
			Dr. Sudip K.Ghosh	IIT, Kharagpur		April 2013	March 2017
97	4021	Enhancing phosphorus availability in alfisols: hydrogel based input delivery approach	Dr. Anupama Singh	ICAR-IARI, New Delhi	0.84	Oct 2013	Sep 2015
98	4022	Behavioral analysis of farmers decision making on agricultural innovations	Dr. M.J. Chandre Gowda	ZPD, Zone VIII Hebbal, Bengaluru	0.89	April 2014	March 2016
			Dr. S.S. Dolli	UAS, Dharwad		April 2014	March 2016
			Dr. M.V. Durga Prasad	IRMA, Gujarat		April 2014	March 2016
			Dr. D. Saravanan	SAMUHA, NGO, Karnataka		April 2014	March 2016
99	5001	Understanding the mechanisms of tolerance to low light intensity in rice	Dr. Prasanta Dash	ICAR-NRCPB, New Delhi	3.05	April 2016	March 2019
			Dr. Bhagawan Bharali	AAU, Jorhat		April 2016	March 2019
			Dr. Renu Pandey	ICAR-IARI, New Delhi		April 2016	March 2019
			Dr. M.J. Baig	ICAR-CRRI, Cuttack		April 2016	March 2019
100	5002	Understanding cellular and genetic mechanisms and identifying molecular markers for seed viability in soybean	Dr. Akshay Talukdar	ICAR-IARI, New Delhi	1.80	July 2015	June 2018
			Dr. Kishore Gaikwad	ICAR-NRCPB, New Delhi		July 2015	June 2018

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101	5003	Developing high oleic safflower genotypes through functional genomics	Dr. N.Y. Kadoo	NCL, Pune	1.89	July 2015	June 2018
			Dr. Vrijendra Singh	NARI, Phaltan		July 2015	June 2018
			Dr. Prakash Ghorpade	Bharati Vidyapeeth University (BVU), Pune		July 2015	June 2018
102	5004	Genetic transformation and development of elite transgenic maize (*Zea mays* L.) for biotic and abiotic stresses tolerance	Dr. Tanushree Kaul	ICGEB, New Delhi	3.93	July 2015	Dec 2018
			Dr. Krishan Kumar	ICAR-IIMR, New Delhi		July 2015	Dec 2018
			Dr. Rakesh Bhowmick	ICAR-VPKAS, Almora		July 2015	Dec 2018
103	5005	Lactation stress association with postpartum anestrus SNP array in buffaloes	Dr. Suneel Onteru	ICAR-NDRI, Karnal	2.70	July 2015	June 2018
			Dr. T.S.Keshava Prasad	IOB, Bangalore		July 2015	June 2018
			Dr. R.K. Sharma	ICAR-CIRB, Hisar		July 2015	June 2018
104	5006	Elucidating the mechanism of Pashmina fibre development: An OMICS approach	Dr. Nazir Ganai	SKUAST, Kashmir	3.11	July 2015	Dec 2018
			Dr. Jai Kaushik	ICAR-NDRI, Karnal		July 2015	Dec 2018
			Dr. A.R. Rao	ICAR-IASRI, New Delhi		July 2015	Dec 2018
105	5008	Leukemia Inhibitory Factor: Pluripotency in buffalo stem cells	Dr. Sudarshan Kumar	ICAR-NDRI, Karnal	1.60	July 2015	June 2018
106	5009	Molecular cross-talk between defense pathways in rice: Antagonism to synergism	Dr. J.S.Bentur	Agri Biotech Foundation, Hyderabad	1.61	July 2015	June 2018
			Dr. Hitendra Kumar Patel	CCMB, Hyderabad		July 2015	June 2018
			Dr. M. Srinivas Prasad	ICAR-IIRR, Hyderabad		July 2015	June 2018
107	5010	Low ovule-to seed ration in range grasses: genetical and physio-chemical basis	Dr. C. K. Gupta	ICAR-IGFRI, Jhansi	1.40	July 2015	June 2018
108	5011	CctA and hyaluronidase gene mutants of *Clostridium chauvoei*: Construction and evaluation of vaccine potential	Dr. K.N. Viswas	ICAR-IVRI, Izatnagar	1.49	July 2015	Dec 2018

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109	5012	Delineating beta casein variants in indian cows and potential health implication of A1 A2 milk	Dr. Monika Sodhi	ICAR-NBAGR, Karnal	3.44	July 2015	Dec 2018
			Dr. A.K. Mohanty	ICAR-NDRI, Karnal		July 2015	Dec 2018
			Dr. Rajat Sandhir	Punjab University, Chandigarh		July 2015	Dec 2018
110	5013	Eliciting soil microbiome responses of rice for enhanced water and nutrient use efficiency under anticipated climate changes	Dr. A. K. Nayak	ICAR-NRRI, Cuttack	2.24	July 2015	June 2018
			Dr. S. Karthikeyan	TNAU, Coimbatore		July 2015	June 2018
			Dr. P. Raha	BHU, Varanasi		July 2015	June 2018
111	5014	Simulating the effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system	Dr. Narendra Lenka	ICAR-IISS, Bhopal	2.63	July 2015	June 2019
			Dr. Punit Chandra	ICAR-CIAE, Bhopal		July 2015	June 2019
			Dr. K. K. Singh	IMD, Delhi		July 2015	June 2019
112	5016	Investigation of effect of structure of jute products on its sound insulation property	Dr. Gautam Bose	ICAR-NIRJAFT, Kolkata	2.30	July 2015	June 2018
			Ms. Mallika Datta	GCETT, Serampore, W.B		July 2015	June 2018
			Dr. Sampad Mukherjee	IIEST, Shibpur W.B		July 2015	June 2018
113	5017	Expression of resistance to diapausing and non-diapausing spotted stem borer, chilo partellus in sorghum and maize: Implications for crop improvement and IPM	Dr. Jaba Jagdish	ICRISAT, Hyderabad	1.18	May 2016	April 2019
			Dr. M. K. Dhillon	ICAR-IARI, New Delhi		May 2016	April 2019
			Dr. G. Shyam Prasad	ICAR-IIMR, Hyderabad		May 2016	April 2019
114	5018	Identification and molecular tagging of gene (s) controlling resistance to chilli leaf curl virus infection in chilli (*Capsicum annuum* L.)	Dr. Arpita Srivastava	ICAR-IARI, New Delhi	2.06	Oct 2016	Sep 2019
			Dr. P. K. Jain	ICAR-NRCPB, New Delhi		Oct 2016	Sep 2019
			Dr. Salesh Jindal	PAU, Ludhiana		Oct 2016	Sep 2019
			Dr. C. Venkata Ramana	Dr. YSR HU, AP		Oct 2016	Sep 2019
115	5019	Biofortification of wheat and maize with zinc and iron using endophytic microorganisms	Dr. Ajit Verma	Amity University, Noida	1.54	March 2017	Feb 2020
			Dr. Hillol Chakdar	ICAR-NBAIM, Mau Nath Bhanjan		March 2017	Feb 2020

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116	5020	Nano-based detection of organophosphate pesticides using metal-organic framework conjugates	Dr. Lalit M Bharadwaj	Amity University, Noida	2.20	Jan 2017	Nov 2020
			Dr. Irani Mukherjee	ICAR-IARI, New Delhi		Jan 2017	Nov 2020
			Prof. Sunil Bhand	BITS, Pilani, Goa		Jan 2017	Nov 2020
117	6001	Information dissemination system(s) for empowering farming community of Uttarakhand	Dr. Shivendra Kumar Kashyap	GBPUA&T, Pantnagar	1.05	Oct 2016	Sep 2019
			Dr. Kushagra Joshi	ICAR-VPKAS, Almora		Oct 2016	Sep 2019
118	6002	Convergence and network analysis of extension organizations for enhancing their effectiveness in pluralistic extension regime	Dr. R. N. Padaria	ICAR-IARI, New Delhi	1.49	Oct 2016	Sep 2019
			Dr. R.P.Singh Ratan	BAU, Ranchi		Oct 2016	Sep 2019
			Dr. Prasant Pandey	ICAR-IGKV, Raipur		Oct 2016	Sep 2019
			Dr. Pankaj Kumar Sinha	ICAR RC for NEH Region, Umiam		Oct 2016	Sep 2019
119	6003	Addressing farmers' suicide issue through capacity building of farming families	Dr Sarabjeet Singh	PAU, Ludhiana	1.38	Oct 2016	Sep 2019
			Dr V Sudha Rani	PJTSAU, Hyderabad		Oct 2016	Sep 2019
			Dr. D.N.Gokhale	VNMKV, Parbhani		Oct 2016	Sep 2019
			Dr Harprit Kaur	PUP, Patiala		Oct 2016	Sep 2019
120	6004	Developing agribusiness models linking farmers groups and farmer produce organizations to markets through value chain management	Dr. S. D. Sivakumar	TNAU, ADAC & RI, Tiruchirapali	1.65	Oct 2016	Sep 2019
			Dr. K. Mahendran	TNAU, Coimbatore		Oct 2016	Sep 2019
			Dr. T.N Balamohan	TNAU, Madurai		Oct 2016	Sep 2019
121	6005	Phenomics of moisture deficit stress tolerance and nitrogen use efficiency in rice and wheat – Phase II	Dr. Viswanathan Chinnusamy	ICAR-IARI, New Delhi	9.84	Jan 2017	Nov 2020
			Dr. Anil Rai	ICAR-IASRI, New Delhi		Jan 2017	Nov 2020
			Dr. Brejesh Lall	IIT, New Delhi		Jan 2017	Nov 2020
			Dr. Padmini Swain	ICAR-NRRI, Cuttack		Jan 2017	Nov 2020

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122	6006	Epigenetic regulation of host-pathogen genetics in leaf rust resistance of wheat	Prof. P. K. Gupta	CCSU, Meerut	3.33	Jan 2017	Dec 2020
			Dr. Neelu Jain	ICAR-IARI, New Delhi		Jan 2017	Dec 2020
			Dr. Pramod Prasad	ICAR-IIWBR, Regional Station, Shimla		Jan 2017	Dec 2020
123	6007	Characterization, mapping and transcriptome analysis of seed protein, -carotene and mineral contents in chickpea (*Cicer arietinum* L.)	Dr. Venkatraman Hegde	ICAR-IARI, New Delhi	2.57	Jan 2017	Sep 2020
			Dr. P. K. Jain	ICAR-NIPB, New Delhi		Jan 2017	Sep 2020
			Dr Satvir Kaur Grewal	PAU, Ludhiana		Jan 2017	Sep 2020
			Mr Biswajit Mondal	ICAR-IIPR, Kanpur		Jan 2017	Sep 2020
124	6008	Population diversity of banana streak viruses (BSV) and understanding the mechanisms of resistance to BSV in diploid seedy banana of North East India	Dr. Susheel Kumar Sharma	ICAR RC for NEH Region, Manipur Centre, Imphal	2.48	Jan 2017	June 2021
			Dr. Virendra Kumar Baranwal	ICAR-IARI, New Delhi		Jan 2017	June 2021
			Dr. Thangjam Robert Singh	Mizoram University, Aizawl		Jan 2017	Dec 2019
125	6009	Chemotyping and molecular profiling of bioactive metabolites in *Hemidesmus indicus* and *Costus speciosus*, adapted to different phytogeographical zones and identification of candidate genes related to metabolic pathways	Dr. Sharad Srivastava	NBRI, Lucknow	2.76	Jan 2017	Dec 2020
			Dr. Narendra A. Gajbhiye	ICAR-DMAPR, Anand		Jan 2017	Dec 2020
			Dr. Krishna madhav Rai	ICAR-NBPGR RS, Bhawali, Nanital		Jan 2017	Dec 2020
			Dr. V. Sunderashan	CIMAP-RC, Bangalore		Jan 2017	Dec 2020
126	6010	Molecular mapping and identification of candidate genes for anthracnose fruit rot disease resistance in chilli	Dr. K. Madhavi Reddy	ICAR-IIHR, Bengaluru	1.11	Jan 2017	Dec 2019
			Dr. Ponnam Naresh	ICAR-IIHR, CHES, Bhubaneswar		Jan 2017	Dec 2019
127	6011	Transgenic overexpression of phosphite dehydrogenase: A comprehensive strategy to enhance phosphorus use efficiency with integrated weed and disease management for sustainable agriculture	Dr. M. K. Reddy	ICGEB, New Delhi	2.87	Jan 2017	March 2020
			Dr. Aundy Kumar	ICAR-IARI, New Delhi		Jan 2017	March 2020
			Dr. M. Srinivas Prasad	ICAR-IIRR, Hyderabad		Jan 2017	March 2020

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
128	6012	Creating a fully characterized genetic resource pipeline for mustard improvement programme in India	Prof. S. S. Banga	PAU, Ludhiana	2.64	Jan 2017	Dec 2019
			Dr. D. K. Yadava	ICAR-IARI, New Delhi		Jan 2017	Dec 2019
			Dr. Kunwar Harendra Singh	ICAR-DRMR, Bharatpur		Jan 2017	Dec 2019
			Dr. Ram Bhajan	GBPUA&T, Pantnagar		Jan 2017	Dec 2019
			Dr. A. R. Rao	ICAR-IASRI, New Delhi		Jan 2017	Dec 2019
129	6013	Synthetic endometrium: A novel model to study early embryonic development and uterine health in ruminants	Dr. Sanjay Kumar Singh	ICAR-IVRI, Izatnagar	2.79	Jan 2017	Dec 2019
			Dr. Rubina Kumari Baithalu	ICAR-NDRI, Karnal		Jan 2017	Dec 2019
			Dr. Dharmendra Kumar	ICAR-CIRB, Hisar		Jan 2017	Dec 2019
130	6014	Detection of peptide biomarkers and development of synthetic anti-microbial peptide hydrogels for bovine mastitis	Dr. Sameer Shrivastava	ICAR-IVRI, Izatnagar	3.35	Jan 2017	June 2020
			Prof. K. Chandrashekara	UAS, Bengaluru		Jan 2017	Dec 2019
			Dr. K. Santhosh Kumar	Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram, Kerala		Jan 2017	Dec 2019
131	6015	Chemical, structural and functional characterization of identified anti-tick lead phytochemicals and optimization of delivery matrix for effective application of natural formulation for the control of acaricide resistant ticks	Dr. Srikanta Ghosh	ICAR-IVRI, Izatnagar	3.88	Jan 2017	Dec 2020
			Dr. Sharad Srivastava	NBRI, Lucknow		Jan 2017	Dec 2019
			Dr. Rajesh Kumar	ICAR-IARI, New Delhi		Jan 2017	Dec 2020
			Dr. Sanis Juliet	COVAS, Pookode, Kerala		Jan 2017	Dec 2019
			Dr. Satyanshu Kumar	ICAR-DMAPR, Anand		Jan 2017	Dec 2020
132	6016	Study the effect of mesenchymal stem cell transplantation on ovarian function and fecundity in goats	Dr. S. D. Kharche	ICAR-CIRG, Makhdoom	2.10	Jan 2017	Dec 2019
			Dr. Monika Sachdev	CDRI, Lucknow		Jan 2017	Dec 2019
133	6017	Lactic acid bacteria based biorefineries for converting agro and food based biomass into PLA and high value-added products	Dr. S.K. Khare	IIT, New Delhi	2.53	Feb 2017	Jan 2020
			Dr. H. N. Mishra	IIT, Kharagpur		Feb 2017	Jan 2020
			Dr. Lata	ICAR-IARI, New Delhi		Feb 2017	Jan 2020

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134	6018	Elucidating the mechanism and assessing amelioration potential of *Ocimum* and *Lucas* in stress-induced impaired homeostasis on growth and reproduction in Zebrafish	Dr. Sudipta Maitra	Vishwa Bharti University, West Bengal	1.85	March 2017	Feb 2020
			Dr. Satya Bhattacharya	Tezpur University, Sonitpur		March 2017	Feb 2020
135	6019	Energy efficient polyhouse and aeroponic system for mini tuber production of tissue cultured potato	Dr. Jaywant Arakeri	IISc, Bengaluru	4.24	March 2017	Feb 2020
			Dr. M.Udayakumar	UAS, Bengaluru		March 2017	Feb 2020
			Dr.K.R.Sreenivas	JNCASR, Bangalore		March 2017	Feb 2020
			Dr.Murtaza Hasan	ICAR-IARI, New Delhi		March 2017	Feb 2020
			Er.Sukhwinder Singh	ICAR-CPRI, Jalandhar		March 2017	Feb 2020
136	6020	Identification of biomarkers for early diagnosis of *Mycobacterium avium* subspecies paratuberculosis (MAP) infection and development of a test to differentiate between Johne's disease infected and vaccinated animals (DIVA)	Dr. K. Gururaj	ICAR-CIRG, Makhdoom	1.09	April 2017	March 2020
			Dr. Shalini Sharma	LUVAS, Hisar		April 2017	March 2020
			Dr. Sangram Biswal	OUAT, Bhubaneshwar		April 2017	March 2020
137	6021	Understanding the molecular basis of peste-des-petits ruminants virus (PPRV) mediated host immune modulation for the development of next generation vaccine	Dr. Rajeev Kaul	DU, South Campus, Delhi	2.28	April 2017	March 2020
			Dr. S. Chandra Sekar	ICAR-IVRI, Mukteswar		April 2017	March 2020
			Dr.Sharvan Sehrawat	Indian Institute of Science Education & Research (IISER), Mohali		April 2017	March 2020
			Dr. Prabhakar Temburne	Nagpur Veterinary College (NVC), MAFSU, Nagpur		April 2017	March 2020

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138	6022	Aflatoxin-tolerant duck production through genetic and epigenetic approaches	Dr. S. K. Mishra	ICAR-CARI, Bhubaneswar	2.93	April 2017	March 2020
			Dr. S. K. Panda	OUAT, Bhubaneshwar		April 2017	March 2020
			Dr. Nikhil C. Nath	AAU, Jorhat		April 2017	March 2020
			Dr. Prasant K. Subudhi	CAU, Aizawl		April 2017	March 2020
139	6023	Development of an electronic nose for the optimum harvesting time and fruit quality in apple and papaya	Dr. Debabrata Sircar	IIT, Roorkee	1.58	June 2017	Feb 2021
			Dr. Javid Iqbal Mir	ICAR-CITH, Srinagar		June 2017	Feb 2021
140	6024	Detection and control of bacterial pathogens in poultry by developing chemical genomic strategies to combat multiple antibiotic resistance	Dr. Naveen K. Navani	IIT, Roorkee	1.09	June 2017	May 2020
			Dr. Ajit Singh Yadav	ICAR-CARI, Izatnagar		June 2017	May 2020
141	6025	Synthesis, characterization and effect of graded levels of nano selenium supplementation on the performance of broiler chicken	Dr. Niranjan Panda	OUAT, Bhubaneshwar	1.13	June 2017	May 2020
			Dr. Ashok Kumar Mohanty	ICAR-NDRI, Karnal		June 2017	May 2020
142	6026	Genetic variability of milk protein and its characterization by proteomic approach in Indian goats	Dr. Pramod Kumar Rout	ICAR-CIRG, Makhdoom	0.88	June 2017	Nov 2020
			Dr. S. N. De	ICAR-NDRI, Karnal		June 2017	Nov 2020
143	6027	Potential gene mining from salt tolerant grasses for improvement of salt tolerance in crops	Dr. Anita Mann	ICAR-CSSRI, Karnal	1.50	June 2017	Nov 2020
			Dr Monendra Grover	ICAR-IASRI, New Delhi		June 2017	Nov 2020
			Dr Parameswaran, C	ICAR-NRRI, Cuttack		June 2017	Nov 2020
144	6028	Resveratrol and catechins-loaded niosomes and nanoparticles as delivery vehicles for fortification of milk and milk products	Dr. P. Heartwin Amaldas	ICAR-NDRI (SRS), Bengaluru	1.56	June 2017	Sep 2020
			Dr. N. Subramanian	Anna University, Tiruchirappalli		June 2017	Sep 2020
145	6029	Development of an automated soil nutrient sensing system	Dr. P. S. Tiwari	ICAR-CIAE, Bhopal	2.37	June 2017	Dec 2020
			Dr. Sanjay Srivastava	ICAR-IISS, Bhopal		June 2017	Dec 2020
			Dr. Babankumar Bansod	CSIO, Chandigarh		June 2017	Dec 2020

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146	6030	Bioremediation of chemical contaminants and their complexes present in drainage wastewater with high dynamic flux used for irrigation in urban and periurban agriculture.	Dr. Dileep Kumar Singh	DU, Delhi	1.79	Feb 2018	April 2021
			Dr. Rosin K.G.	ICAR-IARI, New Delhi		Feb 2018	April 2021
			Dr. Jaya N. Surya	ICAR-NBSS&LUP, RC, New Delhi		Feb 2018	April 2021
147	6031	Development of biological filter for safe wastewater irrigation exploiting microbial bioremediation trait	Dr. Sachidulal Raychaudhuri	ICAR-IIWM, Bhubaneswar	2.51	Feb 2018	Nov 2021
			Dr. Asheesh Kumar Yadav	ICAR-IMMT, Bhubaneswar		Feb 2018	Nov 2021
148	6032	Enhancing decomposition rate and quality of bio-waste through microbial consortia for improving soil health	Dr. A.B. Singh	ICAR-IISS, Bhopal	1.49	Feb 2018	March 2021
			Dr. Dipak Ranjan Biswas	ICAR-IARI, New Delhi		Feb 2018	March 2021
			Dr G. Selvakumar	ICAR-IIHR, Bengaluru		Feb 2018	March 2021
149	6033	Development of electronic sensing system for safe management of potato, onion, and tomato in storage	Dr. Debabandya Mohapatra	ICAR-CIAE, Bhopal	2.38	Aug 2018	Jan 2022
			Dr. Alokesh Ghosh	C-DAC, Kolkata		Aug 2018	Jan 2022
			Dr Bharat Modhera	MANIT, Bhopal		Aug 2018	Jan 2022
150	6034	ICT based extension strategies for nutrition sensitive agriculture in the states of UP and Odisha	Dr. Satyapriya	ICAR-IARI, New Delhi	1.70	Nov 2018	Oct 2021
			Dr. K.N. Singh	ICAR-IASRI, New Delhi		Nov 2018	Oct 2021
			Dr. Shantanu Dubey	ICAR-ATARI, Kanpur		Nov 2018	Oct 2021
			Dr. P. J. Mishra	OUAT, Bhubaneshwar		Nov 2018	Oct 2021
151	6035	Genomics strategies for improvement of yield and seed composition traits under drought stress conditions in soybean	Dr. Milind B. Ratnaparkhe	ICAR-IISR, Indore	2.38	Dec 2018	Nov 2022
			Dr. Ajay Kumar Singh	ICAR-NIASM, Malegaon, Baramati		Dec 2018	Nov 2022
			Ms. Annapurna Chitikineni	ICRISAT, Hyderabad		Dec 2018	Nov 2022
152	6036	Studies on thermal degradation of crop residues for kinetics, bio-polymeric transitions and value added products	Dr. Sandip Gangil	ICAR-CIAE, Bhopal	1.53	April 2019	March 2022
			Dr. Dinesh C. Pant	TERI, New Delhi		April 2019	March 2022
			Dr. P. Subramanian	TNAU, Coimbatore		April 2019	March 2022

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153	7001	Identification and characterization of gram pod borer resistant transgenic chickpea and pigeonpea for conducting confined field trials	Dr. Alok Das	ICAR-IIPR, Kanpur	0.51	Feb 2018	Jan 2019
154	7002	Utilization and refinement of haploid/doubled haploid induction systems in rice, wheat and maize involving molecular and in-vitro strategies	Dr. Sanghamitra Samantaray	ICAR-NRRI, Cuttack	3.86	Feb 2018	Jan 2022
			Dr. Puja Srivastava	PAU, Ludhiana		Feb 2018	Jan 2022
			Dr. Rajesh Kumar Khulbe	ICAR-VPKAS, Almora		Feb 2018	Jan 2022
155	7003	Genetic improvement of rice for yield, NUE, WUE, abiotic and biotic stress tolerance through RNA guided genome editing (CRISPR-Cas9/Cpf1)	Dr. Viswanathan Chinnusamy	ICAR-IARI, New Delhi	6.92	Feb 2018	Dec 2021
			Dr. M. K. Reddy	ICGEB, New Delhi		Feb 2018	Dec 2021
			Dr. Prasanta K. Dash	ICAR-NIPB, New Delhi		Feb 2018	Dec 2021
			Dr. Parameswaram	ICAR-NRRI, Cuttack		Feb 2018	Dec 2021
			Dr. Satendra Kumar Mangrauthia	ICAR-IIRR, Hyderabad		Feb 2018	Dec 2021
			Dr. D. Sudhakar	TNAU, Coimbatore		Feb 2018	Dec 2021
156	7004	Production of multiple copies of elite buffalo bulls using animal cloning technology	Dr. Prem Singh Yadav	ICAR-CIRB, Hisar	7.50	April 2018	March 2022
			Dr. Manoj Kumar Singh	ICAR-NDRI, Karnal		April 2018	March 2022
157	7005	Improving the usability of buffalo spermatozoa by sperm surface remodelling and immune acceptance in female reproductive tract.	Dr. Rakesh Kumar	ICAR-NDRI, Karnal	1.87	July 2018	June 2021
			Dr. Sarika Jaiswal	ICAR-IASRI, New Delhi		July 2018	June 2021
158	7006	Development of a rapid and robust high throughput reporter cell based bioassay for detection of xenobiotics in milk	Prof. Surya Pratap Singh	BHU, Varanasi	2.77	Aug 2018	Jan 2022
			Dr. Dheer Singh	ICAR-NDRI, Karnal		Aug 2018	Jan 2022
			Prof. Rakesh K Tyagi	JNU, New Delhi		Aug 2018	Jan 2022
			Prof. Partha Roy	IIT, Roorkee		Aug 2018	Jan 2022

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159	7007	Production and processing of microalgal biomass for biodiesel and other industrially important co-products: an algal refinery approach	Dr. Nirupama Mallick	IIT, Kharagpur	2.61	July 2018	June 2022
			Dr. O.N. Tiwari	ICAR-IARI, New Delhi		July 2018	June 2022
160	7008	Valorization of industrially produced soybean and groundnut de-oiled meals/ cakes by extraction, purification and production of protein isolates	Dr. Deep Narayan Yadav	ICAR-CIPHET, Ludhiana	1.80	Aug 2018	Dec 2021
			Dr. Suman Kapila	ICAR-NDRI, Karnal		Aug 2018	Dec 2021
161	7009	CRISPR/CAS9 guided functional analysis of genes regulating early embryonic survival in buffalo	Dr. Sukanta Mondal	ICAR-NIANP, Bengaluru	1.96	Aug 2018	July 2022
			Dr. D.N. Das	ICAR-NDRI (SRS), Bengaluru		Aug 2018	July 2022
			Dr. D. Malakar	ICAR-NDRI, Karnal		Aug 2018	July 2022
162	7010	Electric field based novel technologies for pilot scale processing of juice and pulp from potential fruits of NE region	Dr. Brijesh Srivastava	Tezpur University, Sonitpur	2.91	Aug 2018	Jan 2022
			Dr. Prem Prakash Srivastav	IIT, Kharagpur		Aug 2018	Jan 2022
			Dr. S. Ruth Assumi	ICAR RC for NEH Region, Umiam		Aug 2018	Jan 2022
163	7011	To elucidate the unique biochemical adaptational strategies that allow two air-breathing catfishes (*Clarias batrachus* and *Heteropneustes fossilis*) to survive in ammonia enriched toxic waste	Prof. Nirmalendu Saha	NEH University, Shilong	2.62	Aug 2018	Jan 2022
			Dr. Surjya Kumar Saikia	Vishwa Bharti University West Bengal		Aug 2018	Jan 2022
			Dr. Hirak Kumar Barman	ICAR-CIFA, Bhubaneshwar		Aug 2018	Jan 2022
			Dr. Vindhya Mohindra	ICAR-NBFGR, Lucknow		Aug 2018	Jan 2022
164	7012	Role of dietary trace minerals in animals under biotic and abiotic stress conditions	Dr. Sunil Ekanath Jadhav	ICAR-IVRI, Izatnagar	2.94	Aug 2018	Jan 2022
165	7013	Effective delivery of nutrients, insecticides and fungicides through nanoparticulates and its effect on uptake and yield in groundnut and chilli	Dr. T.N.V.K.V. Prasad	ANGRAU, Tirupati	1.31	Aug 2018	Nov 2021
			Dr.G.C. Satisha	ICAR-IIHR, Bengaluru		Aug 2018	Nov 2021

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166	7014	Identification of super donors and alleles for spikelet fertility and low chalkiness under thermal stress in rice	Dr. Anil Grover	DU, South Campus, Delhi	3.95	Aug 2018	Jan 2022
			Dr. Madan Pal Singh	ICAR--IARI, New Delhi		Aug 2018	Jan 2022
			Dr. Girish Chandel	ICAR-IGKV, Raipur		Aug 2018	Jan 2022
			Dr. Manu Agarwal	DU, North Campus, Delhi		Aug 2018	Jan 2022
			Dr. S.Vanisri	PJTSAU, Hyderabad		Aug 2018	Jan 2022
167	7015	Process development for production of Dipeptidyl Peptidase-IV (DPP-IV) inhibitory peptides from milk of gir cows and their encapsulation through double emulsification technique	Dr. Satish Kumar	ICAR-NDRI (SRS), Bengaluru	1.16	Aug 2018	Jan 2022
			Dr. Lata Sabikhi	ICAR-NDRI, Karnal		Aug 2018	Jan 2022
168	7016	Epigenomics of drought acclimatization and stress memory in rice	Dr. Suresh Kumar	ICAR-IARI, New Delhi	2.90	Aug 2018	July 2021
169	7017	Targeted immobilization of Y-bearing spermatozoa and modulation of oviduct milieu for skewing sex ratio towards female offspring in dairy cattle	Dr. A.Kumaresan	ICAR-NDRI (SRS), Bengaluru	2.72	Aug 2018	Jan 2022
			Dr. Ravi Sundaresan	IISc, Bengaluru		Aug 2018	Jan 2022
			Dr. D. Rajendran	ICAR-NIANP, Bengaluru		Aug 2018	Jan 2022
			Dr. Rakesh Kumar	ICAR-NDRI, Karnal		Aug 2018	Jan 2022
170	7018	Exploiting alien genetic resources for developing climate resilient wheat and understanding mechanism of heat tolerance	Dr. Sindhu Sareen	ICAR-IIWBR, Karnal	1.58	Aug 2018	Jan 2022
			Dr. Satindar Kaur	PAU, Ludhiana		Aug 2018	Jan 2022
			Dr. Jasdeep Chatrath Padaria	ICAR-NIPB, New Delhi		Aug 2018	Jan 2022
171	7019	Assessing the potential impact of climate change and management on soil carbon and nitrogen storage in selected ecosystems of India	Dr. Sangeeta Lenka	ICAR-IISS, Bhopal	2.05	Aug 2018	July 2022
			Dr. Kaushik Batabyal	BCKV, Mohanpur		Aug 2018	July 2022

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172	7020	Identifying the genomic regions and genes for drought and heat tolerance in groundnut	Dr. Ramesh Bhat	UAS, Dharwad	2.22	Aug 2018	Jan 2022
			Dr. Manish K. Pandey	ICRISAT, Hyderabad		Aug 2018	Jan 2022
			Dr. P. Latha	ANGRAU-IFT, RARS, Tirupati		Aug 2018	Jan 2022
173	7021	Identification of host factors responsible for infection and development of nano-particle based dsRNA delivery system for imparting resistance to begomoviruses	Dr. P.N. Sivalingam	ICAR-NIBSM, Raipur	3.18	Aug 2018	Dec 2021
			Dr. Senthil Kumar	ICAR-NIPGR, New Delhi		Aug 2018	Dec 2021
			Dr. Bikash Mandal	ICAR-IARI, New Delhi		Aug 2018	Dec 2021
			Dr. Neetu Singh	IIT, New Delhi		Aug 2018	Dec 2021
174	7022	Long-term conservation agriculture impact on microbiome and soil health indicators for resource efficiency and resilience in maize systems	Dr Shankar Lal Jat	ICAR-IIMR, New Delhi Unit	1.82	Nov 2018	Oct 2021
			Dr. Aundy Kumar	ICAR-IARI, New Delhi		Nov 2018	Oct 2021
			Dr. Rakesh Kumar	RCER, Patna		Nov 2018	Oct 2021
175	7023	An inclusive agri-business model for sustainable cotton marketing in the state of Maharashtra	Dr. Sundaramoorthy C.	ICAR-CIRCOT, Mumbai	0.75	Nov 2018	Oct 2021
			Dr. A.R. Reddy	ICAR-CICR, Nagpur		Nov 2018	Oct 2021
176	7024	Targeted editing of potato genome to develop variety specific true potato seed (TPS)	Dr. Vinay Bhardwaj	ICAR-CPRI, Shimla	2.34	Nov 2018	Oct 2022
			Dr. Kashmir Singh	Punjab University, Chandigarh		Nov 2018	Oct 2022
			Dr. Ravi Maruthachalam	Indian Institute of Science Education & Research (IISER), Thiruvananthapuram		Nov 2018	Oct 2022
177	7025	Re-designing rice crop for improvised grain micronutrient quality using CRISPR-Cas9/Cpf1 genome editing	Dr. Tanushri Kaul	ICGEB, New Delhi	1.47	Jan 2019	Dec 2022
178	7026	Artificial intelligence based mobile app for identification and advisory of maize diseases and insect pests	Dr. Sudeep Marwaha	ICAR-IASRI, New Delhi	1.87	Jan 2019	Sep 2022
			Dr. Brejesh Lall	IIT, New Delhi		Jan 2019	Sep 2022
			Dr. P. Lakshmi Soujanya	ICAR-IIMR, Ludhiana		Jan 2019	Sep 2022

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179	7027	Development and validation of smart aquaculture model (SAM): Application of ICT and data analytics for sustainable shrimp aquaculture	Dr. M. Kumaran	ICAR-CIBA, Chennai	0.68	Jan 2019	June 2022
180	7028	Entrepreneurship development through farmer led innovations – a case study in plantation sector	Dr. S. Senthil Vinayagam	ICAR-NAARM, Hyderabad	0.85	April 2019	March 2022
			Dr. T.S. Manojkumar	ICAR-CPCRI, Kasaragod		April 2019	March 2022
			Dr. K. Venkateswaran	IIPM, Jnana Bharathi Campus		April 2019	March 2022
181	7029	Developing climate resilient adaptive strategies for empowerment of farmers	Dr. Bheemappa Anjinappa	UAS, Dharwad	1.04	April 2019	March 2022
			Dr. Nagaratna Biradar	ICAR-IGFRI, Dharwad		April 2019	March 2022
			Dr. Bathula Vijayabhinandana	ANGRAU, Guntur		April 2019	March 2022
182	7030	Development of sensors for blast and blight diseases and stomatal activity measurement in rice (*O. sativa* L.)	Dr. Samarendra Pratap Singh	Shiv Nadar University, Gautam Buddha Nagar	3.17	June 2019	May 2023
			Dr. B. K. Sarma	BHU, Varanasi		June 2019	May 2023
			Dr. P.N. Jha	BITS Pilani, Rajasthan		June 2019	May 2023
			Dr. Debabrata Sircar	IIT, Roorkee		June 2019	May 2023
			Dr. Kavitha Sankaranarayanan	Anna University, Chromepet, Chennai		June 2019	May 2023
183	7031	Causes and consequences of e-national agriculture market (e-NAM) on the economic development of Indian agriculture – a case study	Dr. K.M. Shivakumar	TNAU, Coimbatore	1.43	June 2019	May 2022
			Dr. I. Bhavani Devi	ANGRAU, Tirupati		June 2019	May 2022
			Dr. T. Lavanya	PJTSAU, Hyderabad		June 2019	May 2022
			Dr Jitender Kumar Bhatia	CCSHAU, Hisar		June 2019	May 2022
184	8001	Development of sustainable management tools for the invasive pest, Fall Armyworm *Spodoptera frugiperda* (J.E.Smith) in maize	Dr. J. C. Sekhar	ICAR-IIMR, WNC, Hyderabad	3.76	Nov 2019	Oct 2023
			Dr. Kesavan Subaharan	ICAR-NBAIR, Bengaluru		Nov 2019	Oct 2023
			Dr. Vinay Kumari Kalia	ICAR-IARI, New Delhi		Nov 2019	Oct 2023
			Dr. Jyothilakshmi Vadassery	NIPGR, New Delhi		Nov 2019	Oct 2023

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185	8002	Genome editing for imparting PRSV resistance	Dr. Anirban Roy	ICAR-IARI, New Delhi	1.46	Nov 2019	Oct 2022
			Dr. M. Krishna Reddy	ICAR-IIHR, Bengaluru		Nov 2019	Oct 2022
186	8003	Women empowerment and gender sensitization – developing a model for bridging gender gap	Dr. Kiran Singh	CCSHAU, Hisar	1.33	Nov 2019	Jan 2023
			Dr. Lipi Das	ICAR-CIWA, Bhubaneswar		Nov 2019	Jan 2023
187	8004	Generation of BMPR-1B gene edited goats using CRISPR/Cas technology to explore the functional role of BMPR-1B gene on goat reproduction	Dr. Vikash Chandra	ICAR-IVRI, Izatnagar	3.81	Nov 2019	Oct 2022
			Dr. Partho Roy	IIT, Roorkee		Nov 2019	Oct 2022
188	8005	Development of electrochemical Sensor tools for soil health analysis	Dr. J. Mathiyarasu	CERI, Tamil Nadu	0.68	Nov 2019	Oct 2022
			Dr. P. Kannan	TNAU, Coimbatore		Nov 2019	Oct 2022
189	8006	Understanding molecular basis of host-pathogen-environment interaction of Tilapia Lake virus disease	Dr. P.K. Pradhan	ICAR-NBFGR, Lucknow	2.12	Nov 2019	Oct 2023
			Dr. K.V. Rajendran	ICAR-CIFE, Mumbai		Nov 2019	Oct 2023
190	8007	Exploiting encapsulated nanoparticle conjugated phytochemicals to combat antimicrobial resistance in poultry	Dr. Deepak B. Rawool	ICAR-NRC on Meat, Hyderabad	1.71	Nov 2019	March 2023
			Dr. Nitin Vasantrao Kurkure	Nagpur Veterinary College (NVC), MAFSU, Nagpur		Nov 2019	March 2023
			Dr. Jess Vergis	CVAC, KVASU, Kerala		Nov 2019	March 2023
191	8008	Delineating the effector biology of phytoplasma affecting selected crop taxa in India with special emphasis on sesame (*Sesamum indicum*L.)	Dr. Suman Lakhanpaul	DU, Delhi	1.65	Nov 2019	April 2023
			Dr. V. Dinesh Kumar	ICAR-IIOR, Hyderabad		Nov 2019	April 2023
192	8009	Pork Marketing Chains in North East India for Sustainable Livelihood of Tribal Women (Assam, Meghalaya and Nagaland)	Dr. Mahua Bhattachary	Amity University, Noida	1.21	Dec 2019	Nov 2022
			Dr. Kadirvel Govidaswamy	ICAR RC for NEH Region, Meghalaya		Dec 2019	Nov 2022
			Dr. Mahak Singh	ICAR RC for NEH Region, Nagaland Centre		Dec 2019	Nov 2022
			Dr. Misha Madhavan M.	ICAR-NRCP, Rani, Guwahati		Dec 2019	Nov 2022

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193	8010	Identification of QTLs for subcomponent traits of WUE through strategic utilization of whole genome sequences and accurate phenotyping in rice	Dr. M.S. Sheshshayee	UAS, Bengaluru	1.87	Dec 2019	Nov 2022
			Dr. M. Raveendran	TNAU, Coimbatore		Dec 2019	Nov 2022
			Dr. Prasanta Dash	ICAR-NIPB, New Delhi		Dec 2019	Nov 2022
194	8011	Improving rural livelihood security of tribal and resource constrained farmers of North Bihar through low cost technology of animal husbandry and allied sector	Dr. Pankaj Kumar	BASU, Patna	1.27	Dec 2019	Feb 2023
			Dr. Sanjeev Kumar	ICAR-CARI, Izatnagar		Dec 2019	Feb 2023
195	8012	Farmer-led extension strategy for enhancing farmers' income through millets-based farming system in hilly and tribal areas	Dr. Rajendra R. Chapke	ICAR-IIMR, Hyderabad	1.17	Dec 2019	Nov 2022
			Dr. E. D. Oliver King	MSSRF, Chennai		Dec 2019	Nov 2022
196	8013	Leveraging institutional innovations for inclusive and market led agricultural growth in Eastern India	Dr. Pramod Kumar	ICAR-IARI, New Delhi	1.21	Dec 2019	Nov 2022
			Dr. P.S Badal	BHU, Varanasi		Dec 2019	Nov 2022
			Dr. Biswajit Mondal	ICAR-NRRI, Cuttack		Dec 2019	Nov 2022
			Dr. Ranjit K. Paul	ICAR-IASRI, New Delhi		Dec 2019	Nov 2022
			Mr. Sathyendra Kumar	NIAM, Jaipur		Dec 2019	Nov 2022
197	8014	Development and validation of need based technology delivery model through farmers' producer organization for Eastern region of India	Dr. Anirban Mukherjee	ICAR-RCER, Patna	1.23	Dec 2019	Nov 2022
			Dr. Virendra Kumar Yadav	ICAR-RCER, Patna		Dec 2019	Nov 2022
			Dr. Shubhadeep Roy	ICAR-IIVR, Varanasi		Dec 2019	Nov 2022
			Dr. Kausik Pradhan	UBKV, West Bengal		Dec 2019	Nov 2022
198	8015	Development of biosensors for detection of fish pathogenic bacteria and hazardous metalloids in selected water bodies	Dr. D. J. Sarkar	ICAR-CIFRI, Barrackpore	3.24	March 2020	Feb 2024
			Dr. D. Pradhan	IIT, Kharagpur		March 2020	Feb 2024
			Dr. Souvik Pal	C-DAC, Kolkata		March 2020	Feb 2024

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
199	8016	Developing precision nutrient management protocols for rice-wheat and rice-maize systems in Indo-Gangetic Plains	Dr. Anchal Dass	ICAR-IARI, New Delhi	2.98	March 2020	March 2024
			Dr. S. Mandal	ICAR-RCER, Patna		March 2020	Feb 2023
			Dr. R.P. Mishra	ICAR-IIFSR, Meerut		March 2020	Feb 2023
200	8017	Dendritic cell platforms for in vitro and in vivo studies of antigen processing and presentation in cattle for combined vaccine antigens using foot-and-mouth disease virus and *Pasteurella multocida* as model	Dr. Bhanu Prakash	ICAR-IVRI, Bengaluru	2.83	March 2020	Feb 2024
			Dr. Praveen Kumar Vemula	InStem, Bengaluru		March 2020	Feb 2023
			Dr. Saravanan Subramaniam	DFMD, Mukteswar		March 2020	Feb 2023
201	8018	Paddy straw residues management through in-situ and ex-situ microbial decomposition and mechanical interventions	Dr Paneerselvam	ICAR-NRRI, Cuttack	2.57	March 2020	Feb 2023
			Dr. P. K. Sahoo	ICAR-IARI, New Delhi		March 2020	Feb 2023
			Dr. Sandeep Sharma	PAU, Ludhiana		March 2020	Feb 2023
			Dr. R.S. Garhwal	CCSHAU, Hisar		March 2020	Feb 2023
202	8019	Molecular biological studies on porcine reproductive & respiratory syndrome (PRRS) virus in pig population of North East region of India for development of sustainable diagnostics and vaccine	Dr. Tridib Kumar Rajkhowa	CAU, Aizawl	2.68	March 2020	Feb 2024
			Dr. Madhuri Subbiah	NIAB, Hyderabad		March 2020	Feb 2024
			Dr Seema Rani Pegu	ICAR-NRCP, Guwahati		March 2020	Feb 2024
203	8020	Development of white grub (*Holotrichia serrata*) resistance in sugarcane and groundnut by deploying novel cry toxin holotype genes	Dr. C. Appunu	SBI, Coimbatore	1.03	Aug 2020	July 2023
			Dr. Pooja Bhatnagar Mathur	ICRISAT, Hyderabad		Aug 2020	July 2023
			Dr. Harish G.	ICAR-DGR, Junagarh		Aug 2020	July 2023
204	8021	Risk assessment of nanoparticle accumulation in soils: Effects of metal oxide nanoparticles on soil bacterial communities, soil microbial processes and evaluation of phytotoxicity using genomic approaches	Dr. T.E. Sheeja	ICAR-IISR, Kozhikode	0.99	Aug 2020	July 2023
			Dr. V. Sajith	NIT, Calicut		Aug 2020	July 2023

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205	8022	Identification and validation of newer approaches for the management of whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae)	Dr. T. Venkatesan	ICAR-NBAIR, Bengaluru	2.18	Aug 2020	Nov 2023
			Dr. S. Subramanian	ICAR-IARI, New Delhi		Aug 2020	Nov 2023
			Dr. R. Asokan	ICAR-IIHR, Bengaluru		Aug 2020	Nov 2023
			Dr. Vikas Jindal	PAU, Ludhiana		Aug 2020	Nov 2023
206	8023	Development of thermostable Peste des petits ruminants (PPR) vaccine using spontaneously assembling, biodegradeable mesoporous silica nano-scaffolds	Dr. Sonal	ICAR-IVRI, Izatnagar	1.59	Jan 2021	Dec 2023
207	8024	Fine mapping and marker-assisted breeding for alternative dwarfing genes Rht14 and Rht18 to develop semidwarf wheat genotype suitable for conservation agriculture	Dr. Ravindra M. Patil	ARI, Pune	1.55	Jan 2021	Dec 2023
			Dr. Harikrishna	ICAR-IARI, New Delhi		Jan 2021	Dec 2023
208	8025	Production of double-muscled mass farm animals using CRISPR	Dr. Selokar Naresh Lalaji	ICAR-NDRI, Karnal	5.07	Jan 2021	March 2024
			Dr. S. D. Kharche	ICAR-CIRG, Makhdoom		Jan 2021	March 2024
			Dr. Riaz Ahmad Shah	SKUAST, Kashmir		Jan 2021	March 2024
			Dr. Dharmendra Kumar	ICAR-CIRB, Hisar		Jan 2021	March 2024
209	8026	Captive breeding of Hilsa, *Tenualosa ilisha*: Phase II	Dr. Srikanta Samanta	ICAR-CIFRI, Barrackpore	5.86	March 2021	Feb 2024
			Dr. Debasis De	ICAR-CIBA, Chennai		March 2021	Feb 2024
			Dr. Suvendu Adhikari	ICAR-CIFA, Bhubaneshwar		March 2021	Feb 2024
			Dr. Gourange Biswas	ICAR-CIFE, Mumbai		March 2021	Feb 2024

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210	8027	Epidemiological studies and development of antiviral therapeutics against coronaviruses	Dr. Naveen Kumar	ICAR-NRCE, Hisar	3.13	June 2021	May 2024
			Dr Ashwin Ashok Rout	ICAR-NIHSAD, Bhopal		June 2021	May 2024
			Dr. Gaurav K. Sharma	ICAR-IVRI, Izatnagar		June 2021	May 2024
			Dr. K. P. Suresh	NIVEDI, Bengaluru		June 2021	May 2024
211	8028	Development of diagnostics for Coronavirus infections	Dr Praveen K. Gupta	ICAR-IVRI, Izatnagar	2.82	June 2021	Nov 2023
			Dr. Nitin Virmani	ICAR-NRCE, Hisar		June 2021	Nov 2023
			Dr. Naveen Kumar	ICAR-NIHSAD, Bhopal		June 2021	Nov 2023
212	8029	Studies on host pathogen interaction and development of vaccine against zoonotic coronaviruses	Dr. Sandeep Bhatia	ICAR-NIHSAD, Bhopal	4.39	June 2021	May 2024
			Dr. C. Madhan Mohan	ICAR-IVRI, Izatnagar		June 2021	Nov 2023
			Dr. B. C. Bera	ICAR-NRCE, Hisar		June 2021	Nov 2023
213	8030	Harnessing haplotype diversity of genes controlling yield, stress tolerance and resource use efficiency traits in rice for accelerating genetic gains	Dr. M. Raveendran	TNAU, Coimbatore	2.25	June 2021	May 2024
			Dr. Ranjith Kumar Ellur	ICAR-IARI, New Delhi		June 2021	May 2024
			Dr. C. Gireesh	ICAR-IIRR, Hyderabad		June 2021	May 2024
			Dr. M.S. Sheshshayee	UAS, Bengaluru		June 2021	May 2024
214	8031	Development of nano sensor and its application through cloud based network for real time irrigation to soil and plant	Dr. Tapan Adhikari	ICAR-IISS, Bhopal	3.04	June 2021	May 2024
			Dr. C. D. Singh	ICAR-CIAE, Bhopal		June 2021	May 2024
			Dr. Samir Kumar Pal	S N Bose NSBS, Kolkata		June 2021	May 2024
215	8032	Exploring aus rice for drought, submergence and phosphorus starvation tolerance: Mining superior alleles and deciphering mechanism of tolerance	Dr. Somnath Roy	ICAR-NRRI-CRURRS, Hazaribag	2.18	July 2021	June 2024
			Dr. Umakanta Ngangkham	ICAR RC for NEH Region, Meghalaya		July 2021	June 2024

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216	9001	Evaluation of semen characteristics and fertility parameters of cloned bulls and performance of clones' progenies -Phase II	Dr. Prem Singh Yadav	ICAR-CIRB, Hisar	8.28	May 2022	April 2025
			Dr. Manoj Kumar Singh	ICAR-NDRI, Karnal		May 2022	April 2025
217	9002	Thrips diversity, virome profiling, and management of thrips and thrips-borne viruses using small synthetic peptide and bacterial endophyte consortium	Dr. Amalendu Ghosh	ICAR-IARI, New Delhi	1.16	June, 2022	May 2025
			Dr. S. Nakkeeran	TNAU, Coimbatore		June, 2022	May 2025
218	9003	Development of vaccine against animal's haemoprotozoan parasites for mitigating biotic stress	Dr. Sanjay Kumar	ICAR-NRCE, Hisar	1.45	June, 2022	May 2025
			Dr. Tarun Kumar	LUVAS, Hisar		June, 2022	May 2025
219	9004	Discovery of novel genes and QTLs conferring resistance to ToLCNDV disease from indigenous sources, genome-wide transcriptional dynamics and allele mining of the candidate genes in Cucurbitaceous vegetables	Dr. Shyam Sundar Dey	ICAR-IARI, New Delhi	2.03	June, 2022	May 2025
			Dr. Sudhakar Pandey	ICAR-IIVR, Varanasi		June, 2022	May 2025
			Dr. Amitha Mithra	ICAR-NIPB, New Delhi		June, 2022	May 2025
			Dr. V. Rajashree	TNAU, Coimbatore		June, 2022	May 2025
220	9005	Development and evaluation of genetically engineered vaccine candidates for African swine fever, Equine Herpes virus-1 and Equine Influenza (clade 1 & 2)	Dr. K. Rajukumar	ICAR-NIHSAD, Bhopal	2.51	July, 2022	June 2025
			Dr. Nitin Virmani	ICAR-NRCE, Hisar		July, 2022	June 2025
			Dr. Vikas Nehra	LUVAS, Hisar		July, 2022	June 2025
221	9006	Developing novel therapeutic strategies for mitigating antimicrobial resistance	Dr. Sameer Shrivastava,	ICAR-IVRI, Izatnagar	1.54	June, 2022	May 2025
			Prof. Sanjay Kumar Singh	IIT-BHU, Varanasi		June, 2022	May 2025
			Dr. Taruna Anand	ICAR-NRCE, Hisar		June, 2022	May 2025
222	9007	Novel approaches for disease-free health certification in finfish and development of high health shrimp for sustainable aquaculture	Dr. Gaurav Rathore	ICAR-NBFGR, Lucknow	1.05	June, 2022	May 2025
			Dr. Subhendu Kumar Otta	ICAR-CIBA, Chennai		June, 2022	May 2025

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223	9008	A comparative metabolomics approach for the analyses of scab-disease resistance in apple and development of a metabolite-based non-invasive sensor for early scab-disease diagnosis	Dr. Debabrata Sircar	IIT, Roorkee	1.09	July, 2022	June 2025
			Dr Javid Iqbal Mir	ICAR-CITH, Srinagar		July, 2022	June 2025
224	9009	Study on immune exhaustion and metabolic reprogramming by *Mycobacterium avium* subspecies paratuberculosis in bovines	Dr. Shalini Sharma	LUVAS, Hisar	0.56	July, 2022	June 2025
			Dr. Shoor Vir Singh	GLA University, Mathura		July, 2022	June 2025
225	9010	Development of nano-micro matrices for the delivery of bioactives, micronutrients and therapeutics	Dr. Rajesh Kumar	ICAR-NDRI, Karnal	4.05	July, 2022	June, 2025
			Dr. Naveen K. Navani	IIT, Roorkee		July, 2022	June, 2025
			Dr. Rajendran D.	ICAR-NIANP, Bengaluru		July, 2022	June, 2025
			Dr. P. Senthil Kumar	TANUVAS, Orathanadu		July, 2022	June, 2025
			Dr. P. Heartwin Amaladhas	ICAR-NDRI, SRS, Bengaluru		July, 2022	June, 2025
226	9011	A detailed foodomics study for food authentication and exploration of nutraceutical potential	Dr. N. A. Deshmukh	ICAR-NRC for Grapes, Pune	2.43	July, 2022	June, 2025
			Dr. Niladri Sekhar Chatterjee	ICAR-CIFT, Cochin		July, 2022	June, 2025
			Dr. Manjusha Verma	ICAR-NBPGR, New Delhi		July, 2022	June, 2025
227	9012	Rice rhizosphere metabolome - and microbiome functions for improved crop establishment, growth, and yield	Dr. B. Ramakrishnan	ICAR-IARI, New Delhi	0.92	July, 2022	June, 2025
			Dr. Shyam Kumar Masakapalli	IIT, Mandi		July, 2022	June, 2025
			Prof. Dwipendra Thakuria	CAU, Umiam		July, 2022	June, 2025
			Prof. Sanjeev Kumar	PRL, Ahmedabad		July, 2022	June, 2025

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228	9013	Allele mining for the epigenetic regulator NGR5 and other yield-associated gene (GRF4) and their modulation using multiple genomic and molecular approaches to enhance rice yield under low nitrogen conditions	Dr. Gireesha T. Mohannath	BITS, Pilani, Hyderabad Campus	1.48	Aug, 2022	July 2025
			Dr. Satendra Kumar Mangrauthia	ICAR-IIRR, Hyderabad		Aug, 2022	July 2025
			Dr. Kutubuddin Molla	ICAR-NRRI, Cuttack		Aug, 2022	July 2025
			Dr. Vivek Thakur	University of Hyderabad, Hyderabad		Aug, 2022	July 2025
229	9014	Identification and characterization of specific genes/ metabolites linked with rancidity and their bioavailability patterns in landraces and elite cultivars of pearl millet for the development of nutri-rich products	Dr. Ranjeet R. Kumar	ICAR-IARI, New Delhi	0.97	Aug, 2022	July 2025
			Dr. Nitin Singhal	NABI, Mohali		Aug, 2022	July 2025
			Dr. U. Mabalirajan	IICB, Kolkata		Aug, 2022	July 2025
230	9015	Metabolomics fingerprinting of body fluids for development of a metabolite-based novel semen extender for enhancing fertility of bull sperm and diagnostic assays for detection of sub-clinical hemoprotozoan diseases in cattle	Dr. Sudhir C Roy	ICAR-NIANP, Bangalore	1.40	Aug, 2022	July 2025
			Dr. Mayukh Ghosh	BHU, Varanasi		Aug, 2022	July 2025
231	9016	Exploiting cross-talk of CAM (Crassulacean Acid Metabolism) photosynthetic transition for management of drought and salinity stress in groundnut	Dr K. K. Pal	ICAR-DGR, Junagarh	0.37	Aug, 2022	July 2023
			Dr. Renjith P.S.	ICAR-CAZRI, RRS-Kukma, Bhuj, Gujrat		Aug, 2022	July 2023
232	9017	Development of transgenic chicken as bioreactor for easy and cost effective production of human therapeutic proteins - tissue plasminogen activator (htPA) and erythropoietin (hERP)	Dr. Jayakumar Sivalingam	ICAR-DPR, Hyderabad	1.34	Aug, 2022	July 2025
			Dr. Nirmalya Ganguli	NIAB, Hyderabad		Aug, 2022	July 2025

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233	9018	Development of small molecular weight bioactives and polysaccharides from marine and coastal bivalves to develop prospective nutraceutical products	Dr. Kajal Chakraborty	ICAR-CMFRI, Cochin	0.72	Aug, 2022	July 2025
			Dr. Bibu John Kariyil	KVASU, Mannuthy, Thrissur		Aug, 2022	July 2025
234	9019	Marker assisting stacking of yellow mosaic disease resistance, null Kunitz trypsin inhibitor, null lipoxygenase-2 genes, and broadening the genetic base of soybean	Dr. Vineet Kumar	ICAR-IISR, Indore	2.10	Aug, 2022	July 2025
			Dr. B. S. Gill	PAU, Ludhiana		Aug, 2022	July 2025
			Dr. Akshay Talukdar	ICAR-IARI, New Delhi		Aug, 2022	July 2025
			Dr. Onkarappa T.	UAS, Bengaluru		Aug, 2022	July 2025
235	9020	Deciphering and deploying low phosphorus tolerance and nitrogen use efficiency in rice using targeted genomics approach	Dr. Devyani sen	CAU (Imphal), Umiam	2.52	Aug, 2022	July 2025
			Dr. C. N. Neeraja,	ICAR-IIRR, Hyderabad		Aug, 2022	July 2025
			Dr. J. Meher	ICAR-NRRI, Cuttack		Aug, 2022	July 2025
			Dr. Avinash Pandey	ICAR-IIAB, Ranchi		Aug, 2022	July 2025
			Dr. Amit Kumar	ICAR-RC NEH, Umiam		Aug, 2022	July 2025
236	9021	CRISPR Crop Network: Targeted improvement of stress tolerance, nutritional quality and yield of crops by using genome editing	Dr. Viswanathan Chinnusamy	ICAR-IARI, New Delhi	7.39	Aug 16, 2022	Aug 2025
			Dr. Parameswaran C.	ICAR-NRRI, Cuttack		Aug 16, 2022	Aug 2025
			Dr. Satendra Kumar Mangrauthia	ICAR-IIRR, Hyderabad		Aug 16, 2022	Aug 2025
			Dr. R. Bhattacharya	ICAR-NIPB, New Delhi		Aug 16, 2022	Aug 2025
			Dr. Prashant Yadav	ICAR-DRMR, Bharatpur		Aug 16, 2022	Aug 2025
			Dr. Sangram K. Lenka	GBU, Gandhinagar		Aug 16, 2022	Aug 2025
			Dr. Anita Rani	ICAR-IISR, Indore		Aug 16, 2022	Aug 2025
			Dr. M. Senthilkumar	ICAR-IIPR, Kanpur		Aug 16, 2022	Aug 2025
			Dr. R. Manimekalai	SBI, Coimbatore		Aug 16, 2022	Aug 2025
			Dr. Ravi Maruthachalam	ICAR-IISER, Thiruvananthapuram		Aug 16, 2022	Aug 2025

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237	9022	Development of a minimal water retting technology of jute	Dr. Avijit Das	ICAR-NINFET, Kolkata	1.00	Sep, 2022	Aug, 2025
			Dr. Bijan Majumdar	ICAR-CRIJAF, Barrackpore		Sep, 2022	Aug, 2025
238	9023	Development of e-extension modules for capacity building in livestock farming	Dr. Prakashkumar Rathod	KVAFSU, Bidar	0.94	Sep, 2022	Aug, 2025
			Dr. Sariput Landge	MAFSU, Nagpur		Sep, 2022	Aug, 2025
			Dr. C. H. Satyanarayana	PVNRTVU, Hyderabad		Sep, 2022	Aug, 2025
239	9024	Genome wide association studies in giant freshwater prawn, *M. rosenbergii*: Linkage mapping and QTL identification	Dr. Lakshman Sahoo	ICAR-CIFA, Bhubaneswar	0.74	Sep, 2022	Aug, 2025
			Dr. Prabina K. Meher	ICAR-IASRI, New Delhi		Sep, 2022	Aug, 2025
240	9025	Traceable value chain for safe pork in the North Eastern region of India	Dr. Pranab Jyoti Das	ICAR-NRCP, Guwahati	1.53	Sep, 2022	Aug, 2025
			Dr. Sukumar Nandi	IIT, Guwahati		Sep, 2022	Aug, 2025
			Dr. S. N. Mandal	Kalyani Government Engineering College, Kalyani		Sep, 2022	Aug, 2025
			Dr. Samir Das	ICAR RC for NEH, Barapani		Sep, 2022	Aug, 2025
			Dr. C. Ramakrishna	ICAR-NRC on Meat, Hyderabad		Sep, 2022	Aug, 2025
241	9026	Identification and characterization of fungal effectors and host factors in rice- false smut pathosystem	Dr. D. Ladhalaksmi	ICAR-IIRR, Hyderabad	2.37	Sep, 2022	Aug, 2025
			Dr. Devanna	ICAR-NRRI, Cuttack		Sep, 2022	Aug, 2025
			Dr. Jagjeet Singh Lore	PAU, Ludhiana		Sep, 2022	Aug, 2025
			Dr. Pramesh D.	UAS-R, Raichur		Sep, 2022	Aug, 2025
			Dr. Kishor U. Tribhuvan	ICAR-IIAB, Ranchi		Sep, 2022	Aug, 2025
242	9027	Hyperspectral reflectance and multi-nutrient extractant based rapid assessment of soil properties for sustainable soil health in India	Dr. Priyabrata Santra	ICAR-CAZRI, Jodhpur	2.10	Sep, 2022	Aug, 2025
			Dr. M. Vassanda Coumar	ICAR-IISS, Bhopal		Sep, 2022	Aug, 2025
			Dr. Achchhelal Yadav	ICAR-IARI, New Delhi		Sep, 2022	Aug, 2025
			Dr. Nirmal Kumar	ICAR-NBSS&LUP, Nagpur		Sep, 2022	Aug, 2025
			Dr. Sushanta Saha	BCKV, Mohanpur		Sep, 2022	Aug, 2025
			Dr. Subbu Maragatham	TNAU, Coimbatore		Sep, 2022	Aug, 2025

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243	9028	Artificial Intelligence and IoT based smart vet ecosystem for animal health, patient care and precision livestock farming	Dr. P. Selvaraj	TNVASU, Chennai	2.15	Jan, 2023	Dec, 2025
			Prof. Sanjay Kumar Singh	IIT, BHU, Varanasi		Jan, 2023	Dec, 2025
			Dr. Sameer Shrivastava	ICAR-IVRI, Izattnagar		Jan, 2023	Dec, 2025
			Dr. A. Kavitha	SSN College of Engineering, Chennai		Jan, 2023	Dec, 2025
			Dr. Pandiyarasan Veluswamy	IIIT, Design & Manufacturing, Chennai		Jan, 2023	Dec, 2025
244	9029	Development of fluorescent and resistive sensors for monitoring the crop health via detection of plant emitted Volatile Organic Compounds (VOCs)	Rajeswara Rao M.	IIT, Dharwad	0.75	June, 2023	May, 2026
			Dr. P. D. Kamala Jayanthi	ICAR-IIHR, Bengaluru		June, 2023	May, 2026
245	9030	Development of unmanned robotic ground vehicle for safe spray application of agrochemicals	Dr. Brajesh Nare	ICAR-CPRI, Shimla (RS Jalandhar)	1.05	June, 2023	May, 2026
			Dr. Mandeep Singh	C-DAC, Mohali		June, 2023	May, 2026
246	9031	The changing dynamics of labour migration on employment, livelihoods and resource productivity patterns in Indian marine fisheries sector	Dr. Shyam S. Salim	ICAR-CMFRI, Kochi	0.59	June, 2023	May, 2026
			Dr. Ananthan P.S.	ICAR-CIFE, Mumbai		June, 2023	May, 2026
			Dr. Aparna Roy	ICAR-CIFRI, Barrackpore		June, 2023	May, 2026
			Dr. Umamaheswari T.	TNJFU- Fisheries College and Research Institute, Thoothukudi		June, 2023	May, 2026
247	9032	Sensor based integrated vertical farming for horticultural crops and aquaponic system	Dr. Murtaza Hasan	ICAR-IARI, New Delhi	1.79	June, 2023	May, 2026
			Dr. Prativa Sahu	ICAR-IIWM, Bhubaneshwar		June, 2023	May, 2026
			Dr. A.K. Verma	ICAR-CIFE, Mumbai		June, 2023	May, 2026
			Dr. Hare Krishna	ICAR-IIVR, Varanasi		June, 2023	May, 2026

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248	9033	Agripreneurship for sustainable agricultural development: Technological and institutional innovations and strategies	Dr. P. Venkatesan	ICAR-NAARM, Hyderabad	1.51	June, 2023	May, 2026
			Dr. Bankey Bihari	ICAR-IISWC, Dehradun		June, 2023	May, 2026
			Dr. Suresh Kumar	ICAR-CSSRI, Karnal		June, 2023	May, 2026
			Dr. P. Mooventhan	ICAR-NIBSM, Raipur		June, 2023	May, 2026
			Dr. N. K. Barik	ICAR-CIFA, Bhubaneswar		June, 2023	May, 2026
249	9034	Global value chain analysis of plantation crops of India with special emphasis on food safety standards	Dr. Jayasekhar S.	ICAR-CPCRI, Kasaragod	0.68	June, 2023	May, 2026
			Dr. K. Venkateswaran	ICAR-IIPM, Bengaluru		June, 2023	May, 2026
250	9035	Development and demonstration of ai enabled weather and market information based decision support system (FARWM- DS) for sustainable farm productivity & profitability and evolve profitable cropping pattern	Dr. Shrishail Dolli	UAS, Dharwad	1.53	June, 2023	May, 2026
			Dr. Kedar Khandeparkar	IIT, Dharwad		June, 2023	May, 2026
			Dr. Kalpana M.	TNAU, Coimbatore		June, 2023	May, 2026
			Dr. M. J. Chandre Gowda	ICAR-ATARI, Bengaluru		June, 2023	May, 2026
251	9036	Design and development of solar-powered prime mover with multi-tool attachments for small farm holdings	Dr. R. Mahendiran	TNAU, Coimbatore	1.11	June, 2023	May, 2026
			Dr. Vijayakumar Pallad	UAS, Raichur		June, 2023	May, 2026
252	9037	Evaluation and refinement of biofloc based new age farming technology through effective microbial management, recirculation and input optimization for sustainable intensification across different aquaculture systems	Dr. Akshaya Panigrahi	ICAR-CIBA, Chennai	2.77	June, 2023	May, 2026
			Dr. P.C. Das	ICAR-CIFA, Bhubaneswar		June, 2023	May, 2026

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
253	9038	Development of smart foods, bio-composites, green packaging and bio-energy from agro-residues	Dr. Suresh Paramasivam	ICAR-NRC for Banana, Tiruchirappalli	3.95	June, 2023	May, 2026
			Dr. K.N. Sheeba	NIT, Tiruchirappalli		June, 2023	May, 2026
			Dr. Ravindra Naik	ICAR-CIAE, RC, Coimbatore		June, 2023	May, 2026
			Dr. A Arputharaj	ICAR-CIRCOT, Mumbai		June, 2023	May, 2026
			Dr. Sajeev M S	ICAR-CTCRI, Thiruvananthapuram		June, 2023	May, 2026
			Dr. S. Anbudayanidhi	ICAR-CIPET, IPT, Kochi		June, 2023	May, 2026
			Dr. S. Anandakumar	ICAR-NIFTEM - Thanjavur		June, 2023	May, 2026
			Dr S. Parveen	TNAU, Coimbatore		June, 2023	May, 2026
254	9039	Building resilience model for the vulnerable hotspots to climate change in smallholder dairy production system of Indo-Gangetic plain region of India using GIS and fuzzy cognitive mapping approach	Dr. Sanjit Maiti	ICAR-NDRI, Karnal	1.35	Sep, 2023	Aug, 2026
			Dr. Rupak Goswami	RKMVERI, Belur Math, Howrah		Sep, 2023	Aug, 2026
			Dr. Bishwa Bhaskar Choudhary	ICAR-IGFRI, Jhansi		Sep, 2023	Aug, 2026
			Dr. Anirban Mukherjee	ICARRC for Eastern Region, Patna		Sep, 2023	Aug, 2026
255	10001	Deployment of genetic and chemical options for the management of major biotic (*Orobanche* and *Alternaria*) stresses in Indian mustard	Dr. R. S. Jat	ICAR-DRMR, Bharatpur	1.45	March, 2024	Feb, 2027
			Dr. Ashish Kumar	ICAR-NIPB, New Delhi		March, 2024	Feb, 2027
			Dr. Amrish Agarwal	IPFT, Gurugram		March, 2024	Feb, 2027
			Dr. K Sarika	ICAR-RC NEH Region, Manipur		March, 2024	Feb, 2027
256	10002	Enhancing abiotic stress tolerance in wheat and pearl millet: insights from integrated epigenetic, physiological and molecular interventions	Dr. S. Barthakur	ICAR-NIPB, New Delhi	1.24	March, 2024	Feb, 2027
			Dr. Sushma Tiwari	RVSKV, Gwalior		March, 2024	Feb, 2027
			Dr. Sudipta Basu	ICAR-IARI, New Delhi		March, 2024	Feb, 2027

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
257	10003	Developing genomic selection strategy for accelerating breeding program in perennial fruit crops grape, guava and mango	Dr. Anuradha Upadhyay	ICAR-NRCG, Pune	1.25	March, 2024	Feb, 2027
			Dr. Anju Bajpai	ICAR-CISH, Lucknow		March, 2024	Feb, 2027
			Dr. A. K. Goswami	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. Kashmir Singh	PU, Chandigarh		March, 2024	Feb, 2027
258	10004	Environmental and nutritional intervention to farm white leg shrimp, *Penaeusvannamei* in low saline water (LSW): A strategy for improving aquaculture production	Dr. S. Munilkumar,	ICAR-CIFE, Mumbai	0.50	March, 2024	Feb, 2027
259	10005	Elucidation of molecular mechanism of captive reproduction of *Clariasdussumieri* and derive relevant molecular cues for successful induced spawning of male Clariasmagur	Dr. Rupam Sharma	ICAR-CIFE, Mumbai	0.67	March, 2024	Feb, 2027
			Dr. J. K. Sundaray	ICAR-CIFA, Bhubneswar		March, 2024	Feb, 2027
260	10006	Bio-nano sulphur formulation of methanotrophs for decarbonisation, disease resistance and sustaining productivity in rice-oilseed cropping system	Dr. P. Bhattacharyya	ICAR-NRRI, Cuttack	1.15	March, 2024	Feb, 2027
			Dr. Rajesh Kumar	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. RachanaDubey	ICAR-RCER, Patna		March, 2024	Feb, 2027
261	10007	The development of a handheld sensor technology for non destructive quality prediction of two economically important medicinal plants and the improvement of their quality	Dr. R. N. Reddy	ICAR-DMAPR, Anand	1.58	March, 2024	Feb, 2027
			Dr. V. S. Rana	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. D. Sircar	IIT, Roorkee		March, 2024	Feb, 2027

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
262	10008	Development, standardization, and optimization of microbial and botanical pesticides and their formulations as efficient delivery systems for the management of agricultural, stored grain pests, nematodes and ticks parasites	Dr. Amrish Agrawal	IPFT, Gurugram	1.42	March, 2024	Feb, 2027
			Dr. V.S Rana	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. M. Sankar	ICAR-IVRI, Izatnagar		March, 2024	Feb, 2027
			Dr. SusantaBanik	NU Medziphema Campus		March, 2024	Feb, 2027
			Dr. Totan Adak	ICAR-NRRI, Cuttack		March, 2024	Feb, 2027
263	10009	Estimation of chemical quality parameters of *Cinchona*, jute and allied fibres and Lac by fluorescence and NIR sensors and development of portable sensor instruments with thrust on fluorometry	Dr. Rajib Bandyopadhyay	JU, Kolkata	1.31	March, 2024	Feb, 2027
			Dr. P. Satya	ICAR-CRIJAF, Barrackpore		March, 2024	Feb, 2027
			Dr. A. R. Chowdhury	ICAR-NISA, Ranchi		March, 2024	Feb, 2027
			Dr. S.K. Masudul Islam	DCOMP, Darjeeling		March, 2024	Feb, 2027
264	10010	Natural grassland ecosystem monitoring system for peninsular and Trans Himalayan India to sustain pastoral communities	Dr. Avijit Ghosh	ICAR-IGFRI, Jhansi	1.06	March, 2024	Feb, 2027
			Dr. A.K. Gupta	GBPNHE, Almora, (Ladakh RC)		March, 2024	Feb, 2027
			Dr. Md A. Haque	ICAR-IASRI, New Delhi		March, 2024	Feb, 2027
			Dr. Bappa Das	ICAR-CCARI, Ela, Old Goa		March, 2024	Feb, 2027
265	10011	Development of infectious clone, point-of-care diagnostics and transcriptome profiling for apple (*Malusdomestica*) exhibiting mosaic disease associated with apple necrotic mosaic virus in Northwestern Himalayan region of India	Dr. Sajad Un Nabi	ICAR-CITH, Srinagar	0.89	March, 2024	Feb, 2027
			Dr. S.K. Sharma	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. Anil Handa	Dr. YSPUH&F, Nauni		March, 2024	Feb, 2027
266	10012	Development and evaluation of robotic harvester for grape bunches	Dr. Syed Imran S	ICAR-CIAE, RS, Coimbatore	0.80	March, 2024	Feb, 2027
			Dr. N.A. Deshmukh	ICAR- NRCG, Pune		March, 2024	Feb, 2027

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
267	10013	Development of novel strategy for the detection and tackling of antimicrobial resistant (AMR) Mastitis pathogens in dairy animals and environment using nanotechnology	Dr. Raghu H. V.	ICAR-NDRI, Karnal	0.82	March, 2024	Feb, 2027
			Dr. Lopamudra Haldar	WBUAFS, Kolkata		March, 2024	Feb, 2027
268	10014	Expanding breeding window of IMC (*Labeocatla*) for year-round seed availability	Dr. P. Routray	ICAR-CIFA, Bhubaneswar	0.75	March, 2024	Feb, 2027
			Dr. A. Chattoraj	KN University, Asansol		March, 2024	Feb, 2027
269	10015	Development of Taluka scale precise crop yield prediction application for selected districts of Gujarat using remote sensing, AI and machine learning	Dr. Parthsarthi A. Pandya	JAU, Junagadh	0.75	March, 2024	Feb, 2027
			Dr. Mukesh Kumar Tiwari	AAU, Anand		March, 2024	Feb, 2027
			Dr. M.J. Kaledhonkar	ICAR-IISWC, Vasad		March, 2024	Feb, 2027
270	10016	Point of care nanobiosensors for antibiotic residue detection in fish	Dr. D. J. Sarkar	ICAR-CIFRI, Barrackpore	0.78	March, 2024	Feb, 2027
			Dr. Souvik Pal	C-DAC, Kolkata		March, 2024	Feb, 2027
271	10017	In vitro production of oocyte- and spermatozoa-like cells from pluripotent stem cells of farm animals	Dr. M. K. Singh	ICAR-NDRI, Karnal	0.89	March, 2024	Feb, 2027
			Dr. Dharmendra Kumar	ICAR-CIRB, Hisar		March, 2024	Feb, 2027
272	10018	Deciphering agricultural soil microbiomes for sustainable management of lignocellulosic wastes and bioremediation of chlorpyrifos (dt50) contaminated sites	Dr. G. P. Jagtap	VNMKV, Prabhani	1.51	March, 2024	Feb, 2027
			Dr. LivleenShukla	ICAR-IARI, New Delhi		March, 2024	Feb, 2027
			Dr. SamsulAlam	IPFT, Gurugram		March, 2024	Feb, 2027
273	10019	Integrating whole genome resequencing, transcriptome sequencing and genome wide association analysis for allele mining of yield and quality traits in Black pepper and Cardamom	Dr. Sheeja T.E.	ICAR-IISR, Kozhikode	1.08	March, 2024	Feb, 2027
			Dr. Preethy T.T.	KAU-CRS, Idukki		March, 2024	Feb, 2027
			Dr. Sarika	ICAR-IASRI, New Delhi		March, 2024	Feb, 2027

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
274	10020	Deciphering the genetic basis of lower susceptibility of indigenous cattle to bovine anaplasmosis	Dr. Sonika Ahlawat	ICAR-NBAGR, Karnal	0.71	April, 2024	March, 2027
			Dr. Anish Yadav	SKUAST, Jammu		April, 2024	March, 2027
275	10021	Artificial intelligence enabled biotic & abiotic stress detection and advisory mobile application for crops	Dr. Sudeep Marwaha	ICAR-IASRI, New Delhi	0.97	April, 2024	March, 2027
			Dr. Sajad Un Nabi	ICAR-CITH, Srinagar		April, 2024	March, 2027
			Dr. Poonam Jasrotia	ICAR- IIWBR, Karnal		April, 2024	March, 2027
			Dr. Devraj	ICAR- IIPR, Kanpur		April, 2024	March, 2027
276	10022	Effects of abiotic and biotic factors on secondary metabolite profiles of *Rauvolfia serpentine* and *Tribulus terrestris*: Optimizing cultivation strategies in different agro climatic regions of India	Dr. Sharad Srivastava	CSIR- NBRI, Lucknow	1.25	April, 2024	March, 2027
			Dr. V. Sundaresan	CSIR-CIMAP, RC, Bengaluru		April, 2024	March, 2027
			Dr. K. A. Kalariya	ICAR- DMAPR, Anand		April, 2024	March, 2027
277	10023	Comparative study on carbon dynamics and functional rhizosphere microbial biomass of agroforestry systems in dry-and wet- tropical climatic situations	Dr. Badre Alam	ICAR-CARI, Jhansi	0.96	April, 2024	March, 2027
			Dr. Kusum Arunachalam	Doon University, Dehradun		April, 2024	March, 2027
278		Developing simulation model of technology diffusion (TechSIM) for forecasting using techno-socio-psycho-economic-ecological factors	Dr. G.A.K. Kumar	ICAR – NRRI, Cuttack	1.19	Under process	
			Dr. Anirban Mukherjee	ICAR-RCER, Patna			
			Dr. Souvik Ghosh	Viswa-Bharati, Shantiniketan			
			Dr. Rajkumar Josmee Singh	CAU, Barapani			
			Dr. Sandeep Deshmukh	ICAR RC for NEH, Umiam			
			Dr. B.K. Jha	BAU, Ranchi			
279		Development of multimedia-based pedagogy models and modules for agricultural extension and education	Dr. Girijesh Mahra	ICAR-IARI, New Delhi	0.50	Under process	
			Dr. Ashish S.Murai	ICAR-ATARI, Zone-I, Ludhiana			

S. No	Project Code	Project Name	Name of PI/CCPI	Centre Name	Total budget (₹ in crore)	From	To
280		Potential of crop residues in NEH region – A circular economy perspective for sustainable livelihood	Dr. Jyoti V. Vastrad	CAU, Imphal	0.60	Under process	
			Dr. L. K. Nayak	ICAR - NINFET, Kolkata			
			Dr. Nabaneeta Gogoi	AAU, Jorhat			
281		Developing indices for agricultural innovation ecosystem to sustain the growth paradigms of agricultural systems	Dr. Ram Datt	RPCAU, Samastipur	0.51	Under process	
			Dr. Rajiv Baliram Kale	ICAR-DOGR, Pune			
282		Strengthening the agri-horticulture systems for the socio-economic development of the rural communities in the Western Himalaya	Dr. Indra Dutt Bhatt	GBPIHE, Almora	0.50	Under process	
			Dr. Rahul Dev	ICAR-VPKAS, Almora			

Projects on Scientific Utilization through Research Augmentation- Prime Products/ Panchagavya from Indigenous Cows (SUTRA-PIC) theme

S. No.	Title of the project	PI/CCPI	Centre name	Total budget (₹ in crore)	Duration	
					From	To
1	Unique innate-immunity genomic signatures identification in Sahiwal, Gir, Tharparkar, Kangeyam, Karan Fries and Holstein Friesian cattle using immunoinformatics	Dr. Suneel Kumar Onteru	ICAR-NDRI, Karnal	0.95	May, 2022	April, 2025
		Dr. R. M. Yennamalli	SASTRA, Thanjavur		May, 2022	April, 2025
2	Isolation of proline-rich polypeptides from colostrum of select indigenous cattle breed and evaluation of their nutraceutical potential	Dr. Sathish Kumar	ICAR-NDRI, SRS, Bengaluru	1.02	May, 2022	April, 2025
		Dr. Shaik Abdul Hussain	ICAR-NDRI, Karnal		May, 2022	April, 2025
3	Exploring medicinal and immunomodulatory properties of the urine of Indigenous Badri cattle	Dr. R. S. Chauhan	GBPUAT, Pantnagar	0.74	June, 2022	May, 2025
		Dr. Prasenjit Dhar	CSKHPK, Palampur		June, 2022	May, 2025
4	Identification of unique signatures of selective sweeps in indigenous dairy cattle breeds	Dr. Manjit Panigrahi	ICAR-IVRI, Izatnagar	0.75	May, 2022	April, 2025

Extra Mural Research (EMR) projects for extension and sanction/release of funds (₹ in lakh)

S. No.	Extra Mural Research Project details	PI/CCPI	Centre name	Total budget (₹ in crore)	Duration	
					From	To
1	Cultivation and value addition of aromatic plants for livelihood security of farmers of Uttrakhand Region	Dr. Jag Mohan Singh Tomar	ICAR - IISWC, Dehradun	0.20	2019-20	2022-23
	Integrated management of Fusarium wilt Tropical Race 4: A devastating strain of banana	Dr. R. Thangavelu	ICAR-NRC for Banana, Tiruchirapalli	0.91	2019-20	2021-22
2	Development of post harvest handling and sensor based smart packaging methods for the export of traditional banana varieties and nano-strip based digital health monitoring of banana	Dr. P. Suresh Kumar	ICAR-NRC for Banana, Tiruchirapalli	0.98	2020-21	2022-23
	Knowledge management system for agricultural extension service	Dr. Alka Arora	ICAR-IASRI, New Delhi	2.05	2015-16	2021-22
3	Application of next generation breeding genotyping, and digitalization approaches for improving the genetic gain in India staple crops	Dr. C. Bhardwaj	ICAR-IARI, New Delhi	28.00	2018-19	2021-22
	Epigenomics of phosphorus use efficiency in rice	Dr. Suresh Kumar	ICAR-IARI, New Delhi	2.71	2018-19	2022-23
4	Valorization of waste water grown algal bio mass and agriculture residues	Dr. Sunil Pabbi	ICAR-IARI, New Delhi	0.16	2019-20	2021-22
5	Production & valorization of muconic acid from agricultural waste to produce adipic acid combined fermentation and chemical catalytic process	Dr. Livleen Shukla	ICAR-IARI, New Delhi	0.20	2019-20	2022-23
6	Biological markers for soil suppressiveness	Dr Y. S. Shivay	ICAR-IARI, New Delhi	0.16	2019-20	2021-22
7	Development of hand held instrument for non-destructive quality testing of mango	Dr. Pranita Jaiswal,	ICAR-IARI, New Delhi	1.88	2019-20	2023-24
8	Efficacy of Kisspeptin and its analogues in the existing estrus synchronization protocols to augment fertility in small and large ruminants	Dr. Kajal Sankar Roy	ICAR-NIANP, Bengaluru	0.75	2018-19	2022-23

Annexure II

List of Persons at NASF Unit

Current Team

Dr. Jitendra Kumar – Assistant Director General

Dr. Ashok Kumar – Principal Scientist

Dr. Manju Gerard – Principal Scientist

Sh. V.K. Pandey – Deputy Secretary

Sh. Amit Kumar Marwari – Finance Assistant Officer

Mrs. Sarita Sharma – Section Officer

Sh. Ravindra Singh – Assistant

Contractual Staff

Dr. Arvind Kumar – Research Associate

Dr. Anuj Singh Sikarwar – Research Associate

Dr. Geetika Gambhir Chopra – Research Associate

Dr. Shweta Mehrotra – Research Associate

Dr. Radhika Tanwar – Research Associate

Mr. Deepak Kumar Singh – Personal Assistant to ADG

Mr. Neeraj Kanwal

Mr. Nakul Khokhar

Mr. Krishna Kumar Singh

Mrs. Varsha

Mr. Madhukant Rai

Mr. Rambux

Former Personal

Dr. A. Bandyopadhyay – National Coordinator

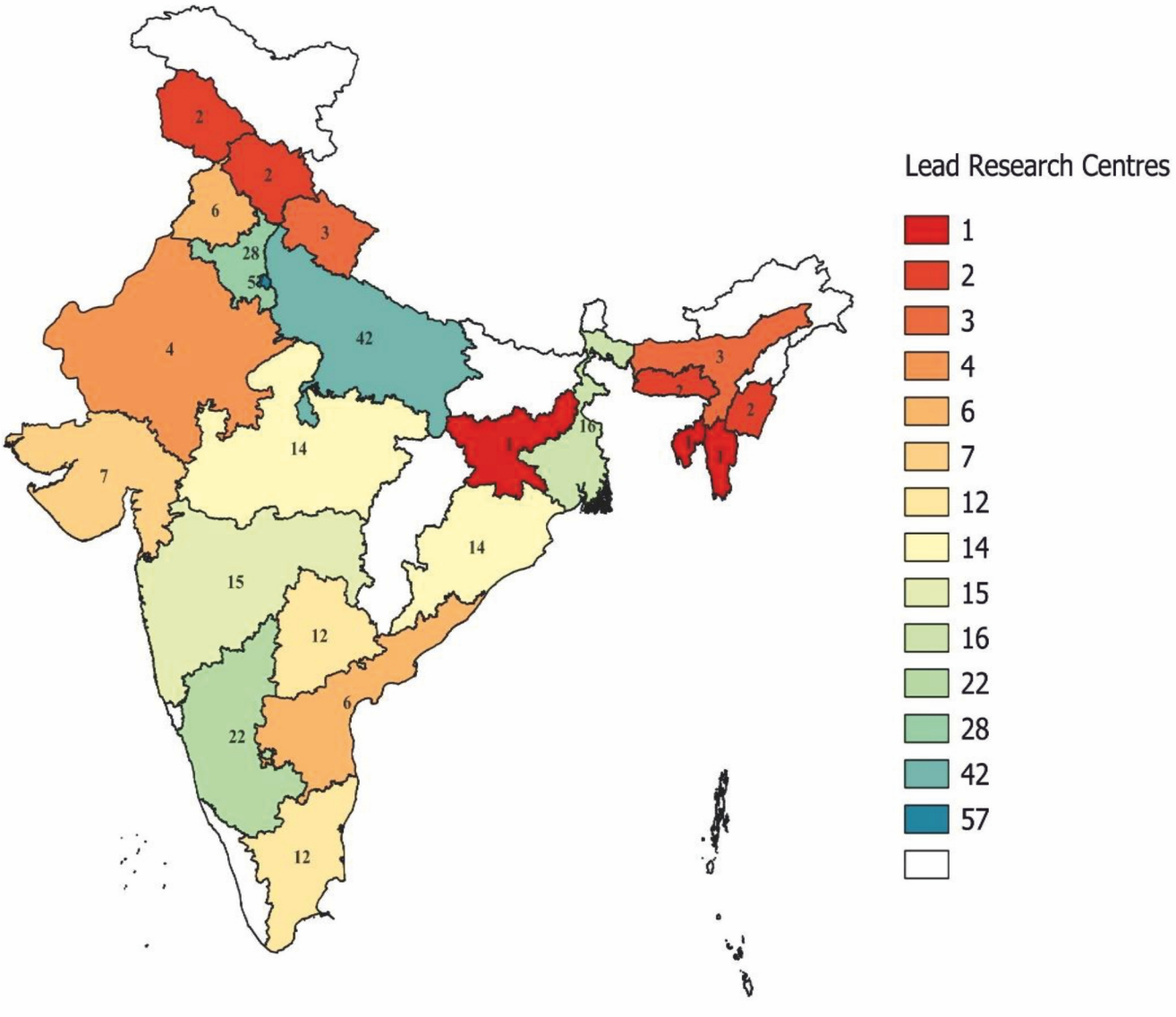
Dr. P.K. Agrawal – Assistant Director General

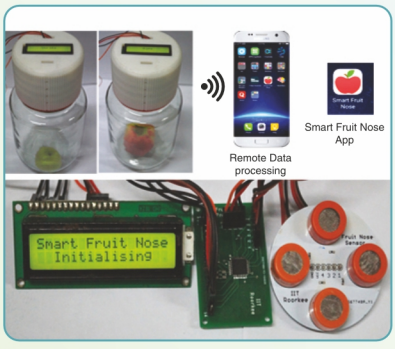
Dr. Sanjeev Saxena – Assistant Director General (Additional Charge)

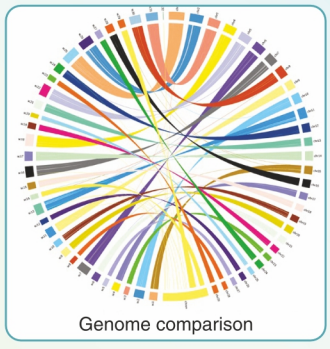
Dr. D.K. Yadav – Assistant Director General (Additional Charge)

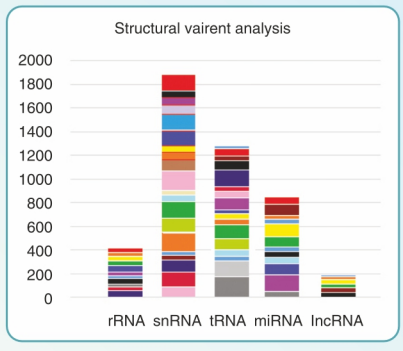
Dr. S.K. Chakraborty – Principal Scientist

Lead Research Centers of NASF funded Projects across the Country









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