NCPGRM

Souvenir

1st National Conference on Plant Genetic Resources Management (NCPGRM)

22-24 November 2022

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NCPGRM

1st National Conference on Plant Genetic Resources Management (NCPGRM)

22-24 November 2022

Souvenir

Organized by

Indian Society of Plant Genetic Resources (ISPGR), New Delhi
Indian Council of Agricultural Research (ICAR), New Delhi
ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi
GEF - UN Environment Programme, Alliance of Bioversity International and CIAT, India Office, New Delhi
Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi

Co-Organized by

Trust for Advancement of Agricultural Sciences (TAAS), New Delhi
International Maize and Wheat Improvement Center (CIMMYT)
International Centre for Agricultural Research in the Dry Areas (ICARDA)
International Centre for Research in Agro-Forestry (ICRAF)
International Crop Research Institute for Semi Arid Tropics (ICRISAT)
National Academy of Agricultural Sciences (NAAS)

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Contents

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Progress Through Science

Dr. R.S. Paroda
Founder Chairman

Message

I am extremely pleased that the Indian Society of Plant Genetic Resources, jointly with Indian Council of Agricultural Research (ICAR), National Bureau of Plant Genetic Resources (NBPGR), Alliance of Bioversity International and CIAT, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), is organizing the 1st National Conference on Plant Genetic Resources Management (NCPGRM) at NASC Complex, New Delhi on 22-24 November, 2022. It is encouraging that several national and global organisations are jointly hosting the conference.

India is fortunate to have rich agrobiodiversity of not only plants, but also of animals, fish, microbes and useful insects. These serve as valuable resource for the livelihood of people. Fortunately, we do have a dynamic national agricultural research system (NARS) for taking care of our genetic resource management, including conservation and sustainable use for increasing agricultural production as well as income of our farmers. Traditionally, farmers possess good knowledge of available genetic resources and try to manage them to suit their specific needs. Considering the importance of plant genetic resources (PGR) for human welfare and for achieving sustainable development goals (SDGs), the 1st National Conference on PGR Management is expected to deliberate important management issues concerning scientific, technical, policy and legal matters.

I am confident that the 1st NCPGRM will provide an opportunity to the participants to share their rich experiences and define a clear 'Road Map' for the management and use of PGR for over all welfare of humankind.

I wish the conference a great success.

(R.S. Paroda)
Chairman, TAAS & President, ISPGR
Former Secretary, DARE &
Director General, ICAR

CIMMYT
International Maize and Wheat Improvement Center

Dr Bram Govaerts

Director General
The International Maize and Wheat Improvement Center (CIMMYT)

MESSAGE

It gives me immense pleasure that the Indian Society of Plant Genetic Resources (ISPGR) is organizing the 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) during 22-24 November 2022, in New Delhi, and we, at the International Maize and Wheat Improvement Center (CIMMYT), are proud to be partners in this endeavor. The conference will offer a great opportunity to advance knowledge through the exchange of ideas and experience by all stakeholders. The topics covered under the various themes of the conference are very important for developing a holistic approach for effective management and enhanced utilization of genetic resources.

I wish the conference great success.

Dr Jacqueline Hughes

Director General
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

MESSAGE

The world's biodiversity, on which food production critically depends, is in danger due to anthropogenic activities such as pollution, habitat loss and degradation, overexploitation, climate change and many others. This biodiversity helps scientists produce varieties and hybrids to meet new, emerging threats to agriculture. The crop diversity preserved in genebanks all over the world, with those backed up at the Svalbard Global Seed Vault, is our lifeline against future threats to humanity.

ICRISAT is proud to be associated with the 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022). We look forward to the deliberations and discussions by the various experts and hope that the Conference will raise awareness to preserve the biodiversity necessary to sustain agriculture.

I wish the organizers all success and look forward for a fruitful outcome.

Dr Ravi Prabhu

Director General a.i
World Agroforestry (ICRAF) on behalf of
CIFOR-ICRAF

MESSAGE

My congratulations to the Indian Society of Plant Genetic Resources (ISPGR) on organizing the first National Conference on Plant Genetic Resources Management (NCPGRM 2022), a vital topic, in collaboration with ICAR, NBPGR, PPVFRA, Bioversity International, TAAS, NAAS, CIMMYT and other national and international organizations from 22-24 November, 2022 in New Delhi. CIFOR-ICRAF shares with all stakeholders our concern for the threat to biodiversity and the enhanced need for conservation and management of genetic resources. Our interest in the success of this conference arises especially from the threats to tree species diversity, including their ex-situ conservation and the need for research on conservation of problematic high-value but recalcitrant species. Hopefully, our complementary efforts go a long way in facilitating a holistic strategy for agrobiodiversity. Thank you for taking this important initiative, we wish you great success!

प्रो. रमेश चन्द
सदस्य
Prof. Ramesh Chand
MEMBER

सत्यमेव जयते

भारत सरकार
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E-mail : rc.niti@gov.in

Message

I am pleased to learn that the 1st National Conference on Plant Genetic Resources Management (NCPGRM2022) is being organized during November 22-24, 2022 at NASC, New Delhi. Scientists from different disciplines from across the world are expected to come together in the conference to share their views, ideas and promote research in different areas of plant genetic resources management. Management of plant genetic resources is assuming greater importance to improve nutrition and health and to address challenges of climate change and sustainability.

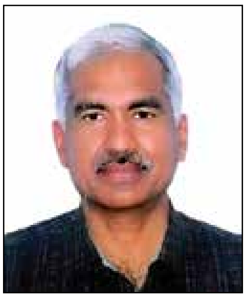
I am hopeful that the interactions between delegates and experts will lead to more meaningful research for the benefit of human mankind. I extend my greetings to the organizers and participants and wish the NCPGRM 2022 grand success.

(Ramesh Chand)

Place: New Delhi
Dated: 11th November, 2022

स्वच्छ भारत
एक कदम स्वच्छता की ओर

MANOJ AHUJA
SECRETARY



भारत सरकार
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कृषि एवं किसान कल्याण विभाग
Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture & Farmers Welfare

MESSAGE

I am delighted to know that 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) is being organized at NASC, New Delhi, during 22-24 November, 2022, jointly by Indian Society of Plant Genetic Resources (ISPGR), Indian Council of Agricultural Research (ICAR), New Delhi, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, Alliance of Bioversity International and CIAT, India Office , New Delhi, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. I hope that the deliberations by the academicians, scientists, professional experts and researchers during the conference would help to promote an approach for further enhancement in agriculture technologies to suit the growing needs of the Farmers and society. I wish the Conference all success.

(Manoj Ahuja)

November 03rd, 2022

सत्यमेव जयते

डॉ. राजेश सु. गोखले
Dr. RAJESH S. GOKHALE

आज़ादी का अमृत महोत्सव

सचिव
भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
जैव प्रौद्योगिकी विभाग
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SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
Block-2, 7th Floor, CGO Complex
Lodhi Road, New Delhi-110003

Message

I am pleased to learn that the 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) is being organized during 22-24th November, 2022 at NASC, New Delhi by the Indian Society of Plant Genetic Resources (ISPGR) in collaboration with the Indian Council of Agricultural Research (ICAR), New Delhi; ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi; Alliance of Bioversity International and CIAT, India Office, New Delhi and Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. I am sure that deliberations during this conference will provide an opportunity to discover the ways and means for achieving the future goal of PGR management.

Global food security is under an immense pressure than ever due to the vagaries of the nature and steep crop losses due to the emerging pest and pathogens. These challenges combined together can have a cumulative effect to reduce global food production to the quantum of ~ 40%. Plant genetic resources in this context are important and are a treasure as they are the reservoirs of genes which could combat stress (biotic/abiotic). Plant genetic resources are key drivers in addressing challenges of hunger and nutrition and are pivotal to the future of agriculture of our country.

The Department of Biotechnology, Government of India has been at the forefront in supporting conservation, characterization and valorization of plant genetic resources. Various programmes of the Department viz Bioresources, Secondary Agriculture and Agriculture Biotechnology are undertaking diverse activities for the vast Plant Genetic Resources of the country. Activities include development of field gene banks, databases and characterization for trait as well as gene discovery.

Recently, through its mission programmes (**Genetic Enhancement of Minor Pulses, Minor Oilseeds of Indian Origin and Characterisation of Genetic Resources of rice, wheat & chickpea**), the Department is undertaking world's largest exercise to characterize genetic resources of 29 crops, available in gene banks, for trait and gene discovery.

My best wishes for the success of the conference.

(Dr. Rajesh S. Gokhale)

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सत्यमेव जयते

डॉ. हिमांशु पाठक
सचिव, एवं महानिदेशक

Dr HIMANSHU PATHAK
SECRETARY (DARE) & DIRECTOR GENERAL (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
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Message

I am pleased to learn that the Indian Society of Plant Genetic Resources (ISPGR) in collaboration of Indian Council of Agricultural Research (ICAR), ICAR-National Bureau of Plant Genetic Resources (NBPGR), Alliance of Bioversity International and CIAT and Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi is organizing 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) on 22-24 November 2022 at New Delhi.

Agriculture and allied sectors continue to be the major source of livelihood security for millions of households across the world, especially in developing countries. This necessitates innovations for improving efficiency, equity and environment with simultaneous enhancements in farm productivity and profitability. Plant genetic resources (PGR) are the basis of crop improvement and their management and enhanced utilization has been an important scientific and socio-economic concern over the past half a century. The theme for the conference is very topical.

I am confident that the deliberations during the National Conference shall cover all the aspects of PGR management for its enhanced utilization for productive use and would help in streamlining the roadmap for addressing the future challenges in PGR management.

I extend my best wishes for the grand success of this Conference.

(Himanshu Pathak)

2 November, 2022

New Delhi

पौधा किस्म और कृषक अधिकार संरक्षण प्राधिकरण
(संसद के अधिनियम द्वारा निर्मित सांविधिक निकाय)
कृषि एवं किसान कल्याण मंत्रालय
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सत्यमेव जयते

के. वि. प्रभु पीएच.डी.
अध्यक्ष
K. V. Prabhu Ph.D.
Chairperson

Protection of Plant Varieties and Farmers' Rights Authority
(A Statutory body created by an Act of Parliament)
Ministry of Agriculture and Farmers Welfare
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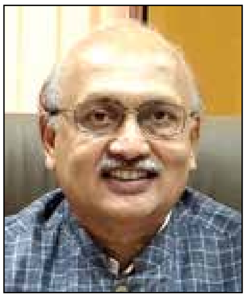

MESSAGE

I am pleased to know that 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) is being organized at NASC, New Delhi, during 22-24 November 2022, together by the Indian Society of Plant Genetic Resources (ISPGR), Indian Council of Agricultural Research (ICAR), New Delhi, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, Alliance of Bioversity International and CIAT, India Office, New Delhi, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. I am sure that the deliberations of the conference will prove a step forward in generating a new perspective for reorientation of PGR management. I convey my best wishes for the success of the congress.

(K.V. Prabhu)

Dated: 14th November, 2022

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MESSAGE

My greetings for the 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) to be held during 22-24 November 2022 at NASC, New Delhi. Plant Genetic Resource (PGR) is the basis of crop improvement and management of PGR has been an important scientific and socio-economic concern over the past half a century. In particular, genomics science has emerged as a potential tool in PGR management. Thus, the theme for the conference is very appropriate and I am confident that it will cover all aspects of PGR management for its enhanced utilization. I extend my greetings to the organizers and participants and wish the NCPGRM 2022 a grand success.

(A.K. SINGH)

डा. आनन्द कुमार सिंह
उपमहानिदेशक (बागवानी विज्ञान)

Dr. Anand Kumar Singh
Deputy Director General (Hort. Sci.)

भाकृअनुप
ICAR

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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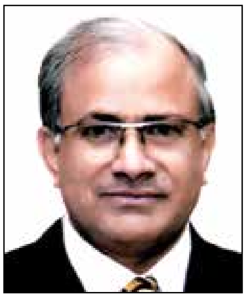
PUSA, NEW DELHI-110 012 (INDIA)



Nov. 10. 2020

Message

It is a matter of great pleasure to know that the Indian Society of Plant Genetic Resources (ISPGR), is organizing the 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) during 22-24 November 2022 at NASC, New Delhi, in collaboration with Indian Council of Agricultural Research (ICAR), New Delhi, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, Alliance of Bioversity International and CIAT, India Office, New Delhi, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. The theme for the conference is very appropriate and I am confident that it will cover all aspects of PGR management for its enhanced utilization. I am sure that the deliberations of the conference will prove a step forward in generating a new perspective for the reorientation of PGR conservation and utilization.

My best wishes for the success of the conference.

(A. K. SINGH)

Phone: (Off.) 91-11-2584 2068, Fax: +91-11-2584 1976;

Dr Gyanendra Pratap Singh

Director
ICAR-National Bureau of Plant Genetic Resources
Pusa Campus, New Delhi

03 November, 2022

Message

I am happy the 1st National Conference on Plant 1st National Conference on Plant Genetic Resources Management (NCPGRM 2022) is being organized at NASC, New Delhi, during 22-24 November 2022, together bythe Indian Society of Plant Genetic Resources (ISPGR), Indian Council of Agricultural Research (ICAR), New Delhi, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, Alliance of Bioversity International and CIAT, India Office, New Delhi, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi.

This initiative at the National level where the deliberations on management of plant genetic resources and their importance is highly appreciated. With the little time left to achieve the target of SDG goals and Aichi targets for food security in this challenging time, the deliberations in this congress would be vital for the future course of action in plant genetic resource management.

This congress would be right platform to deliberate on the country's position on various decisions taken during the recently concluded GB-9 of ITPGRFA and would provide the participants exposure to the policy matters related to PGR management.

The conference would strengthen the linkage of NBPGR with various stakeholders and help in dissemination of new knowledge and value-added germplasm of different agri-horticultural crops. Any shortcoming of the stakeholders would be deliberated on and the same would be taken for further refinement of value addition to germplasm.

I wish all the delegates and the resource person to have wonderful stay during conference with warm hospitality from great team of organizers from NBPGR and to have deliberation for effective management of PGR to achieve SDGs.

GPSingh 3/11/2022

Gyanendra Pratap Singh

Managing Our Agrobiodiversity

R.S. Paroda

Chairman, Trust for Advancement of Agricultural Sciences (TAAS);
Former Secretary, DARE and DG, ICAR, New Delhi.

Agrobiodiversity, a vital sub-set of biodiversity comprises: (i) harvested crop varieties, livestock breeds, fish species; and (ii) non-domesticated resources in production ecosystems, *viz*., soil micro-biota, pollinators, and other non-harvested species in the environment that support food production ecosystems. It is a result of interaction between genetic resources and environment as influenced by natural/anthropological selection processes over millennia. Agrobiodiversity encompasses the variability of genetic resources for food and agriculture as well as local knowledge and culture that are necessary for the key functions of human survival. It has helped in increasing agricultural productivity, food and nutrition security through diversification and needed stability of farming systems. Thus, agrobiodiversity immensely helps in reducing pressure on exploitation of fragile areas, forests and endangered species.

Population explosion especially during the last one century has exponentially increased the demand for food, feed and fiber leading to over-exploitation of natural resources and the negative effects of climate change. Further, agrobiodiversity profiles have rapidly altered in the recent past resulting in genetic vulnerability of agriculture. Its eenhanced and scientific use is critical for breeding better varieties and breeds. Also, it would help in combating both biotic (insect-pests and diseases) and abiotic (drought, heat, cold) stresses, building better ecosystem services (pollinators) and reducing the use of costly inputs (fertilizers, pesticides, energy, etc.). Science and technology developments in areas such as genetic engineering, genomics, biotechnology, nanotechnology, bioinformatics, and synthetic biology, coupled with information and communication technology (ICT), have increased the speed, scale and efficiency in genetic improvement activities. New technologies such as genome-editing, phenotyping, genotyping, genetic engineering etc. are the real game-changers that will dictate how genetic resources are researched in future and used effectively. Hence, the existing agrobiodiversity would remain the 'hardware and software codes of nature', requiring systematic deciphering through innovations for enhancing effective use of agricultural crop varieties and animal breeds for their use, through new science. Hence, sustainably conserving through use of available diversity would be the best option for the sustainability of agriculture in future.

India is a mega diversity hotspot, endowed with broad spectrum of agrobiodiversity. To manage this agrobiodiversity, Indian NARS has established five Genetic Resources Bureaux dedicated to plants, animals, fish, microbes, and useful insects. Significant progress has been made over the past three decades for collecting, conservation, documentation, and use of genetic resources. Despite such a strong institutional network in place, much is still required to be done to meet the emerging challenges towards food, nutrition and environmental security of our ever-growing population. Also, concerted efforts are needed for greater exchange of genetic resources, traditional knowledge and advanced technologies.

The National Gene Bank at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi currently houses over 4.5 lakh valuable accessions (80% indigenous and 20% exotic) which need to be systematically evaluated, characterized, documented and used gainfully. Regarding indigenous breeds, India, has unique 199 registered breeds of livestock and poultry. However, considering country's vast geographic and ecological regions, a sizeable undefined and non-descript population, especially of cattle and goat exist, which must be studied scientifically. In this regard, the National Bureau of Animal Genetic Resources (NBAGR), Karnal has initiated characterization and documentation of all non-descript animal genetic resources in a mission mode. Also, greater attention is required for exploring and characterizing new breeds of indigenous farm animals, establishment of the breed societies, cryopreservation of germplasm, and development of information system. Agriculturally important microorganisms are crucial for humankind due to their direct involvement in cycling of biologically important minerals and nutrients, environmental remediation, crop production as well as protection. Therefore, acquisition, characterization, cataloguing and conservation of microbes from different habitats has to be taken care of. Globally, around 820 culture collections exist in 78 countries holding more than 3 million registered microbial strains. The Microbial Culture Collection at the National Bureau of Agriculturally Important Microbes (NBAIM), Mau, comprises 7,647 accessions of bacteria, fungi and yeasts. The National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, maintains 2 lakh preserved insects and 130 live insects. It annually supplies 100 million insect samples in addition to insect control agents.

To have an effective and efficient management system for our valuable agrobiodiversity, a forward-looking science-based strategy around Delhi Declaration is required to be adopted to address the following:

- Delineate the expected contributions of agrobiodiversity to achieve Sustainable Development Goals (SDGs) as well as to sustain our food, nutrition, and environmental security. There is need to develop Agrobiodiversity Index at the national level to monitor and enhance both sustainable conservation and germplasm utilization.
- Accord priority to "conserve through use" the landraces and traditional cultivars, both *ex situ* and on-farm, by ensuring availability of their quality seeds, strengthening local seed systems and community seed banks, and creating niche by studying specific consumer-market linkages. Documenting and monitoring agrobiodiversity 'on-farm' is also required for preventing losses of both genetic diversity and available rich indigenous knowledge.
- Strengthen genetic resources informatics at the national level such that gene banks function as "Bio-Digital Resource Centers".
- Develop enabling policies to strengthen research and use of local food systems mainly around millets, pseudo-cereals, pulses, local vegetables, spices, medicinal plants, perennial fruit yielding shrubs, etc. to effectively address malnutrition and hidden hunger among women and children.
- List of crops included in Annex 1 of ITPGRFA needs to be expanded to include other agricultural crops of national, regional, and global significance.
- National Gene Fund must be strengthened for supporting conservation and sustainable use of agrobiodiversity, especially at the farm and community levels. Through this Fund, incentives could be given to farmers cultivating native genetic resources of crops, and animals having economic importance.
- Traditional knowledge, associated with agrobiodiversity, available with rural and tribal communities, must be comprehensively documented on priority before it is lost for ever.
- Effective use of new science, especially the genomics, phenomics, genome-editing, genetic engineering, bioinformatics, AI, IoT, 'big data' etc be taken full advantage of, especially for

searching the new genes and their effective deployment for needed genetic enhancement and faster growth of Indian agriculture.

- Greater importance to agrobiodiversity management be henceforth accorded through networking and partnership among stakeholders, especially by promoting the public-private partnership at the national, regional, and global levels.
- Continued exchange of genetic resources under both bilateral and multi-lateral systems ensuring legal protocols, standard material transfer (SMT) agreements and mutually agreed access benefit sharing (ABS) systems.
- Develop a national level invasive alien species policy and strengthen the quarantine system for greater biosecurity during exchange of germplasm

Contributions of Dr R.S. Paroda to the Field of Genetic Resource Management*

Anuradha Agrawal

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ABSTRACT

Dr RS Paroda has been a champion for the cause of genetic resources (GR) management for over five decades. His passion for the subject has led to massive reforms in infrastructure, capacity building and projects/programs in the arena of agrobiodiversity management and use, which has a direct bearing in increasing agricultural productivity leading to food and nutritional security. The Indian Society for Plant Genetic Resources (ISPGR) established in 1987, was his brainchild and as the Founder (1987-88) as well as current (2022-24) President of the society, he has immensely contributed in its overall growth and visibility. This paper gives a brief overview on the contributions of Dr RS Paroda in the area of GR management.

Keywords: Genebank, ISPGR, National Bureau, Regional and Global Networks

Introduction

Genetic resources are the building blocks for global food, nutrition and environmental security. Accordingly, their efficient management such as exploration, evaluation, exchange and conservation through use is fundamental for the survival of humanity and for posterity. Recognising this and being an ardent supporter, Dr Rajendra Singh Paroda has made extra-ordinary contributions in the field of genetic resource (GR) management at the national, regional and global level, as elaborated below.

GR Contributions at National Level

As Director, National Bureau of Plant Genetic Resources (NBPGR) from 1985-1987, Dr Paroda took major initiative to build one of the most modern Indian Genebank at New Delhi, seeking then the funding support of US $ 25 million from the United States Agency for International Development (USAID). The Genebank was inaugurated by the then Hon'ble Vice-President of India, during the II Crop Science Congress organised by Dr Paroda in 1996. This Genebank, the second largest in the world, currently houses more than 460, 000 valuable accessions of different crops.

Considering the importance of capacity building in the field of genetic resources, he not only got all 100 scientists of NBPGR trained in the USA, but was also instrumental in initiating MSc (PGR) course in 1997 and PhD (PGR) from 2004 onwards at the Post-Graduate School of Indian Agricultural Research Institute (IARI), New Delhi.

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For promotion of PGR science and realising the importance of publishing scientific literature, Dr Paroda established the Indian Society of Plant Genetic Resources (ISPGR) in 1986 which got registered in 1987 and has made significant contributions, including holding of a few national and international conferences. These include: i) National Symposium on Plant Genetic Resources held in New Delhi in 1987; ii) National Symposium on Conservation of Agrobiodiversity held in 1997; iii) Role of Science and Society towards Plant Genetic Resources Management – Emerging Issues, held in 2005, New Delhi; iv) National Symposium on Recent Global Developments in the Management of Plant Genetic Resources held at New Delhi, 2009 v) Brainstorming Meeting on Strategies for Implementation of Delhi Declaration for Agrobiodiversity Management in New Delhi in 2017; vi) National Webinar on Implementation of Access to Plant Genetic Resources and Benefit Sharing (ABS) in 2020. The proceedings of these events have served effectively the purpose of knowledge dissemination among PGR scientists.

Convinced of the importance of genetic resources, Dr Paroda as Director General, Indian Council of Agricultural Research (from 1994-2001) created four new National Bureaux on: (i) Animals, (ii) Fish, (iii) Micro-organisms, and (iv) Insects. He also launched a National Action Plan on PGR management in 1999, which spurred collections (almost doubled in five years) and evaluation of genetic resources through inter-institutional collaboration at the national level.

Under his visionary leadership, two important national laws relating to genetic resources were drafted, which were enacted by the Parliament in record time. These are: i) Protection of Plant Varieties and Farmers' Rights Act (2001), and ii) Biological Diversity Act (2002). He also served from 2011-2014 as the Chairman, National Advisory Board on Management of Genetic Resources and ensured effective coordination and collective action by all the Bureaux.Recognising his significant contributions in the field of genetic resource management and agricultural development, Dr Paroda was awarded the most prestigious national civil honour 'Padma Bhushan' by the Hon'ble President of India in 1998. He also received the famous 'Dr Norman Borlaug Award' from President of India in 2006 and 'Dr MS Swaminathan Award' in 2020. Recognising his enormous support for genetic resource programs, ICRISAT honoured him by naming its Genebank as 'Rajendra S. Paroda Genebank' in 2005.

Dr R.S. Paroda receiving the Padma Bhushan award from Hon'ble President of India, Shri K.R. Narayanan in 1998

GR Contributions at Regional Level

(i) At the regional level, while working as Regional Plant Production and Protection Officer, FAO, Bangkok (1992-1994), and as Executive Secretary, Asia Pacific Association of Agricultural Research Institutions (APAARI) for more than 22 years, Dr Paroda could initiate a number of regional PGR networks for evaluation and use of genetic resources in different countries. These were on:

(ii) Tropical Asian Maize Network (TAMNET) involving International Maize and Wheat Improvement Center (CIMMYT), Mexico;

(iii) Cereals and Legumes Asia Network (CLAN) involving the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, International Centre for Agricultural Research in the Dry Areas (ICARDA), Syria and World Vegetable Center (AVRDC), Taiwan.

(iv) Council for Partnership on Rice Research in Asia (CORRA) involving International Rice Research Institute (IRRI), Philippines.

(iv) Inter-regional Network on Cotton in Asia and North Africa (INCANA) involving Association of Agricultural Research Institutions in the Near East & North Africa (AARINENA), APAARI, Central Asia and the Caucasus Association of Agricultural Research Institutions (CACAARI), Agricultural Research, Education and Extension Organization (AREO) Iran and ICARDA.

(vi) Inter-Regional Network on Cotton in Asia and North Africa (INCANA) involving Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), APAARI and CACAARI.

(vii) Asia-Pacific Group of Fisheries and Aquatic Research (GoFAR) involving World Fish Center, Malaysia.

(viii) Three regional PGR networks for South Asia, Southeast Asia and the Pacific region facilitated by Bioversity International.

(ix) These networks helped in joint evaluation and exchange of useful genetic resources by concerned NARS in each sub-region.

As Head of CGIAR Consortium for Sustainable Agriculture in Central Asia and the Caucasus (CAC) region, Dr Paroda catalysed the process of strengthening the Genebanks in Azerbaijan and Uzbekistan and created new Genebanks in Armenia, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan. The one stablished at Krasnyvadopad in Kazakhstan has been named as 'Raj Paroda Genebank'. For these extra-ordinary efforts, the CAC team under the leadership of Dr Paroda had won the prestigious "King Baudouin Award" of CGIAR.

To promote regional cooperation and scientific networks, Dr Paroda took major initiative to organise a number of Regional Expert Consultations as follows:

(i) Regional Roundtable Meeting on Implementation of the International Treaty for Plant Genetic Resources for Food and Agriculture in 2005 in Bangkok;

(ii) Expert Consultation on Progress of Research Networks at ICRISAT in 2007;

(iii) International Symposium on Agrobiodiversity in Suwon in 2010 which led to adoption of The Suwon Agro-Biodiversity Framework.

(iv) Regional Workshop for Implementation of Suwon Agrobiodiversity Framework in 2011 in Kuala Lumpur;

(v) Regional Consultation on Genetic Resources in the Pacific held at Fiji (2012);

(vi) Regional Consultation on Medicinal Plants in 2013 in Bangkok

GR Contributions at Global Level

At the global level, Dr Paroda served as the Chairman of the Working Group on Farmers' Rights of FAO Commission on Plant Genetic Resources (1995-97) when he could get the Farmers' Right defined and agreed by the Commission. He also served as member of the International Committee constituted for Plant Genetic Resources by the Board on Agriculture, National Academy of Sciences, Washington for the period 1990-94 and recommended renovation and strengthening of the Genebank.

As founder chairman, Global Forum on Agricultural Research (GFAR), FAO, Rome, Dr Paroda had organised a Global Conference in 2000, in collaboration with Bioversity International in which "Dresden Declaration on Plant Genetic Resources for Food and Agriculture" was adopted, which defined a road map for strengthening PGR activities at the global level. Dr Paroda as Chair of GFAR also worked passionately and closely with Dr Ismail Serageldin, Chairman, CGIAR and Dr Geoff Hawtin, Director General, IBPGR to convince donors to support the cause of conserving global genetic resources. These efforts eventually led to the establishment of Global Crop Diversity Trust (GCDT) in 2004.

As Chairman, TAAS, Dr Paroda organised a 'Global Consultation on Use and Management of Agrobiodiversity for Sustainable Food Security' in 2013 at New Delhi. As President, ISPGR (2016-18), he further visualised and organised very successfully the '1st International Agrobiodiversity Congress (IAC)' with 1,000 participants from 60 countries during 6-9 November, 2016 at New Delhi, which was inaugurated by the Hon'ble Prime Minister Mr Narendra Modi. Besides its proceedings, the conference also adopted "Delhi Declaration on Agro-biodiversity Management''. The IAC has now become a regular event as 2nd Conference was held in November, 2021 in Rome organised by the Government of Italy in collaboration with Bioversity International and ISPGR. The third one is expected to be held in China in 2025.

Publications on GR

Dr Paroda brought out several important publications including books, strategy papers and reports for creating awareness on conservation and use of agrobiodiversity. Significant ones include:

(i) Life Support Plant Species - Diversity and Conservation. National Bureau of Plant Genetic Resources, New Delhi. Eds. Paroda R.S., Kapoor Promila, Arora R.K. and Bhag Mal. 1987. 190p.

(ii) Plant Genetic Resources-Indian Perspective, Eds. - Arora R.K., Chandel K.P.S. and Paroda R.S., National Bureau of Plant Genetic Resources, New Delhi 1988. 545p.

(iii) Plant Genetic Resources - Conservation and Management Concepts and Approaches. Eds - Paroda R.S. and Arora R.K., International Board for Plant Genetic Resources, 1991, 392 p.

(iv) Agro-Biodiversity, Conservation, Management and Use. Eds.-Paroda R.S., Rai M. and Gautam P.L., 1998.

(v) Status of Plant Genetic Resources Conservation and Utilization in the Asia-Pacific Region: Regional Synthesis Report. Eds. – Paroda R.S. and Chandel K.P.S., 2000.

(vi) Strategy Paper on Implementing the International Treaty to Address Current Concerns about Managing our Plant Genetic Resources by Dr. R.S.Paroda, January, 2012.

(vii) "Reorienting Indian Agriculture" by Dr RS Paroda published by CABI, London, 2018. 296p, which has a Section on Managing Plant Genetic Resources encompassing three chapters (a) The International Treaty–Current Concerns; (b) Agrobiodiversity: Dynamic Change Management, and (c) Managing Agrobiodiversity Through Use: Changing Paradigms.

Conclusion

Dr RS Paroda has been a champion for the cause of genetic resources management for over five decades. Rightly nicknamed as "Genebank Guru", his passion for the subject has led to massive reforms in infrastructure, capacity building and projects/programs in the arena of agrobiodiversity management and use, which has a direct bearing in increasing agricultural productivity leading to food and nutritional security. The ISPGR established in 1987, was his brainchild and as the Founder (1987-88) as well as current (2022-24) President of the society, he has immensely contributed in its overall growth and visibility. Indian agriculture is fortunate to have a globally recognized visionary like him. On the occasion of his 80th birthday on August 28, 2022, the genetic resources fraternity wishes this octagerian and living legend many more years of healthy life and happiness, and he continues to remain a torch bearer for generations ahead.

The Biological Diversity Act 2002 and The Proposed Revision Bill 2021: An Analysis

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ABSTRACT

The regulations for access and use of biodiversity are provided in the Biological Diversity Act 2002 (BDA) of India. The BDA was promulgated after India's accession to the Convention on Biological Diversity. After the implementation of BDA various stakeholders expressed concerns for effectiveness of regulations to meet the objectives of the BDA. The Ministry of Environment Forests and Climate Change initiated the process of Amendments in the BDA with consultations among various stakeholders, Ministries, Industries and researchers. The paper attempts to address concerns for regulation of components of agrobiodiversity as a research organisation involved in exchange of these components. Suggestions are provided for improvements in the proposed Amendment Bill 2021 for facilitated access to such resources for the research community involved in improvement of crops, livestock, and agriculture production, essential for food security of the current and future generations.

Key words: Biological Diversity, Agrobiodiversity, regulations for access and Benefit Sharing, Amendment Bill

Introduction

Biological diversity is the sum total of all life forms on earth. It includes diversity within species, among species and ecosystem diversity. Triggered by demographic changes, climatic changes and human activities, several species are now facing extinction. The United Nations Environment Programme (UNEP) established an *Ad Hoc* Working Group of Experts on Biological Diversity way back in November 1988 to explore the possibility of an International Convention on Biological Diversity, and in May 1989 it established the *Ad Hoc* Working Group of Technical and Legal Experts to prepare an international legal instrument for conservation and sustainable use of biological diversity. Its work culminated in May, 1992 with the Nairobi Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity (CBD). The Convention was opened for signature on 5 June, 1992 at the United Nations Conference on Environment and Development (the Rio "Earth Summit"). It remained open for signature until 4 June 1993, and by that time it had received 168 signatories, including India. The CBD, 90 days after the 30th ratification, entered into force on 29 December, 1993. The CBD was inspired by the world's growing commitment to sustainable development. It was a major step towards the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources (https://www.cbd.int/history/).

India being a Party to the CBD enacted the Biological Diversity Act (BDA), 2002, and notified the Biological Diversity Rules (BDR), 2004. Further, being a Party to the Nagoya Protocol on Access and Benefit Sharing, 2010, the Guidelines on Access to Biological Resources and Associated Knowledge and Benefit Sharing were notified in 2014 (referred hereinafter as ABS Guidelines). The objectives of the BDA are (i) conservation of biodiversity, (ii) sustainable use of its components, and (iii) fair and equitable sharing of benefits arising out of the use of biological *resources*, commonly known as Access and Benefit Sharing (ABS). The major provisions in the CBD on benefit sharing are enshrined in Article 8(j), 15, 16 and 19 of the Convention. Though Article 8(j) of the CBD promotes sharing of benefits arising out of the utilization of traditional knowledge of indigenous and local communities, and it leaves the responsibility to achieve this objective on the domestic policies of the member countries. Article 15 of the Convention stipulates provisions regarding access to genetic resources. Article 16 focuses on access to and transfer of technology, and Article 19 deals with handling of biotechnology and distribution of its benefits.

The two main concepts in the CBD that provide a link for the legal ABS system for the countries as providers of the biological resources, are Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT). Prior Informed Consent (PIC) refers to permission given by the competent national authority of a provider country to a user prior to accessing genetic resources, in line with an appropriate national legal and institutional framework. The MAT refers to the agreements reached between the providers of genetic resources and users on the conditions of access and use of the resources, and the benefits to be shared between both parties (https://www.cbd.int/abs/about). The ABS serves as a compensation mechanism between the providers and the users of genetic resources.

Due to the limitations of the voluntary Bonn guidelines in operationalizing ABS, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization to the Convention on Biological Diversity (The Nagoya Protocol, 2010) was adopted as a legally binding instrument to further facilitate access and sharing of benefits. Along with the basic provisions of the CBD on ABS, the Protocol forms the central body of law that defines how the ABS system should operate among countries in a bilateral exchange of biological resources. The Nagoya Protocol rephrases and makes more concrete the objectives of CBD pertaining to ABS (IEEP, Ecologic and GHK, 2012). Accordingly, benefit sharing entails more than sharing a certain percentage of the profits when a product is developed on the basis of a genetic resource (Grieber *et al*, 2012). The Nagoya Protocol specifies that benefit sharing arrangements shall be established through MAT between the provider and user of genetic resources, on a bilateral contract basis.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), 2004, popularly known as *The Plant Treaty*, established a multilateral system (MLS) of access and benefit sharing for plant genetic resources, whereby contracting parties agree to virtually pool a subset of the genetic resources of 64 crops, 35 food crops and 29 forage crops (popularly referred to as Annex I crops), to be used for utilization and conservation for research, breeding and training for food and agriculture (Article 12.3(a)). The benefits arising from use of plant genetic resources are to be shared fairly through methods such as exchange of information, access to technology, capacity building, and sharing of monetary and other benefits of commercialization. The Treaty establishes a multilateral system where parties who benefit monetarily from materials from the MLS are to make a payment to a joint fund, which can be shared with all parties.

Further, a *Material Transfer Agreement (MTA)* was included in the Treaty, which contains the benefit-sharing requirement under certain conditions (Moore *et al*, 2005).

Implementation of the BDA 2002

The Government of India established the *National Biodiversity Authority (NBA)* in 2003 to implement the BDA. The provincial governments established State Biodiversity Boards (SBBs) as provided for in Section 22 of the Act, and constituted Biodiversity Management Committees (BMCs) at local level, as provided for in Section 41. Similarly, the Union Territories (UTs) are in the process of establishing the Biodiversity Councils.

The BDA regulates activities of access to biological resources and/ or associated knowledge for research, commercial utilization, bio-survey and bio-utilization (Section 3); transfer of results of research to non-Indian entities (Section 4); applying for Intellectual Property Rights (IPR) in or outside India, based on any research or information on biological resources (Section 6) and transfer of accessed biological resources (Section 20). The NBA is implementing the provisions of the BDA and BDR thereof (www.nbaindia.org).

The process of Revision of the BDA 2002

After enactment of the Act many stakeholders expressed concerns for somewhat stringent regulations for access to components of Biological diversity especially for research. The process of revision of the Act was thus initiated by the Ministry of Environment Forests and Climate Change (MOEF&CC), the nodal Ministry for implementation of the Act with the following steps:

(a) MOEF&CC conducted series of meetings with stakeholders (Ministries, Departments and other Sectors) during 2017-19.

(b) First draft shared by MOEF&CC for Inter-ministerial consultations 2020.

(c) The Revised Amendment Bill 2021 was tabled in the Parliament on December 16, 2021

(d) The Bill was opened up for public opinion

(e) Joint Parliamentary Committee (JPC) set up to review the Amendments on January 16, 2022

(f) JPC is now engaged in the review of the content of the Bill and will provide recommendations in a report expected to be placed before the Parliament soon. In the meantime, the JPC has met several times,

The Amendments were analysed with special reference to Agrobiodiversity with the understanding that the cultivated agrobiodiversity is different from naturally occurring biodiversity and it iand its the grobiodiversity is different from naturally occuring with the following steps: rocess of revision of the Act was s the mandate of Ministry of Agriculture and Farmers Welfare (MoA&FW). The rationale brought out in the following points is the basis of the changes suggested in the Amendments:

1. Genetic Resources for Food and Agriculture (GRFA) are the basic requirement indispensable for genetic improvement of crops/animals/fish etc. which in turn are the basic requirements for food, nutritional and health security. Their distinctive features and special nature is well-recognized and constitute the most important part of biodiversity (called agro-biodiversity) important for sustenance of humanity.
2. Reiterating the fact that GRFA are very important for food security and no country is self-sufficient in terms of GRFA, access to a wide range of GRFA and related information is crucial for sustainable agriculture and food security.

3. In 2001, at the global level, Food and Agriculture organization of the United Nations promulgated a legally binding International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (www.planttreaty.org), in harmony with CBD, to (i) recognize the enormous contribution of farmers to the diversity of crops that feed the world; (ii) establish a global system to provide farmers, plant breeders and scientists with access to plant genetic materials and (iii) ensure that recipients share benefits they derive from the use of these genetic materials. The ITPGRFA facilitate PGRFA under a multilateral system of exchange for crops listed under Annex 1 of the text of the treaty (www.planttreaty.org),.
4. India ratified the ITPGRFA on June 10, 2002. To fulfil its obligations to provide facilitated access to PGRFA, Ministry of Environment & Forest and Climate Change (MoEF&CC) vide its notification No. S.O. 3232 (E) dated 17.12.201, in consultation with the National Biodiversity Authority (NBA), declared that the Department of Agriculture and Cooperation [now designated as Department of Agriculture and Farmers' Welfare, (DA&FW)] under the Ministry of Agriculture and Farmers' Welfare (MoA&FW) may from time to time specify such crops as it considers necessary from the crops listed in the Annex-I of the ITPGRFA, being food crops and forages covered under the MLS thereof; and accordingly exempt them from Section 3 & 4 of BDA 2002, for the purpose of utilization and conservation for research, breeding and training for food and agriculture. Thus, for the purpose of utilization and conservation or research, breeding and training for food and agriculture, are accessed and used as per the guidelines (https://agricoop.nic.in/en/guidelines/seeds) of DA&FW.
5. Further, the DA&FW under MoA&FW is also responsible for providing the best planting materials available in the world to the Indian farmer and to increase productivity, farm incomes and export earnings under the New Policy on Seed Development, 1988 (https://agricoop.nic.in/en/divisiontype/seeds). This includes import of seeds and planting materials on case-to-case basis under license issued by Plant Protection Adviser on the basis of the recommendations of EXIM Committee.
6. The Department of Agricultural Research and Education (DARE) under the MoA&FW coordinates and promotes agricultural research and education in the country, primarily through Indian Council of Agricultural Research (ICAR), an autonomous body under its administrative control (http://dare.nic.in). DARE is a premier research organization for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. This is done through >97 ICAR institutes, 53 agricultural universities, 6 Bureaux, 18 National Research Centres, 25 Project Directorates, and 89 All India Coordinated Research Projects spread across the country, making it one of the largest national agricultural research systems in the world.
7. As per allocation of business (w.e.f.1973), and as per list I of the Seventh Schedule of the Constitution of India, international cooperation and assistance in the field of agricultural research and education including relations with foreign and international agricultural research institutions and organizations is assigned to ICAR/DARE. Consequential to the business allocated, ICAR/DARE has the mandate to introduce, exchange and explore new resources in crops, animals, fish, microbes and insects from other countries. The release of new varieties in these resources is dependent on unrestricted use of useful genetic resources (collectively known as Biodiversity for Food and Agriculture or GRFA) (see achievements on https://icar.org.in/).
8. The rules/guidelines for the purpose of exchange of GRFA, are being followed by DARE though duly approved instruments like Material Transfer Agreements for Indian researchers/ farmers/ breeders (www.nbpgr.ernet.in). These were formulated in consultation with

MoEF&CC and NBA. The import and quarantine procedures for exchange of GRFA are also delegated to ICAR/DARE including issuance of phytosanitary certificates and import permits under the Plant Quarantine (Regulation of Import into India) Order 2003 (https://plantquarantineindia.nic.in). For all material exported through ICAR/DARE using MTAs, information is duly provided to the NBA as per provisions of Section 5 of BDA 2002. Thus, ICAR/DARE is already fully geared to execute exchange of GRFA as per provisions of BDA 2002.

9. Conservation, research, and sustainable use have been the mandate of five National Bureaus (for GRFA of plants, animal, fish, microbes and insects) established by ICAR. The institutional infrastructure, trained human resources, expertise and experience in the area of GRFA exists with ICAR in India. ICAR has been partnering NBA in all technical, scientific, and implementation matters ever since NBA has started functioning. Just as ICFRE has been added in addition to the Ministry, ICAR need to be included as the *ex officio* member to assist/oversee matters related to access to GRFA, exchange internationally, conservation ex situ, documentation and data-cross-talks, technological advances posing challenges to conventional systems, etc.

10. With the enactment of BDA 2002, subsequent BDA Rules 2004, and regulations, a decline of exchange of GRFA has been experienced, affecting the overall research especially for genetic improvement. ICAR-National Bureau of Plant Genetic Resources (NBPGR) has found that only 27% of the requests of Indian scientists for germplasm access from other countries have been met after implementation of the BDA 2002 (http://naas.org.in). This issue was flagged by ICAR/DARE in earlier consultations with NBA and MOEF&CC.

11. The purpose of the Amendments should be to facilitate the allocation of business to different Ministries and Departments rather than affecting the activities in adverse manner. For example, ease of doing business has been addressed in case of normally traded commodities such as cultivated medicinal plants in the Amendment. However, the issues faced by breeders, scientists, researchers in India and those in other countries, has not been addressed in the Bill. The foreign researchers provide germplasm requested by Indian scientists free of cost (or with minimal handling charges on per sample basis). However, they do not receive such response from Indian researchers due to BDA regulations. For example the prescribed fee as per Form No. 1 of BDA Rules 2004 (Rs. 10,000/- for application, besides subsequent monetary ABS) often acts as a deterrent for foreigner researchers as well as farmers, seeking GFRA for research purposes. To rectify this, there is need to allow reciprocal exchange and good-will exchange on a case-to- case basis under the Act with delegation of powers to DARE.

Three major concerns and changes suggested in Principal Act (BDA 2002) dealing with Agro-biodiversity (Section 13) for Delegation of Powers to Department of Agriculture Research and Education (DARE), Ministry of Agriculture & Farmers Welfare (under Section 16)

1. There is need for special treatment for access and use of GRFA, also known as Biodiversity for Food and Agriculture, a major subset of agrobiodiversity. The Amendment has rightly given importance to sustainable use of cultivated medicinal plants; similar treatment is required for GFRA, since the research, development and breeding using GFRA is very important for ensuring long-term food, nutritional and health security for humanity. To facilitate efficient access and use, powers need to be delegated to Secretary DARE & DG ICAR (MoA&FW) for access and use of GRFA, under Section 13 of the BDA 2002, in the Amendment Bill 2021.

2. **Section 2 in the Amendment Bill 2021regarding definitions of terms**

   Some of the definitions need rectification both in the Amendment Bill 2021 (e.g. "access", "bio-survey", "biological resources", "derivatives", "folk varieties"), as well as in the Principal Act ("Commercial utilization", "agrobiodiversity"). Further, certain terms have not been defined in the Principal Act and Amendment Bill like "occurring in India", such that to distinguish indigenous (native) biological resources, biological resources that are available in India but were imported (exotic) and have naturalized, biological resources imported in India (post-CBD),Exotic/imported material that may arrive in future for commercial and or research purpose. Therefore, the regulation to be defined accordingly; Other terms like "conventional breeding", "traditional practices", "codified traditional knowledge" and "farmers' varieties" need to be included in the Act for clear interpretation, and for harmonization with other related statutes e.g. Protection of Plant Varieties and Farmers Rights Act (PPV&FRA), 2001.

3. **Concerns regarding conservation of biological diversity**

   Amended bill facilitates registered AYUSH practitioners (indigenous medicine) to access any biological resource and associated knowledge for commercial utilisation, without giving prior intimation to the State Biodiversity Boards (SBB). This raises ecological concerns and may lead to greater trade in biodiversity as opposed to primary objective of the BDA 2002, namely conservation and sustainable utilization of biodiversity and associated knowledge.

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Role of NBPGR in PGR Conservation and Utilization in India

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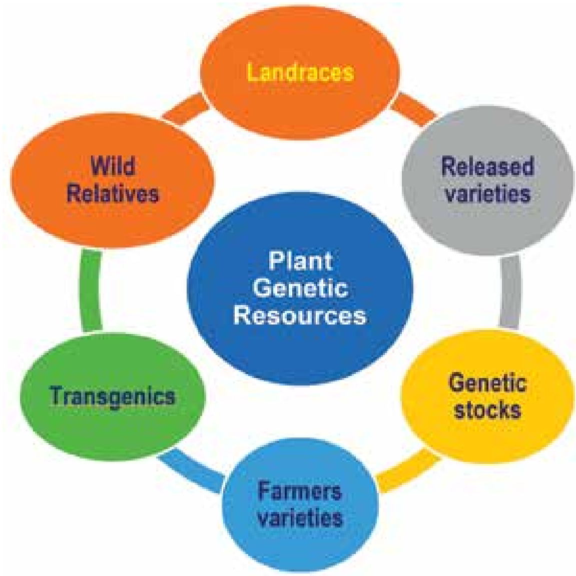
The National Bureau of Plant Genetic Resources (ICAR-NBPGR) was established by the Indian Council of Agricultural Research (ICAR) in 1976 with its headquarters at New Delhi. It is a nodal institute at the national level for acquisition and management of indigenous and exotic plant genetic resources (PGR) for agriculture, and to carry out related research and human resources development for sustainable growth of agriculture. The Bureau is also vested with the authority to issue Import Permit and Phytosanitary Certificate and conduct quarantine checks in seed material and vegetative propagules (including transgenic material) introduced from abroad or exported for research purposes.

ICAR-NBPGR has its headquarters in New Delhi that hosts the second largest genebank in the world. The operations of the bureau are Plant Exploration and Germplasm Collection, Germplasm Evaluation, Germplasm Conservation, Genomic Resources and Plant Quarantine in addition to the Units of Germplasm Exchange and Tissue Culture and Cryopreservation. It has the network of 10 Regional Stations covering different agro-climatic zones to carry out PGR activities.

The infrastructural facilities and research at the Bureau have been strengthened manifold since 1985. In November 1996, the new genebank building along with its most modern facilities was inaugurated and was notified as the National Genebank. This facility was modernized, upgraded and retrofitted in 2021. Medium-term germplasm storage modules are installed and operational at the regional stations located at Hyderabad, Jodhpur, Shimla, Bhowali, Akola, Thrissur and Shillong. The network of 10 regional/ base centres and linkages with the national active germplasm sites (NAGS), got constituted collectively forming the Indian National Plant Genetic Resource System. There are at present 59 crop-based institutes including AICRPs that have been declared as NAGS. A project on the National Containment/ Quarantine Facility for testing transgenic planting material has been made operational which has resulted in the development of a CL-4 level containment facility for quarantine of transgenic planting material. In the XI Plan, a 'National Genomic Resource Centre' was established which is a fully functional Division now. the Bureau has a strong national network comprising Regional Stations/ Base Centers and ICAR Institutes/ SAUs that provide access to representative agro-ecological situations in the country.

In order to fulfill need of plant breeder exploration to different parts of country to collect trait-specific germplasm of various crops from diversity-rich spots. The institute has so far undertaken 2833 explorations and collected about 2.81 lakhs accessions of crop species and their wild relatives. Focus on North-East region of India an important plant diversity hotspot where intense exploration were carried out in recent year (165 explorations - 9,698 accessions (more than 30% wild) and to natural calamity affected areas of Uttarakhand were undertaken. Priority was given to the crop wild relatives (CWR) which resulted in collection of 576 unique accessions which resulted in a significant increase in the share of wild species (32%) in the total collection. An exploration was also conducted in 2019-20 to Andaman group of Islands covering Little Andaman, Diglipur, Saddle Peak, Ross & Smith Islands, Mayabunder (incl. Karen tribal area), Mount Harriet NP, Chidyatop Biological Park, Swaraj Dweep (Havelock Island) in collaboration with ICAR-IISR, Kozhikode, Kerala &ICAR-CIARI, Port Blair, A&N Islands. A total of 159 samples in 102 species/taxa including wild relatives were collected.



ICAR-NBPGR is the nodal agency for import and export of all PGR for research purpose, adhering to guidelines of National Biodiversity Act, 2002. ICAR-NBPGR is instrumental in introduction of several new crops in India such as soybean, sunflower, kiwi, tree tomato, oil palm, jojoba, guayule, hops etc. and aromatic plants like rose geranium which are getting popular in Himalayan states, Uttarakhand and HP. It also helped researches to access germplasm from other countries and has given very valuable genetic resource to the world. Some of the classical examples of use of germplasm of Indian origin are as: The entire rice crop of Indonesia was threatened some decades ago by a growth-stunting virus. A gene transferred from *Oryza nivavra* from Odhisa saved rice crop against the virus. It was single gene from India for downy mildew resistance that saved the muskmelon crop in the United States. Another gene from Indian that provided American sorghum resistance to green bug insect had resulted in millions of dollars of annual benefit to American farmers. Dr. William Saunders of Canada used wheat variety Hard Red Calcutta and released new series of wheat later called Marquis A and B which were early and resistant to rusts. Recently in rice, Sub1A (from FR13A) and PSTOL1 (from Kasalath) are being used globally to save rice from losses due to flooding and improving P use efficiency.

Introduction of planting material, including transgenics from other countries carries risk of entry of the associated pests (fungi, bacteria, viruses, insects, nematodes and weeds etc.). Hence, all genetic resources acquired from foreign countries are tested using plant quarantine measures (legislative measures) to prevent the entry of exotic pests and to avoid their spread to the fields. ICAR-NBPGR has been empowered under the Plant Quarantine (Regulation of Import into India) Order 2003 of the Government of India to carry out quarantine checks on the germplasm being exchanged meant for research purposes, including transgenics. It undertakes quarantine processing of germplasm meant for export and issues the Phytosanitary Certificate for the material meant for export. The quarantine has resulted in the interception of several pests of high economic significance including (>75) those not yet reported from the country. Such interceptions signifies the success of quarantine as otherwise these pests could have entered the country and played havoc with the plant biodiversity and Agriculture. examination of 49,97,795 samples of PGR during 1976–2021 of which 1,78,507 samples were found infested/ infected by insects (1,08,615); pathogens (42,123); Nematodes (23,952) and weeds (3,817) and 78 exotic pests intercepted. Any inadvertent introduction of any pest not present in the country could lead to serious economic losses to farmers and the country.

The Indian National Genebank (NGB) was established at ICAR-NBPGR to conserve the PGR for posterity in the form of seeds, vegetative propagules, *in vitro* cultures, budwoods, embryos/embryonic axes, genomic resources and pollen. The NGB has four kinds of facilities, namely, Seed Genebank (18°C), Cryo genebank (-170°C to -196°C), In vitro Genebank (25°C), and Field Genebank, to cater to long-term as well as medium-term conservation. The NGB with a capacity to conserve about one million germplasm in the form of seeds is currently conserving about 0.46 million accessions belonging to nearly 1,800 species. Over 12,000 samples of seed, dormant buds, and pollen are cryopreserved and about 1,900 accessions are conserved in the *in vitro* genebank. The NGB is supported by active partnership of other institutions designated as the NAGS. The NAGS are responsible for maintaining, evaluating and distributing germplasm from their active collections to NGB and other user scientists. The present status of collections in the Seed Genebank is given in Table 1

The Bureau has supplied germplasm, collected indigenously or from exotic sources, to breeders and other researchers in the country. The germplasm supplied by ICAR-NBPGR to various breeders have been used in varietal development. Several indigenously supplied germplasm accessions have helped to develop improved varieties in various national programmes.

During last decade, large scale characterization and mega-evaluation of national genebank collections of various crops including wheat (~27,000), barley (~7,000), lentil (~2,000), chickpea (20,800), *Vigna* spp. (10,000), pea (~3000), mustard (5,000), sesame (~7,000), soybean (10,000) etc. have been accomplished to develop core sets, mini-core sets and trait-specific reference sets under NICRA project, DBT funded Network project and In-house projects. Various core sets have been developed (wheat: 2226 acc.; chickpea: 1103 acc.; barley: 688 acc.;

Table 1: Status of Base Collection National Genebank (-18°C) as on October 31, 2022.

Crop / Crop Group	No. of accessions conserved
Cereals	1,73,456
Millets	60,222
Forages	7,473
Pseudo-Cereals	8,093
Legumes	68,465
Oilseeds	63,237
Fibres	16,920
Vegetables	28,666
Fruits & Nuts	300
MAP & Narcotics	9,090
Ornamental	732
Spices & Condiments	3,627
Agroforestry	1,695
Safety Duplicates (Lentil, Pigeonpea)	10,235
Trial Material (Wheat, Barley)	10,771
Total	**4,62,982***

*The figure includes 5,034 Released Varieties and 4,316 Genetic Stocks; No. of Crop Species conserved: 1,762. *Source: http://www.nbpgr.ernet.in accessed on 9.11.2022*

Germplasm in in vitro and Cryo-preservation facility as on 31 March, 2022

Crop Group	Status
***In vitro* bank**	
Tropical fruits	447
Temperate and minor tropical fruits	382
Tuber crops	527
Bulbous crops	173
Medicinal & aromatic plants	186
Spices and industrial crops	228
TOTAL	**1,943**
Cryobank	
Recalcitrant	0
Intermediate	7,327
Orthodox	3,942
Dormant bud	389
Pollen	616
TOTAL	**12,274**
Genomic Resources	
DNA	2,19

(Source: http:// www.nbpgr.ernet.in accessed on 9.11.2022)

lentil: 170 acc., ricebean: 252 acc.; mungbean: 400 acc.; cowpea:425 acc.) for utilization by respective crop researchers.

Under CRP on Agro-biodiversity-PGR Component-II, a total of 24,602 accessions comprising wheat (7,763 acc.), rice (5,900 acc.), okra (3,412 acc.), chickpea (2,136 acc.) and brassica (2,953 acc.) were evaluated at AICRP centres/ hotspots for quality traits, abiotic and biotic stresses. Promising accessions and GWAS panel were identified for genomics study and introgression breeding. Trait-specific germplasm for resistance to rust disease (4), spot blotch (4) and zinc content (2) in wheat, *Aschochyta* blight resistant (2) in chickpea and white rust resistant in Indian mustard (2) was identified.

A PGR Portal has been hosted on NBPGR website, which is a gateway to information on plant genetic resources conserved. The Portal contains information on about 0.4 million accessions belonging to about 1800 species. The PGR documentation is done in various forms including printing of books, crop catalogues, inventories, research papers, popular articles, pamphlets etc. In addition, NBPGR has developed mobile apps Genebank and PGR map in PGR Informatics which can accessed through NBPGR web pages, genebank.nbpgr.ernet.in and http://pgrinformatics.nbpgr.ernet.in/pgrmap/ two mobile apps "Genebank" and "PGR Map" have been developed to enhance access to PGR information with an easy user interface. The apps have been hosted on Google Play and App Store. "Genebank App" provides a dashboard view of indigenous collections (state-wise), exotic collections (country-wise), addition of accessions to genebank, etc. The app also helps generate routine genebank reports. The app uses databases live on the backend and hence always gives updated information "PGR Map App" offers three benefits: "What's around me" helps user to obtain quickly the accessions that have been collected and conserved in the genebank from a particular location in India where the user is located at the moment; “Search the map” helps user to list the accessions that have been collected and conserved in the genebank from any selected location in India; “Search for species” helps user to map the collection sites of a crop species. Establishment of geo-informatics portal in PGR: A study to link germplasm to changing climatic regimes was earlier carried out with the funding of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). A web interface named PGR CLiM was also developed to access information (www.nbpgr.ernet.in:8080/climate).

Recognizing the importance of PGR with novel, unique, distinct and high heritability traits of value that could be used in crop improvement, and to facilitate flow of germplasm to users, ICAR-NBPGR plays a vital role in germplasm registration. More than 1900 potentially valuable germplasm of over 120 species of various crops registered so far. To facilitate smooth registration process, a fully online system of filing registration applications, their scrutiny, review and communications at every stage has been developed (http://www.nbpgr.ernet.in:8080/registration/). Details of the registered germplasm can be accessed at http://www.nbpgr.ernet.in:8080/ircg/index.htm.

Abstracts of Keynote and Invited Lectures

Plant Exploration, Germplasm Collection: Challenges and Opportunity in Indian Himalayan region

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The Indian Himalayan region (IHR), spread over about 5 lakh km2 (about 16.2 % of country's total geographical area), is one of the youngest, fragile, and complex ecosystems in the world. The great variety of climatic and habitat conditions, not only endowed with rich variety of gene pools but also recognized as the centres of origin and centre of diversification of many wild as well as the domesticated plant. IHR supports more than 50 % of the total flowering plants so-far recorded in India. Botanical Survey of India (BSI), the apex research organizations on plant taxonomy have been pursuing taxonomic research in the Himalayan region through its four Regional Centres since independence. This has not only resulted successful collection of huge number of botanically and horticulturally important plants, but also accumulation of information on economically important plant species, gene pools of wild plants, wild relatives of crop plant, prioritizing of future collections, for technology intervened research on crop development, drug development, food security and livelihood generation. As per the current estimate, more than 11157 taxa of flowering plants belonging to 2359 genera under 241 families occur in IHR. Poaceae with 912 species Asteraceae with (820 species), Orchidaceae with 819 species, Leguminosae with 434 species are among the top ten families with maximum diversity.

Botanical Survey of India, is undertaking major efforts in documenting the economically important plant resources of Indian Himalayan region. Many of the western Himalaya wild relative species of the genera of *Pyrus*, *Prunus*, *Sorbus*, *Rubus*, *Ribes*, *Hordeum*, *Elymus*, *Eremopyrum*, *Avena*, *Aegilops*, *Allium*, *Lepidium*, *Carum*, *Linum*, *Cicer* and *Cucumis*, and the eastern Himalayan wild relatives of the genera *Musa*, *Elaeocarpus*, *Myrica*, *Coix*, *Digitaria*, *Oryza*, *Vigna*, *Mucuna*, *Trichosanthes*, *Momordica*, *Cucumis*, *Solanum*, *Brassicaceae*, *Piper*, *Amomum*, *Alpinia*, *Curcuma*, *Zingiber* and *Saccharum* are being conserved in the botanic garden of BSI. As habitat loss in Indian Himalayan region is one of the major threats, these germplasm collections in botanic gardens will pave a way for prioritized future explorations to renew for collection of different populations of threatened species in order to maximize genetic diversity from all population.

Climate change has a huge implication for biodiversity and germ plasm conservation. Three possibilities i.e., adaption of plants to a new climate regime with selective plasticity, migration of plant to higher latitudes, and loss (extinct) of species from the ecosystem have been forecasted. While the past plant exploration efforts focused on collecting a broad range of species and many accessions; the future plant exploration demands for collection of priority taxa, threatened species particularly with narrow range of distribution, and insufficiently represented taxa in, existing *ex situ* germplasm collections.

In the post 2020 global biodiversity framework scenario, issues such as involvedness of *ex situ* plant conservation, the impacts of climate change, the spread of invasive species, access to genetic resources, equitable sharing the benefits, and the change in policies and regulations are the key challenges for the plant exploration and germplasm collection. Therefore, there is an urgent need for revamp each of these efforts for effective conservation of biodiversity and sustainable uses natural resources of our country. The issues listed above present opportunities for BSI, NPBGR, other likeminded research institutes of India to help meet the challenges presented by our changing world.

Science Led Legal Decision Making Policies in Plant Varieties Protection through Plant Breeder's & Farmer's Rights in India

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Introduction

Considering India's agricultural set up as an evolving heritage along with the civilization itself which has unfolded into a modern India, taking agriculture along its strides. As India resorted to engage in global competitive trade through World Trade Organization and became its founder member, it required India to be compliant to the Trade Related Intellectual Property Rights (TRIPS) Agreement. India opted for *the sui generis* option to provide for the establishment of an effective system for the protection of plant varieties, the rights of farmers and plant breeders that encouraged development of new varieties as well as those which were in common knowledge of the farmers or were in the possession of farmers traditionally. "The Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001" was enacted by the Parliament of India in accordance to the Article 27.3b of TRIPS Agreement.

Indian legislation has sufficient provisions based on scientific principles of plant breeding recognizing the contributions of both modern plant breeders and farmers in plant breeding activity and also provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions, as well as resource-constrained farmers. There is an overarching recognition of the farmers as conservers of traditional plant varieties, land races, wild relatives of crops for specific traditional practices of saving, producing, sharing or exchanging seed amongst farmers as their farm produce while fully recognizing the contributions of both commercial plant breeders and farmers in plant breeding activity in developing new varieties.

The execution of the PPVFR Act integrates uniquely, a balance between plant breeders' rights and farmers' rights. This integration is a major deviation from the otherwise followed in 78 countries which are member countries of The International Union for the Protection of New Varieties of Plants (UPOV)that is limited only to new plant varieties and to only plant breeder's rights. There are no rights to farmers as envisaged in the Article 9 of ITPGRFA in both principal option Acts of 1973 and 1991 which makes PPVFR Act implementation, a unique execution.

1. Recognition of scientific distinction between Farmers' Varieties and Plant Breeders' Varieties

The Objectives of the Act focus on the establishment of an effective system for protection of plant varieties, rights of farmers and plant breeders and to encourage development of new varieties of plants while protecting the rights of the farmers in respect of their contribution madein conserving, improving and making available plant genetic resources for the development of new plant varieties. The genetic principles that enable the evolution of plant varieties based on their adaptation and persistence over several generations are kept in forefront in being able to recognize the traditional varieties or land races as farmers' varieties in the concerned plant species.

2. Definition of a plant variety under PPVFRA distinguishes pure lines, populations and hybrids as well as vegetatively propagated varieties

(i) A plant variety is a group of plants together belonging to a known botanical species or subspecies which can be

(ii) defined by the expression of the characteristics resulting from a given genotype of the group of plants;

(iii) distinguished from any other group of plants on the basis of difference in the expression of at least one of its characteristics; and

(iv) considered as a unit with regard to its suitability for being propagated, which remains unchanged after such propagation.

Farmers' varieties are those which are traditionally cultivated and evolved by the farmers by way of selection of variants naturally evolved or which are wild relatives or maintained over generations about which the farmers possess common knowledge, within the above definition. The New varieties or varieties of common knowledge bred by plant breeders and are compliant to the above definition qualify to be protected.

3. The meaning of protection of plant varieties in India

Protection of a plant variety is an intellectual property right that the breeder (who could be an individual, farmer, community of farmers, institution or a government) enjoys over the variety along with designation in the plant species as the variety's owner who is entitled to plant breeders rights on the variety with the exception of farmers rights on the variety, that shall remain with the registered breeder or his assignee. It also technically symbolizes a certification that the registered variety is distinctive from others in its characteristics, is uniform and genetically stable. The primary reason, a hybrid cannot be protected minus its parents is the cause related to lack of genetic stability in the hybrid.

The protection of the plant variety also means that no one including the registered breeder can sell any other variety with the same denomination or sell the protected variety with any other denomination, commitment of which is also a punishable act of infringement.

4. A variety claimed as a farmer's variety is clearly distinguishable from a plant breeder's variety

Any crop species that has undergone organized plant breeding process will bear the manifestation of genetic recombination effected by the breeding process among the characteristics that relate to adaptation, agronomy, tolerance or resistance to pests and diseases, quality improvement, photo-thermo insensitivity, synchronised reproduction phase, etc., which generally represent such assemblage by human intervention with an obvious increment in productivity. Whereas, the typical farmer's variety is either a landrace itself (claimed as community variety by the community) or a natural mutant \identified in the landrace or traditional variety cultivated for a long period by farmers in the region, but with a difference in one or two traits from the known traits of the land race or traditional variety. The registration process considers this difference along with legal bona fide certification from the Director (Research) of the State Agricultural University or any Central or State Government established commodity plant species research centre, to the effect that the material being applied under farmers' variety category is indeed without human plant breeding intervention through artificially created variability.

Comparison of Provisions in Seed Act 1966 & Draft Seed Bill 2019 *vis a vis* IPR Protection Environment of Plant Varieties

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Seed is a vehicle for delivery of improved technologies and is a mirror for portrayal of inherent genetic potential of a variety. Seed offers to integrate production, protection and quality enhancement technologies in a single entity, in a cost-effective way. Use of quality seeds alone could increase productivity by 15-20 %, indicate the critical role of seed in agriculture. With reference to significant advances registered in Indian Agriculture, the progression of the seed sector is of having pivotal importance. The importance of quality seed in agriculture has been recognized since time immemorial, dating back to Vedic period (Yajur Veda, 1500 to 1100 BC). In one of the oldest literatures on agriculture, Parashara from before CE states 'Origin of plentiful yield is seed'. *Manu Smriti* states '*Subeejam Sukshetre Jayate Sampadyathe*' meaning 'Good seed in good soil yields abundantly'. The use of high-quality seeds is one of the most important elements in increasing agricultural production in any farming system. This element has become more crucial than ever for providing enough food security for the rising number of people in the world, which is expected to exceed nine billion by year 2050. Selecting high yielding varieties adapted to the area of production, with disease, insect, lodging, and shattering resistance, along with other desirable characteristics are basic keys for satisfactory crop performance and yield. The production of high-quality seed is the cornerstone of any successful agriculture programme.

Organized activities to promote the quality seed usage in modern history of India started in 1925 when "Royal Commission on Agriculture (RCA)" was constituted for spread of improved varieties and progress of seed distribution. In 1946, Vegetable seed producers from Quetta organized themselves to form "All India Seed Grower, Merchants and Nurserymen's Association". "Grow More Food Enquiry Committee" and "Expert Standing Committee" of ICAR way back in 1952 stressed the need for improved seed with prerequisite purity, that resulted in setting up of several seed farms. Institutionalized programmes for varietal improvement and testing began in 1957 with the formulation of AICCIP on maize that was followed by sorghum in 1960 and in pearl millet in 1961.1961 also holds a prominent place for seed sector in India as the year the first seed testing lab was established at IARI, New Delhi under supervision of Mr. J. E. Douglas. These beginnings led to the promulgation of first Seed Act of India in 1966 and ensuing "*The Seeds Rules*" in 1968 which laid foundation for organized seed sector in India. Maharashtra was first state to establish official seed certification agency under Department of Agriculture in 1970.

From a predominantly public sector producing varieties suited for food production in the 1960's, the Indian seed industry has evolved into a multi-faceted industry with a large involvement of private firms and increasing emphasis on research and development. Today India has sizeable public and private sector seed businesses. Giant public sector players include the National Seeds Corporation (NSC), the State Farms Corporation of India (SFCI) and the thirteen State Seed Corporations (SSCs). There are about 150 - 200 organized seed companies existing in India today. Several companies have recognized Research and Development Units by Government of India and have developed a large number of varieties and hybrids in several crops.

India and the World has come a long way since the sixties in terms of humongous developments on technological front and a sea change in the perception and implementation of Intellectual Property Rights for biological resources and the restriction-based practices in World Trade. These have necessitated the formulation of multiple regime-based legislations in the country to facilitate the fulfilment of international commitments. In order to provide for the establishment of an effective system for the protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants, The Govt. of India enacted "The Protection of Plant Varieties and Farmers' Rights Act, 2001" adopting sui generis system. Indian legislation provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions, as well as resource-constrained farmers. It has been considered necessary to recognize and to protect the rights of the farmers in respect of their contributions made at any time in conserving, improving and making available plant genetic resources for the development of new plant varieties. For Indian Seed Act which was passed in 1966 and is still in effect, it is being felt that considering the international milieu based on above given considerations, an amendment is long overdue. Hence, there have been efforts from time to time to come out with a comprehensive act covering all the technological domains with the adequate protection to all stake-holders, facilitating fair practices should be developed with a consensus among all. Last such effort was in 2019 wherein a Draft Seed Bill 2019 was circulated among the stake-holders to develop a consensus. Though the said bill 2019 is still in a draft form, a comparison based on draft that existed in 2019 has been taken up purely for academic purpose. Draft Seed Bill 2019, is unique in many features than its earlier version of 1966 and PPVFRA Act 2001 in terms of compulsory registration of varieties through national and state seed committees, basis of registration and its duration, compensation to farmers, issue of mis-branding of seeds etc. etc. These changes require a thorough discussions and clarification among all the stake holders before finalization of the legislation.

Designing Germplasm Management Systems to Maximize Use of Maize Genetic Resources

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Maize (*Zea mays* L.) is an unique cross-pollinated species offering numerous optionsin cultivar development, breeding methodologies, seed production practices, and several specialty corn types. During the 20th century lot of emphasis was placed worldwide on exploration and collection of traditional maize types adapted to varied environmental conditions. Potentially useful races or racial complexes were identified for further improvement work to develop OPVs, hybrids or both. Only a fraction or a small proportion of total genetic diversity was exploited in breeding programs. The situation today is no different in other crops as well. The purpose of my oral presentation is to share strategies, germplasm management systems and heterotic models which maize scientists have actually used to maximize use of existing genetic resources as well as the ones waiting to be exploited lying safely in the gene banks around the world. It is important to emphasize that accessions in gene bank be evaluated, categorized and passport datamade available to end users in addition to core and subcore collections. My own experience in maize suggests that we must design germplasm management system(s) which may have multiple tiers involving materials with different level of performance such as useful bank accessions, gene pools and populations as attempted by CIMMYT since early 1970s. This system permits introgression of promising bank accessions and some exotic materials into appropriate pool(s). Counter pools and populations can also be developed that are heterotic as has been practiced by some breeders in the developed world. Next I want to share my own experience in exploiting rich genetic wealth that exists in various gene banks around the world and also that has been created through conscious breeding efforts using a spectrum of both intrapopulation as well as interpopulation breeding schemes. As an inexperienced research associate with Rockefeller Foundation I was fortunate to be part of team of scientists to develop Thai Composite which later on with the inclusion of downy mildew resistance was named Suwan-1. The formation of Thai composite was accomplished by recombining 46 accessions from Mexico. This material has been widely used across the globe in different ecologies. It is alsoan excellent combiner with several CIMMYT populations and pools in hybrid development work. As I moved to Mexico in 1970, CIMMYT was still in its early stages of inception and lacked international perspective. A few of CIMMYT scientists including me developed a two-tier germplasm management system of backup pools and advanced populations resulting in 28 populations and 34 gene pools meeting germplasm needs of varied adaptation ecologies. Combining ability studies of all such materials through international collaboration was done to establish heterotic patterns. I will also describe in detail development of new heterotic pools, hybrid-oriented source germplasm, trait specific populations, synthetics as well as heterotic groupings and patterns of materials being handled at CIMMYT and elsewise. New approaches to develop multifunctional heterotic models will also be presented.

Genomics for Improving Germplasm Management and Utilization

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ABSTRACT

This presentation will highlight latest break throughs in plant genomics that have resulted in a remarkable progress in characterization and utilization of germplasm resources. Availability of cutting-edge and affordable DNA sequencing and genotyping platforms have facilitated dense genetic profiling of large collections archived in genebanks worldwide. Some recent studies on genome variations of thousands of accessions in various crop species will be presented. These studies demonstrate the power of new genetic technologies for in-depth characterization of germplasm resources. Furthermore, some strategies will be presented for use of sequencing/genotyping data to optimize strategies for better management and utilization of germplasm resources for harnessing unexploited of genetic diversity.

Key words: Allele, genebank, genetic diversity, genome, germplasm, sequencing

Plant genetic diversity provides the raw material for selection and breeding in crop improvement programs (Varshney *et al*. 2021a). Genetic diversity is preserved in genebanks that currently host more than 7.4 million germplasm accessions worldwide as sources of traits and alleles crucial to future agriculture and food security (Bohra *et al*. 2022). Unfortunately, limited information on germplasm characterization has greatly constrained their genetic and breeding potential for developing new crop varieties. According to Nguyen and Norton (2020), breeding programs across different crop species have exploited less than 10% of the germplasm accessions held in genebanks. Resource-intensive methods used for germplasm characterization and management have remained a major stumbling block for incorporating valuable traits or alleles from genebank repositories to breeding programs. Selection and use of appropriate accessions from genebanks is also challenged by the lack of trait-specific subsets of germplasm.

In recent years, advancements and afford ability of modern DNA sequencing and genotyping technologies have facilitated comprehensive genetic profiling of plant germplasm resources, thus allowing generation of valuable data and information for better germplasm management and exchange. For instance, we recently sequenced whole genomes of 3,171 cultivated and 195 wild accessions of chickpea (Varshney *et al*. 2021b). The genome-wide sequence variation dataset enabled identification of redundancies within and between collections following analysis of genetic similarities of the accessions. In parallel, the germplasm sequencing and genotyping data can also contribute significantly towards identification of collection gaps and mislabelling of biological status in the historical records in genebanks. This was exemplified by the genome analysis of chickpea accessions that elucidated a wild-specific allele of the *SHATTERPROOF2* homolog guiding identification and correction in labelling of the chickpea accession ICC 16369 (Varshney *et al*. 2021b).In the wake of the continuously evolving DNA sequencing chemistry, examples of whole genome sequencing were made available for large number of accessions across different crops like rice (Wang *et al*. 2018), pigeonpea (Varshney *et al*. 2017a), pearl millet (Varshney *et al*. 2017b), common bean (Wu et al. 2020). Besides low coverage whole genome resequencing (WGRS), other high-density genotyping methods like genotyping by sequencing GBS) and single nucleotide polymorphism (SNP) chips have enabled genetic characterisation of genebank collections in several crops such as barley (Milner *et al*. 2019), wheat (Schulthess *et al*. 2022) and soybean (Bandillo *et al*. 2015).

Acquisition of large-scale genotype and phenotype information on germplasm sets may help develop genomic selection (GS)/prediction models to assess the value of a germplasm accession that lacks morphological characterization data. Based on the genome-wide marker information, genomic prediction could help optimizing selection strategies for choosing worthy germplasm accessions in the absence of phenotypic information. For example, by generating GBS data on 962 sorghum accessions, Yu *et al*. (2016) investigate defficacy of genomic prediction as a novel and cost-effective strategy for "turbocharging" genebanks. A training set of 299 accessions having information on both its phenotype and genotype was used to assess this approach.

Advances in the field of omics science have provided new opportunities to exchange germplasm and associated information by integration of data from multiple omics platforms; such as the one established bythe DivSeek International Network (https://divseekintl.org/)where researchers, genebank curators, database and computational experts collaborate to integrate and interpret the information coming from diverse omics and Big Data technologies. In this context**,** global platforms like germplasm resource information system (GRIN)-global (https://www.grin-global.org/) with huge potential for germplasm management and utilization have resulted from collaborative effort among international organizations/institutes. We advocate that establishment of global and independent information systems are crucial for sharing of germplasm and associated data since integration of such information systems with genebank management will improve interoperability between passport records and phenotypic and genotypic/other omics data.

Generation of massive sequence information and other omics data on germplasm resources has led to the development of digital sequence information (DSI) to accelerate access and benefit sharing of the new information to individuals, institutions and countries (https://www.cbd.int/dsi-gr/). However, fair and equitable sharing of DSI arising from germplasm resources remains arguable in context to the biodiversity related international instruments: the Convention on Biological Diversity (CBD) and International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). Therefore, evidence-informed discussions, coordinated efforts and favourable policy regimes are needed era to address the challenges associated with access and benefit sharing arising from germplasm in the current digitization, particularly in relation to the developing countries.

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Stringent Plant Quarantine System to Ensure National Biosecurity

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Agriculture production is having risk from exotic pests due to free trade of agricultural commodities under new regime of Word Trade Organization, unrestricted movement of people and commodities within and across the borders. Same time, there is also a risk from new virulent population of a pest present in a particular part of the country. Huge losses amounting to billions of rupees are caused by these pests. Over the years, we have always raised the issue of increasing public awareness about plant quarantine and the risk of introducing unwanted pests and diseases in bringing undeclared plant materials from abroad. To save the agriculture / plant biodiversity from the ravages of introduced exotic pests and diseases, almost all countries in the world have plant quarantine system in place. They are enforced through legislative measures to regulate the introduction of planting materials, plant products, soil, living organisms etc. in order to prevent inadvertent introduction of pests (including fungi, bacteria, viruses, nematodes, insects and weeds) harmful to the agriculture of a country/ state/ region and if introduced, prevent their establishment and further spread.

Plant quarantine is a government endeavour to prevent the entry and establishment of exotic pests into the country which if introduced could cause severe economic and environmental losses. Destructive Insects and Pests Act, 1914 has been implemented to prevent introduction of exotic pests. Further, to comply with the requirements under the International Plant Protection Convention and World Trade Organization to which India is a signatory, the Plant Quarantine (Regulation of Import into India) Order, 2003 has been legislated and came into force from April 1, 2004, under which import of commodities, additional declarations for freedom from quarantine pests is based on pest risk analysis. Presently, there are 73 Plant quarantine Stations (including 7 regional stations at Mumbai, Kandla, Chennai, Bengaluru, Amritsar and New Delhi) working across the country with its Headquarters at Faridabad. A total of 96 entry points including 47 seaports, 25 airports and 24 land custom stations are notified points of entry for import of plants and plant material. Besides, 79 Inland Container Depot/Container Freight Station, 11 Foreign Post Offices have also been notified for the entry of plants/plant material under the PQ Order, 2003. Ninety-five amendments of the PQ Order 2003 have so far been notified to revising various quarantine regulations to meet the National requirement under international obligations. The lists of crops are mentioned under Schedule VI and VII which include 700 and 519 crops/ commodities, respectively and 57 weed species in schedule VIII. ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR) is authorized to issue import permit and undertake quarantine of plant germplasm including transgenics and for issue of Phytosanitary Certificate for material under export.

The potential damage by the introduced pest depends on new areas, finding suitable environmental conditions as well as susceptible hosts to survive and complete their life cycles. These pests vary considerably, some being short lived and resistant to desiccation and extremes of temperature, while others susceptible to these factors, delicate and short lived. The scope of quarantine is influenced by biological characteristics of the pest; the kinds and part of plants affected; whether or not the part is used in commerce (such as root, tuber, cutting, seed or flower); alternate hosts; the nature of the inoculum in case of a plant disease and whether the host or other potential carrier can be treated to eliminate the possibility of it carrying any viable reproductive form of the pest, etc. Essentially, plant quarantine measures act as filters against the entry of exotic species and check or delay the introduction of unwanted organisms. There are several recently introduced pests such as root knot nematode *(Meloidogyne enterolobii)* in guava, *Puccinia horiana* causing white rust in chrysanthemum, tomato pin worm *Tuta absoluta*, fall army worm *Spodoptera frugiperda*, Neotropical coconut whitefly *Aleurotrachelus atratus*, cassava mealybug *Phenacoccus manihoti* and re-invasion of South East Asian thrips, *Thrips parvispinus* in chilli spread across the length and breadth of India and its neighbours. All these examples and happenings in history have clearly demonstrated how introduction and spread of agricultural pests have devastated industries causing colossal losses to the economy resulting in shift in cultivation pattern, famines and migration of people, etc.

Agricultural biosecurity has emerged as solution requiring both policies and technological capabilities to prevent, detect, and respond to biological threats. Biosecurity is a strategic and integrated approach encompassing policy and regulatory frameworks to analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risk. It is a holistic concept of direct relevance to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity. Biosecurity in an agricultural context refers to the preventive and mitigative measures designed to reduce the risk of transboundary and in-country movement of pests in crops and livestock, quarantine pests, invasive alien species and genetically modified organisms (GMOs). India also has other national regulations related to biosecurity which provide a fragmented legislative system which needs to be harmonized and integrated in to a holistically deal with biosecurity while complying with international norms. Government of India has taken several steps including single window system for introduction of Biological Research Regulatory Approval Portal (BioRRAP) under DBT, the establishment of National Agricultural Biosecurity Board and enactment of Seed Bill etc. There is an urgent need to support research, training, capacity-building, networking and information sharing activities at both national and regional levels.

Due to changes in climate, changes in cropping patterns/agro-ecosystem, loss of forest cover and expansion of host range resulted in acclimatization to varied climatic conditions by pests. Living industry implies the trade of living organisms including landscaping or horticultural crops, agriculture, aquarium, pet trade, live seafood trade etc. help in introduction of the exotic pests. The increase in number of tourists has also increased the chances of invasive pests. There has been enhanced domestic conveyance with enriched networks of railways, highways, airways and harbours which further facilitate the easy spread of the introduced pests all over the country. Minimizing the loss caused by exotic pests require an International management approach with strict legislation laws and better cooperation among countries with respect to exchange of information regarding the exotic pests species and their natural enemies.

Certified Post Entry Quarantine (PEQ) facilities, development of rapid and reliable diagnostics for the quarantine pests and eco-friendly salvaging techniques and awareness among various stakeholders are needed to make quarantine more efficient. Additionally, the Pest Risk Analysis procedure is one of the biggest challenges for quarantine workers. Further, there is a need for integrated agricultural biosecurity efforts and international policy to predict the possible invasion of the species to different countries and also to suggest mitigation measures every year will help to save the biodiversity, crop loss/food security and increase economy of the nation. Therefore, the plant quarantine system in the country needs to be strengthened both in the terms of manpower and facilities.

A Systems Approach to Germplasm Health Protection and Preventing the Transboundary Spread of Seed-transmitted Pests and Pathogens

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The CGIAR genebanks conserve over 730,000 germplasm accessions of the most important food, forage, and tree crops in 35 ex-situ collections in nearly 20 countries. The viable and disease-free germplasm from these collections is distributed to the global community on demand for food and agriculture. The CGIAR breeding programs located in multiple countries contribute to the development of improved varieties of rice, wheat, maize, cassava, yam, sweetpotato, potato, food legumes, oilseeds, and forages, distribute breeding lines and improved varieties for international trials and adoption by national programs, including through globally coordinated crop improvement networks. Rapid and timely germplasm distribution is vital for international trials linked to accelerated breeding programs focused on genetic gains, developing climate-resilient germplasm, and supplying source seed for seed systems. CGIAR genebanks and breeding programs distribute over 1000 germplasm samples annually to 90 to 120 countries. However, the global distribution of germplasm presents several challenges from the perspective of phytosanitary procedures implemented by the countries to minimize the risk of pest and pathogen (here afterward referred to as pest) introduction through the plant and plant products.

Planting material (seed and vegetative propagules) can act as a pathway for introducing all types of pests, including bacteria, fungi, insects, nematodes, phytoplasma, viruses, viroids, and weeds, as part of the infected tissue or external contamination. Numerous examples of the global spread of seed-borne pests exist. For instance, the spread of maize chlorotic mottle virus (MCMV), a seed-borne virus, into East Africa in 2011, and the spread of Sri Lankan cassava mosaic virus (SLCMV) into East Asia has resulted in devastating crop damage. The risk of pest introduction through planting material is considered a high-impact but low-probability event due to the low rate of pest transmission through botanic seed and a high-probability event in the case of vegetative propagules.

Phytosanitary procedures that include regulations and technical procedures to ascertain the health status of the seed and treatments to eliminate pests, inactivate pests and regenerate healthy propagules have been established at the national and international levels to mitigate the risk of pest introduction through planting materials. CGIAR, through its Germplasm Health Units (GHUs), uses a systems approach to minimize the risk of pest spread through planting materials. These procedures cover both seed and clonally propagated crops and are based on the risk identification and use of risk mitigation procedures from planting material production to distribution. It involves using state-of-the-art diagnostic tools for specific and generic diagnostic tools to ascertain germplasm health, using optimum phytosanitary methods to eliminate pests and produce pest-free germplasm, and standard operating procedures for quality control.

This presentation summarizes transboundary pest risks to international germplasm distribution; procedures used by the GHUs to ensure the production and distribution of pest-free germplasm from the CGIAR programs; bottlenecks to germplasm distribution and consequences of delayed germplasm access on crop improvement programs; and a need for an internationally accepted protocol for germplasm distribution, provisions for which are insufficient in the phytosanitary regulations guided by the International Standards for Phytosanitary Measures (ISPMs) of the International Plant Protection Convention (IPPC).

Genetic Resources and Traditional Knowledge & Cultural Expressions - Protection, Preservation and Promotion

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India is home to valuable traditions and culture, that has been passed through several generations over thousands of years. However, traditional knowledge still has no general definition that is accepted internationally. Considering the diversity and historical perspectives of nations world-wide, traditional knowledge is a complex subject matter. Countries like India possess traditional knowledge both as disclosed and undisclosed knowledge. The former covers traditional knowledge captured in texts such as classical and ancient texts, and manuscripts, often available in public domain. The undisclosed traditional knowledge largely is of knowledge that belongs to local and indigenous communities that have passed on through generations by word of mouth as well as manuscripts that are part of private collection. The latter category i.e., oraltraditional knowledge is a sensitive subject matter both nationally and internationally, as it is linked to a nation's and the concerned people's rights.

India's rich heritage traverses various diverse domains that include food, health and wellness, medicine, agriculture, metallurgy, architecture, among many others. Our traditions and culture are observed to be largely oriented to the availability and utility of local bio- and genetic resources, besides others, leading to respecting and preserving the ecology around. This traditional knowledge that includes traditional cultural expressions is relevant not only today but is important for our future as well.

In the mid-1990s, India was faced with challenges of misappropriation of its traditional knowledge. Patents were filed and granted on turmeric, basmati rice and neem, among many others. As patents are legal provisions, when granted they provide complete ownership to its inventors and assignees, who in turn can use it for their vested commercial interests. However, in the aforesaid cases of turmeric and others, the granted patents were threat to the rightful owner, i.e., India and its people. Efforts from the government of India included requests, deliberations and also litigation. Nation-wide efforts from the country finally led to the revocation or amendment of the concerned patents. The challenges associated with protecting our traditional knowledge from misappropriation and biopiracy were centered around making this information available as prior-art information to patent offices, so to prevent erroneous grant of patents on our traditional knowledge. The important initiative from the government of India after these instances of misappropriation was the birth of the Traditional Knowledge Digital Library (TKDL). India's TKDL is a first of its kind globally to address the rising challenges of protecting a nation's TK from vested interests. The TKDL was set up in 2001 as a prior-art database, based on which evidences are provided and thereby patent applications are revoked, amended, withdrawn or at times abandoned. The Traditional Knowledge Resource Classification (TKRC) classification system is yet again an unique and important aspect of the TKDL to facilitate ease of search by patent examiners. The language and format barriers are broken and the traditional knowledge is made available in a format that is easily understandable and accessible by the patent examiners.

While the aforesaid is manageable with codified texts, the oral and yet undisclosed traditional knowledge offers greater challenges for protection and preservation. The oral traditional knowledge which is associated with people's livelihoods is a highly sensitive subject matter as the people's rights are to be protected too. Thus, in the context of traditional knowledge, the Intellectual Property Rights (IPR) gain significant importance in ensuring that the rights of the concerned are safeguarded.

Despite the understanding that traditions and culture play an important role, in the context of nations' race to be globally competitive and lead others, countries have often ignored or given low importance and priority tosuch knowledge. However, countries in more recent times, especially after the COVID-19 pandemic are giving due importance to their traditions and culture. Though slow, nationsare acknowledging that socio-economic growth and development can be strengthened when one grows on the strong foundations of their traditional knowledge. Thus, in the context of traditional knowledge, both defensive and positive protection gain importance, with the latter to contribute towards its promotion for livelihood enhancement of the concerned stakeholders. The underlying advantage of these is that the traditional knowledge gets to be preserved for longer and to address future needs as well.

While the TKDL primarily is a tool for defensive protection of Indian traditional knowledge and associated genetic resources, the other frameworks from India include Geographical Indications (GI) of Goods (Registration and Protection) Act, 1999, The Design Act of 2000, The Protection Of Plant Varieties and Farmer's Rights Act, 2001, Biological Diversity Act, 2002, and The Scheduled Tribes And Other Traditional Forest Dwellers (Recognition Of Forest Rights) Act, 2006, among others.

The talk shall be focused on the importance of Traditional Knowledge and Cultural Expressions, with focus on genetic resources and the associated 3Ps - Protection, Preservation and Promotion for AtmaNirbhar Bharat and Global Good.

Genetic Diversity for Improving Production Systems, Landscape Restoration, and Adaptation to Climate Change

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Over millennia, farmers domesticated plant species and created the crops and traditional varieties we know today. They maintained and modified the genetic diversity found within different plant species through their management of production systems, the farming practices that they used, and the ways in which they maintained and selected crops and varieties to secure their own livelihoods and produce a surplus to help feed the world's growing population.

The last 100--150 years have seen an increasing use of chemical inputs, mechanization, and a dependence on uniform varieties newly developed by professional plant breeders. The technological advances have made it possible for global agricultural production to triple in the last 50 years, although the levels of productivity are not consistent around the world, and many countries are still suffering from malnutrition and/or undernutrition. According to the World Bank, the world population is expected to reach 10 billion people by 2050, this growth represents a challenge for agriculture to respond and satisfy the growing food demand. Climate change is also expected to cause substantial reductions in potential crop production in some parts of the world which are already suffering from food insecurity, due to the increasing temperatures and the unpredictability of climatic patterns and the outbreaks of pests and diseases difficult to control. Modern agriculture has certainly achieved incredibly good results in its capacity to feed the world, but the production practices have resulted in environmental degradation through biodiversity loss, pesticide impacts, soil degradation, and water pollution. This uniformity has been at the cost of reduced availability of crop and varietal diversity that is key for the needs and resilience of poor small-scale farmers.

Conventional agricultural production relies on an incredibly limited number of crop and animal breeds, which are produced in simplified systems, where agricultural inputs (chemical, water) are used as a replacement for diversity and at the expense of sustainability. Of the approximately 150 edible species, rice, wheat and maize supply more than 50% of the world's plant-derived calories, and only 12 crop and five animal species provide 75% of the world' sfood. This has changed nutritional patterns across the world, which are now based on a limited number of energy dense food at the expenses of other minor crops, such as the wild, semi-domesticated, and cultivated vegetables and fruits, spices, that provide important micronutrients. Breeding programmes have focused on the use of highly selected materials adapted to high input farming techniques (irrigation, fertilizers and pesticide application) developed from a narrow genetic base.

Despite the investments done both by governments and international research centers on technology and production of improved varieties, traditional varieties can still be found across the world and food production still continues to rely on these particularly in marginal environments where cultivars lose their competitive advantage. The contribution of small-scale farmers to the global food production is not negligible. Graueub et al. (2016) have estimated that 98% of all farms are small holders working on 53% of agricultural land. In 2012 Kremen at al.32 reported that their contribution to global food production accounts for 50% of the worlds' cereal, 60% of the world's meat and75% of the world's dairy production.

Of the three billion people living in the rural areas of developing countries, 1.2 billion people practice low-input traditional agriculture on small plots, based on traditional or informal sources to meet their seed or planting material needs. These farmers depend on crop and varietal diversity to cope with unpredictable and severe weather patterns, droughts and floods, as well as changes in pests and pathogens, soil salinization, low soil fertility and land degradation that result from climate changes, but also in response to market fluctuations.

The heterogeneity in the genetic make-up makes landraces more versatile in their capacity to adapt to different environments and respond to biotic and abiotic stresses. The continuous planting of the landraces over time, together with farmers' selection, are responsible for a high adaptability in the environment where they are grown, in terms of biotic and abiotic stresses. Coevolution of landraces with the local environment, including pests and pathogens, is a process that makes landraces particularly valuable for those production systems characterized by unpredictable environmental conditions. The capacity to tolerate biotic and abiotic stress results in yield stability. Furthermore, with their rich genetic variability traditional varieties represent a precious repository of genepool for breeding,

The resilience and productivity of smallholder farmers is dependent on the diversity in their farming and production system and access to seeds of adapted crop planting material. Management and use of these traditional crop varieties under low input conditions, has been shown to increase farmers' capacities to cope with biotic, abiotic and economic shocks, leading to increased yield stability, food security and reducing poverty.

The assessment of the distribution and use made of intraspecific crop diversity is required for a better understanding of how this diversity is maintained and used locally and worldwide, as diverse sets of crop varieties, and how it can help feed and restore our planet. Examples from Uzbekistan, Nepal, China and Sri Lanka show how a better knowledge of the agrobiodiversity preserved and managed by farmers and its distribution as well as of its associated knowledge and practices supported an efficient decision-making using a heuristic framework and helped landscape restoration, income improvement, diversification of nutrients, reduction of migration and adaptation to climate change.

In order to facilitate the assessment of diversity in farmers' fields the Diversity Assessment Tool for Agrobiodiversity and Resilience (DATAR) was created. The tool also provides information on the genetic material provider, allows to assess management, market, policy and institutional constraints and provides the heuristic decision-making framework with goals and constraints and offers a portfolio of diversity-related interventions to support the improvement of local communities' livelihoods and benefits from the use of their local intraspecific diversity and restore ecosystem health.

Application of Plant Cryopreservation for the Conservation of Plant Genetic Resources, Production, Virus Eradication and as a Tool for Modern Breeding Techniques

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By cryopreservation we understand the conservation of biological materials at ultralow temperature. For this, mostly the tissues are submerged in liquid nitrogen (temperature of -196°C) or exposed to its vapor phase (temperature between 190°C and 170°C). At these low temperatures no metabolic, physical nor chemical processes take place in the tissues making it the ideal condition for long term and stable storage. The main problem when exposing biological materials to such low temperatures is the formation of ice crystals as these penetrate membrane structures causing loss of their semi-permeability and thus cell death. Water is essential in all living tissues so removing all of it would kill the cells. The ultimate way of avoiding ice crystal formation is making use of a physical phase called "vitrification" (or glass formation). All cryopreservation methods developed over time irrespective of their origin (animal, human or plant) are thus based on the successful introduction of a vitrified state of the intracellular solutes.

In plants, efficient cryopreservation methods were developed for a wide range of plant species; originating from tropical to temperate regions, herbaceous as well as woody species as well as for diverse tissue types; pollen, meristems, calli, zygotic as well as somatic embryos, seeds and dormant buds. The mostly used cryopreservation protocols applied to plant tissues are the classical slow freezing protocol, droplet vitrification, encapsulation dehydration and dormant bud cryopreservation (Panis *et al*., 2019).

Plant cryopreservation is increasingly becoming a widely accepted and applied method for the long term conservation of plant genetic resources that can not be conserved through seeds. This because there are plants that do not produce seeds (sterile crops like edible bananas), that produce non storable, recalcitrant seeds (cacao, avocado, coconut) or that, in the case of sweet potato, are clonally propagated—since its offspring does not have the same genetic set up when propagated by seed. For such species field, *in vitro* and cryopreserved collections are setup. Currently, between 20000 and 25000 accessions are safely preserved in liquid nitrogen and more initiatives to increase these numbers are in the pipeline. Crops with more than 1000 accessions cryopreserved are apple, banana, mulberry, cassava, garlic and potato. It is estimated that worldwide between 100000 and 150000 unique accessions of vegetatively propagated and recalcitrant seed crops are currently held in field and *in vitro* and genebanks. A global initiative is thus needed to make sure that all these accessions are safely maintained for next generations. Like the Svalbard global seed vault that is storing almost one million seed samples as backup for national and international seed banks, a safety cryopreservation back up facility should be established (Acker *et al*., 2017).

Besides for storage of genetic resources, cryopreservation can also be applied to store cell lines with specific characteristics for the long term. For example, the initiation of embryogenic banana cell suspensions is time and labor consuming (Strosse *et al*., 2006). Once they are initiated they are subject to loss of regeneration capacity, somaclonal variation and contamination. Since these suspensions are for the application of modern breeding techniques such as genetic engineering (Sagi *et al*., 1995) and gene editing (Zorrilla-Fontanesi *et al*., 2020), their safe conservation is outermost important. Hundreds of cryotubes containing transformation competent embryogenic cell lines of Musa species (bananas) are safely stored in liquid nitrogen for already more than 20 years and are being used on a regular base. Also in case of conifers, cryopreservation can be used to store embryogenic calli derived from breeding for 10-20 years, awaiting their final evaluation in the tree plantation (Cyr, 1999).

Another but equally important application of cryopreservation is its use for the eradication of plants from pathogens such as viruses, phytoplasmas and bacteria. The mode of action of cryotherapy is based on the fact that after cryopreservation only the most meristematic part (often only a few cell layers of the apical dome) survives and is able to grow out into a new plant. Since this is also the region that, depending in the aggressiveness of the organism, contains no or a low titer of pathogens, often a healthy, pathogen-free plant will result from cryopreservation (Helliot *et al*., 2007). Cryotherapy has already been applied for pathogen eradication from a wide range of crops such banana, Grapevine, Potato, Raspberry and sweet potato (Wang *et al*, 2009).

Finally, cryopreservation van be applied in in vitro plant production companies. This for cultures in production since it is advised to store a "clean", true to-type back-up *in case of problems of contamination, hyperhydricity and somaclonal variation. But it is also important to store cultures that are put "On hold" that comprise putative interesting lines that are currently not in production but of which their maintenance is costly and subject to risks of loss.

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PGR Informatics Tools for Efficient Conservation and Use

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Varietal development programs depend upon the availability of trait specific plant genetic resources (PGR). PGR utilization, in turn, depends upon the availability of reliable information. Lack of an operational PGR portal can lead to redundant investments in PGR characterization and evaluation and inefficient utilization of valuable genetic resources. It is imperative to compile, curate and make accessible the PGR information to users. Such information should be up to date, accurate, reliable, systematically stored and easily accessible. Therefore, documentation of plant genetic resources (PGR) for 'accession data' as well as 'trait data' is a pre-requisite for their efficient management and utilization. PGR Informatics is the management (creation, storage, retrieval and presentation) and analysis (discovery, exploration and extraction) of diverse information (facts, figures, statistics, knowledge and news) about PGR. PGR informatics brings transformation essentially because an organized digital information system provides fair and just opportunity for all to access. PGR Informatics has come in the limelight because:

- Increased awareness about PGRFA
- Various international agreements coming into force
- Availability of information in text, images, maps, videos, etc.
- Technologies to record, link and archive such diverse types of information
- Ever-increasing power of computers and internet

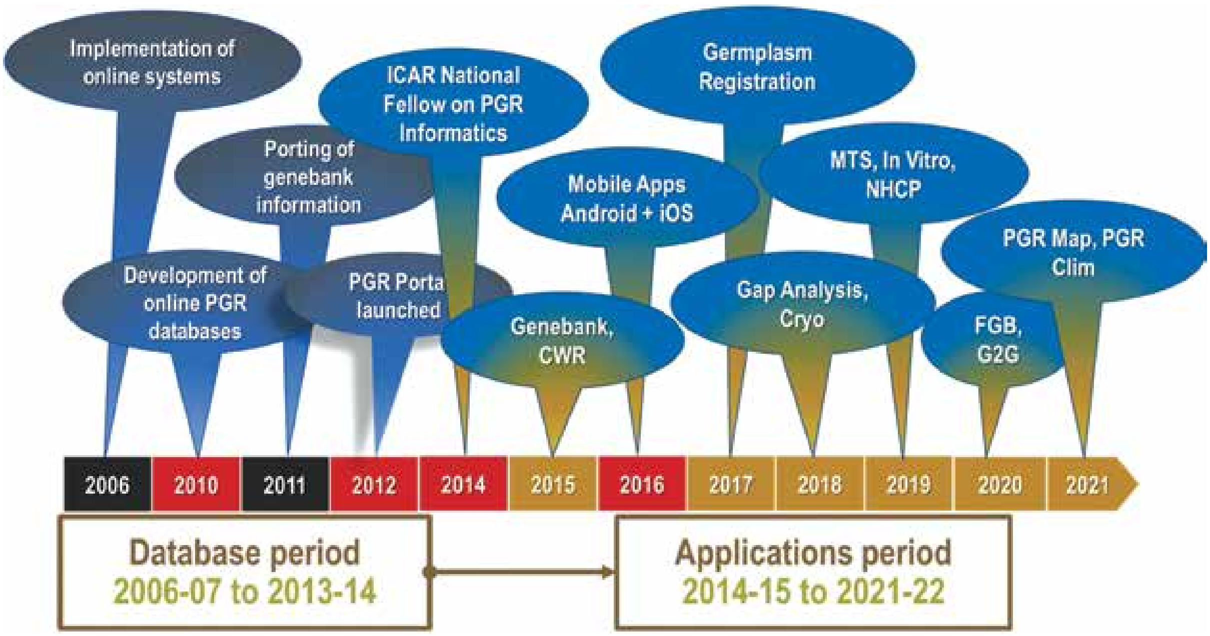
An effective PGR Informatics can only be built upon sound scientific grounds which go beyond computer expertise to encompass genetic, taxonomic, geo-informatic, bioinformatic and genomic linkages. A user-centric approach is needed that includes (i) Growth – through richer content and metadata especially field genebanks, horticultural genetic resources and farmers' efforts; (ii) Scalability – through established architecture and decentralized services; (iii) Capacity – through development of appropriate tools, products and services; (iv) Visibility – through development of a powerful and user-friendly data portal, nodes, thematic portals and rich internet applications. Research and development in PGR analytics will accelerate cognitive decisions that facilitate PGR utilization. PGR analytics, at varying levels of analysis and complexity, includes (i) Descriptive - reporting and querying of data to identify problems and solutions; (ii) Predictive - modelling, forecasting, and simulating outcomes based on the data; and (iii) Prescriptive - recommend the best course of action based on the data. Above-mentioned developments are not possible without laying down data standards as well as benchmarks for algorithms and modules. These in turn can't be developed without creating sufficient knowledge body based on basic research in PGR Informatics. NBPGR, being the nodal organization for PGR management in India, holds the responsibility of research and development in PGR Informatics.

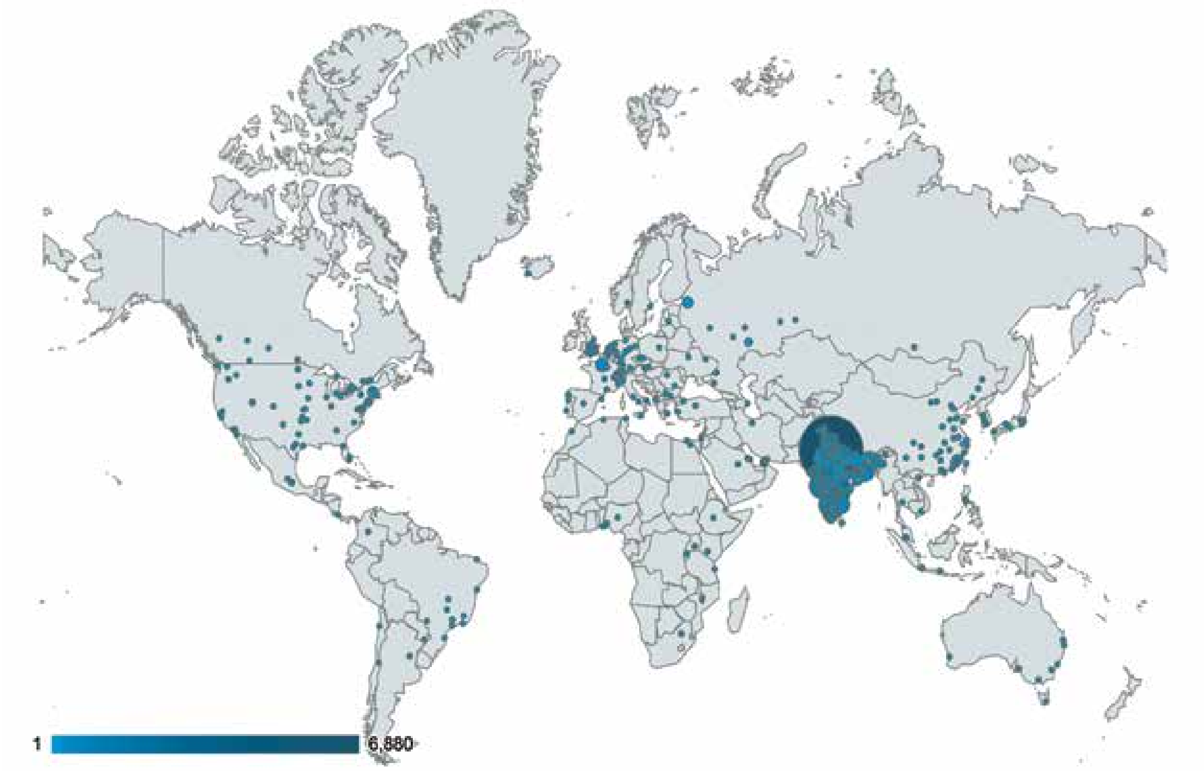
In the past two decades, three seminal changes have shaped PGR informatics (i) Technology change in computers, internet and mobile phones; (ii) Policy change from open access to regulated access; (iii) Objective change from conservation-centric to utilization-centric management. All the genebanks need to build and manage their PGR information systems accordingly. However, today, the genebank information systems are limited to 11 CGIAR genebanks and seven major national genebanks and is implemented at multiple levels: (i) Genebank level (e.g. CGN-PGR, Netherlands; IPK, Germany; CRF, Spain; VIR, Russia; EMBRAPA, Brazil; Kew's, UK; NIAS, Japan); (ii) National level (e.g. AusPGRIS, Australia; PGRC, Canada; NORDGEN; ARS-GRIN, USA); (iii) Regional level (e.g. EURISCO, Europe; EAPGREN, Eastern African Nations; REMERFI, Latin America; SPGRC, South African Countries; GRENEWECA, West and Central Africa); and (iv) Global level (System-wide Information Network for Genetic Resources, SINGER and GENESYS; Global Biodiversity Information Facility, GBIF). USDA genebank developed an information management system called GRIN Global in 2008. In 2010, GeneSys, a web portal for all the CG genebanks as well as EURISCO information system was launched. Unfortunately, at the other end of the spectrum, almost all the gene rich countries absolutely lack informatics facilities.

A number of tools and algorithms have been developed in the field of informatics applicable in distinct areas like banking, clinical studies, engineering, social sciences and forensics. Some examples in biology include tools like Darwin Core Archive and communication protocols namely DiGIR, BioCASE, TAPIR–TDWG, etc. However, customizing available algorithms for PGR informatics continues to remain a challenge. Please note that PGR algorithms are unlike statistical algorithms of machine learning, clustering, etc. and also unlike graph and greedy algorithms of computational biology. PGR informatics algorithms are non-canonical problem-solving computer operations with rules set by biology.

We find that there are critical gaps and there is a need for research in PGR informatics. Germplasm information management suffers not only because of inadequate digitization, collation and curation of data but also because the neither the information is standardized nor the compatible software and data models implemented. Absence of all-encompassing scientific questions to guide PGR informatics is resulting in developments that have no connection to genuine insight and forward progress. Researching on the links between diverse dimensions of plant genetic diversity– conservation status, taxonomy, distributional biology, ecology, interactions, genomics, and phylogenetics– will enable a transition from data management to informatics science. There is a general lack of emphasis on PGR Analytics to facilitate cognitive decisions. Typically, data availability and technology have driven many of the ideas and concepts in the PGR informatics field. The desirable state of the field would see ideas and concepts driving development of new technology and new data resources.

At ICAR-NBPGR, Digitalized documentation of germplasm, in real earnest, began in 1997 with Computerized allotment of IC numbers and massive efforts to digitize data began in 2002. Implementation of online systems could only start in 2006. With a decade long incessant efforts, supported by Directors and colleagues, PGR databases were developed by 2010-11. However, to facilitate the access to databases, graphic user interface-based applications were yet to be built. NBPGR neither had the expertise nor the experience of developing and operating web applications. In fact, CG-genebanks had begun to adopt GRIN-Global (that was developed via collaborative efforts of GCDT, Bioversity, USDA-ARS at a cost of $2.5 million). NBPGR was invited to espouse GRIN-Global, which was not acceptable to due to lack of clarity on data sharing. Alternative and alluring option was to outsource the software development to firms viz. Infosys, Wipro, TCS, etc. For obvious reasons, NBPGR took it upon herself to actually build a software application to be named as "PGR Portal". The Portal was launched on 6 December





2012 by the Director General (ICAR) and Secretary (DARE) Dr. S Ayyappan at a gathering of all DDGs, PCs and PDs of AICRPs at NBPGR. PGR Portal is an open access information portal on PGR conserved in the National Genebank of NBPGR. Ever since, PGR Portal was accessed from all around the world by >35K users with 440K page views across 52K sessions. Although the user tracking was put in place only in 2013, the average values indicate that the PGR Portal was accessed every day at the rate of 122 page views in 15 sessions. In the ten years, PGR Portal functioned uninterrupted (except for a month in covid forced shut-down). The figures show the interest and need for PGR information, which also means need for a technical overhaul of the Portal with contemporary design and tools.

Subsequently, several unique and useful applications have been developed at NBPGR including PGR Map, PGR Clim, GRIS, E-Herbarium, CWR, Genebank dashboard, G2G, Gap analysis tool, etc. All the applications can be accessed at http://pgrinformatics.nbpgr.ernet.in.

PGR informatics operations face various technical, logistical and financial challenges including but not limited to:

- Data quality
- Trait specific evaluation data; merger of genetic and genomic data
- Dynamic linking and updating; Inter-operability
- Institutional mechanism for sustainability
- Accessibility guidelines; Harmonization
- Efficient data delivery
- Information services in local languages (specific to India)
- Dedicated funding

Future lies in providing a comprehensive system of seamless access to genetic and genomic data and their analyses; building dashboards to enable flawless reporting facilitating planning, resource allocation and collaborations.

Strategies for Enhancing Use of Germplasm Collections in Crop Improvement for Sustainable Conservation

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Agriculture is vulnerable to global warming and depletion of natural resources. Global warming causes loss of agrobiodiversity, increased incidence of droughts and floods, changes in pest dynamics, potentially reducing food quality and increasing risk of food contamination (mycotoxins). South Asia and sub-Saharan Africa are particularly vulnerable to climate change and variability effects. The risk absorbing capacity of the farmers in these regions is low, and developing high-yielding climate-resilient cultivars with a broad genetic base together with judicious management of natural resources is an important way to address global food and nutritional security. Germplasm diversity contributes to developing improved crop cultivars aimed at increasing crop productivity. Globally, 7.4 million accessions are conserved in more than 1,750 genebanks. However, scant use (<1%) of assembled germplasm in breeding programs is a major concern, leading to narrow genetic bases of crop gene pools. The main reasons for low use of genetic resources are the large size of collections and lack of reliable data on traits of economic importance, noting that such traits show high genotype x environment interaction and require extensive testing. These problems can be mitigated by developing 'core' (10% of entire collection, Frankel 1984) and 'mini core' (10% of core or 1% of entire collection, Upadhyaya and Ortiz, 2001) collections sampling the diversity in a collection.

Our research revealed that mini cores that were selected using phenotypic traits were as good as those based on simple sequence repeat DNA markers. Mini core collections often meet the needs of plant breeders for variation in multiple traits. Systematic evaluation of mini core collections has resulted in identification of a number of germplasm lines with agronomically and nutritionally beneficial traits in addition to resistance/tolerance to abiotic and biotic stresses in chickpea, groundnut and sorghum (Upadhyaya *et al* 2013, 2014, 2019). Use of diverse germplasm lines identified from a groundnut mini core resulted in developing exceptionally high oil (up to 63%, compared to ~48% in control cultivar) and high-yielding breeding lines, indicating that new germplasm sources contribute to enhancing genetic gains. Crop wild relatives harbour genes for stress tolerance, seed yield and nutritional traits Several promising sources were identified for agronomic and nutritional traits and abiotic and biotic stress resistances. Systematic and sustained efforts to infuse diversity from wild relatives are required. In groundnut TXAG 6, an amphiploid has been successfully used to enhance 100-seed weight (up to 87 g, cultivated parent ~ 40 g), pod yield (up to 27% more than cultivated) and traits related to drought tolerance such as specific leaf area and SPAD chlorophyll meter reading. Similarly, in sorghum, recombinant inbred lines of *S. bicolor* x *S. propinquum* were crossed as pollen parents with four cultivars, Teshale, Macia, Lata and BTx623. The resulting F_1s showed rich variation for important traits. Hybrids flowered earlier and 15 of them yielded more (up to 22%) than the highest yielding parent (BTx623). The RIL 234, which has 75% of *S. bicolor* and 25% *S. propinquum* alleles, increased seed yield in F_1 combinations with all four cultivars This was not an artifact of poor yield of the RIL itself, as the RIL 234 was among the highest yielding RILs. Availability of genotypic data for large numbers of germplasm accessions helps in understanding of crop genomes and their diversity. Identification of genetically diverse lines with multiple traits is an essential starting point for breeders to develop high-yielding cultivars with a broad genetic base.

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In situ Conservation, Characterization, Commercialization: Incentivizing Communities

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Way back in 1989-90, a question was raised whether we could conserve biodiversity by keeping people poor (Gupta, 1991 a,b)? In 2004, poverty maps showed that the regions having biodiversity hotspots had much higher share of stunted children and poverty around the world. We have to find ways in which we can conserve biodiversity, improve incomes of the communities that conserve, and at the same time expand constituency of consumers and other stakeholders who will sustain bio-enterprises. The characterization of local agro as well as wild/ uncultivated biodiversity will play a crucial role in this value chain. The traditional knowledge associated with the biodiversity is like an index without which books in a library will be difficult to locate. We will discuss how grassroots innovations, outstanding traditional knowledge can be blended with modern science, technology, Innovation and entrepreneurial value chain to serve nature and communities both sustainably.

Policy implications for community-based biodiversity value chain development

(a) A debate was triggered in early nineties that one could not conserve biodiversity by keeping people poor. The fear that with economic development, erosion of biodiversity takes place is often true empirically. But is it inevitable? Can we not design portfolio if such incentives which make conservation and economic development compatible? Can we not make market consumers to pay extra for bio-products derived from diverse contexts? Has not the price of milk of grazed cattle of indigenous breeds been often more than double that of stall-fed improved breeds of cows/buffaloes. The emerging market of organic food and minor millets indicate changes emerging in market place. But we have not used block chain technology yet to show to a consumer how much diversity exists in the regions from where a crop or its products are being sourced and why they should pay for sustaining it keeping traceability, trust and transparency in mind.

(b) We have argued about this issue many times before that the descriptors of various crops and other plants should include the dimensions of i) climate resilient parameters such storability of grain/seeds in millets (low storability made hybrid millers unfit for procurement by public distribution system, and related factor about dormancy of seeds to prevent germination in the ear due to unseasonal rains and spoilage of harvested crops), ii) suitability of crops for food processing or as functional foods (traditional knowledge and recipes could play a very important role. It was suggested to NBPGR several times that by characterizing the germplasm collection for these purposes, once could motivate the food and beverage industry to become a stakeholder in the conservation of biodiversity;

(c) Recent studies in Eastern Uttar Pradesh, UT of J&K, Sikkim and Nagaland besides Gujarat and other regions including Andaman Islands have shown that women's knowledge about edible weeds, wild plants and local crop/horticultural varieties can be a very powerful driver of bio-enterprises through in situ value addition and augmentation of family income besides meeting conservation goal (Dey, Singh and Gupta, 2018);

(d) The low cost, easy to operate equipment with relevant materials for vacuum frying, fractional distillation, sustainable packaging; food processing etc., can give spur to in situ value addition and thus create market-based incentives for conservation;

(e) There is an urgent need for a nation/worldwide coordinated program for developing protocols for sustainable extraction of bioresources from the wild. This also has been pleaded for decades but hardly much action has taken place. If there are five clumps of some grasses or tubers, should one extract one or two plants from each, or harvest two clumps fully and leave three in different niches or alternate harvesting in some and leave others for annual or biennial rotational harvesting? Which method of harvesting which plants will maximize regeneration and maximum sustainable yield needs to be figured out by careful collaborative experiments in collaboration with local communities.

(f) Local communities have known unique functional and ecological properties of wild relatives of crops for millennia. Studies have shown a rich folklore and songs highlighting these properties in Mali (Gupta, 2004) and India (Dey, Singh and Gupta, 2018). However, there is hardly any collaborative research program or joint investigation by social and natural scientists and local communities in this regard even at CG centres, much less at NRCs. It is well known the *O. sativa* incorporates hardly 20 per cent genetic diversity of its close relative *O. rufipogan* (Ricachenevsky and Sperotto, 2016) found in eastern India or *O glaberrima* widely available in Africa. This is true for metal tolerance and transportation from soil but also other features. There exists a strong case for reinvestigation of functional and agro-ecolgical features of wild relatives for seeking genes of future relevance including for climate resilience by building upon the local knowledge. Studies have shown that vitamin C, E, A in some of the land races are double of the ones found in cultivated crops.

(g) In a study in Mali, it was found that migrants labourers from Timbuktu knew more about such properties of *O. Longistaminata* than farmers, for whom it was a weed and who wanted to remove it. Knowledge of workers/ labourers have been neglected almost all over even when farmer's knowledge has been drawn upon to a limited extent (Gupta, 2004, 2009).

(h) Several By-products of crops which are almost completely neglected for high value medicinal purposes such as silk of corn and industrial material purposes such as hulled cobs. Stone of mango of local varieties, larger in size and with lesser pulp is thrown away when it has so many rich ayurvedic and industrial applications. There is a need for a whole new branch of agricultural science to emerge (by-product science) to reinvestigate the value addition local communities can get from in industrial applications of local biodiversity. This might enhance the incentives for *in situ* conservation.

(i) Long term monitoring of *in situ* plot-wise agrobiodiversity is a dire need to understand under what conditions for some local varieties or selection thereof still survive while most others have already disappeared. In a recent three decadal study, it is found that the traditional varieties of paddy which were reported in 1988-89 have completely vanished from the three villages of flood prone area of eastern Uttar Pradesh by 2017 (Dey *et al* 2018). It is also seen that many women farmers had tremendous knowledge about some of the traditional varieties as well as weeds which help them to meet out their nutritional requirements during the lean months (Dey *et al* 2018). When a poll of a matrix of incentives to encourage farmers to conserve traditional varieties on farm was done, the preferred choices included incentives like providing seeds of chosen varieties; compensation for yield forgone; collective decisions like panchayat allocating space for cultivating some of the traditional varieties. Community nursery of contingent varieties suitable for different weather conditions was another idea which sprang up among community preferences.

(j) Similarly, a large number of local varieties of maize, millets, pulses and rice are vanishing from the tribal regions of Gujarat, Maharashtra and Goa. On the other side, the databases of Honey Bee Network and Protection of Plant Varieties & Framers' Rights Authority India (PPVFRA) besides SRISTI, GIAN and NIF have many innovative farmers bred varieties and farmer land races which can be conserved through their characterization as healthy foods.

(k) The fortieth-year study is due next year in the same villages. Authentic climate resilient or smart solutions will not emerge unless such sites are decided in different agro-climatic conditions and at least 100-200 years research program is launched through an international network to study and solve the challenges in climate resilience at community level (INSSoCCC). I hope this meeting can pass a resolution to this effect and take lead in this regard. The Honey Bee Network will obviously provide all the support for such a study.

(l) In the globalized economy, consumer awareness about foods with functional health advantage is increasing rapidly. Since the same crop and variety may have different mineral, enzymatic, hormonal and nutrient content in different kinds of soils, this makes the analysis and characterization of the varieties imperative in varying contexts. The Functional food industry is growing into a billion-dollar global market and the proper application of analytical chemistry, physiology and other applied sciences will help in incentivizing consumer to trigger traction for traditional varieties (Watanabe *et al* 2004, Shahidi & Chandrasekara 2013). In the drought and flood prone region, some of the traditional varieties may have unique functional advantage for human and livestock health, for example recently, three paddy varieties were found to have anti-cancer properties. The example of flax seed is very illustrative in this regard. From around Rs 70 for 1000 g, flax seed fetches same amount for just 100 g. The characterization by the scientists validating tradition al knowledge added this value.

(m) There is a need for a network of mobile and fixed distributed labs to support community efforts in characterizing local biodiversity and use STI to empower communities in recognizing the market potential of the resources they may have neglected so far,

(n) Scientists have seldom shared the science they advance while working in plant genetic resources back with conservators of the PGR. It is time they correct this asymmetry in the profession and empower local communities not just with the fruits of their labour but also the process by which these fruits were obtained. The key community elders and contributors should be made co-authors for the selections made out of their long term conserved populations and of course the habitats.

The contribution of local communities in the conservation, characterization and possible commercialization or DIY bioproducts has not been adequately recognized and rewarded as an inalienable process of modern cataloguing of germ plasm and breeding. We suggest that new ethical and professional guidelines be developed to correct this asymmetry. This will invigorate the partnership between formal and informal actors in PGR value chain. Honey Bee Network and its collaborative institutions are ever willing partners in this exchange.

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Using Genetic Resources to Stack and Complement Climate Resilience Traits

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CIMMYT and The Heat and Drought Wheat Improvement Consortium

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It is imperative to increase climate resilience of wheat as it provides20% of all human calories and protein (Shiferaw *et al*., 2013). Multiple crop failures due to extreme weather are predicted to increase (Sarhadi *et al*., 2018; Gaupp *et al*., 2020; Kornhuber *et al*., 2020), and severe water scarcity is expected to impact more than half of wheat cultivated globally before the end of the century (Trnka *et al*., 2019). For every 1°C average increase in temperature, models predict wheat yield will decline by 6% globally, and much more in already stressed environments(Liu *et al*., 2016; Zhao *et al*., 2017). Replacement of old cultivars with novel climate resilient ones by farmers is crucial to adaptation (Challinor *et al*., 2014).

In collaboration with hundreds of public and private breeders forming the International Wheat Improvement Network (IWIN),a number of potential disease pandemics have been avoided through mining genetic resources to transfer disease resistance genes into modern cultivars (Ortiz *et al*., 2008; Trethowan and Mujeeb-Kazi, 2008). More recently, physiological characterization of landraces and other genetic resources encompassing genes from wheat's wild relatives, have provided outstanding sources of heat and drought tolerance traits (Reynolds *et al*., 2007; Lopes and Reynolds, 2011; Cossani and Reynolds, 2015). Subsequent crossing and selection pilot programs at CIMMYT's research site in the Sonoran Desert showed that traits like deeper roots and high radiation use efficiency can be transferred from relatively exotic but stress-adapted genetic resources into agronomically modern wheat (Fig 1) (Pask *et al*., 2014; Reynolds *et al*., 2017; Molero *et al*., 2018). The process can be accelerated using molecular tools, for example to prioritize among available genetic resources (Sansaloni *et al*., 2020), as well as by remote sensing that permits high throughput phenotyping in realistic field environments atbreeding scale (Tattaris *et al*., 2016; Reynolds *et al*., 2020).

In collaboration with national programs in South Asia and other climate vulnerable regions, novel germplasm encompassing climate resilience traits derived from landraces and wild relatives were tested against the best locally adapted lines. Lines encompassing novel sources of adaptive traits have shown outstanding performance under these multi-location field trials(Reynolds *et al*., 2017), even resulting in rapid release of cultivars in Pakistan and Afghanistan. These outputs reveal that well-targeted crossing and selection strategies can overcome potential negative linkage drag -which is frequently observed when crossing elite lines with more exotic genomes such as the products of interspecific hybridization.

Genetic bases for several of the traits used have been identified in parallel studies (Pinto *et al*., 2016; Li *et al*., 2019; Liu *et al*., 2019); for example a common genetic basis was identified for adaptive root architecture under both heat and drought stress, respectively (Pinto and

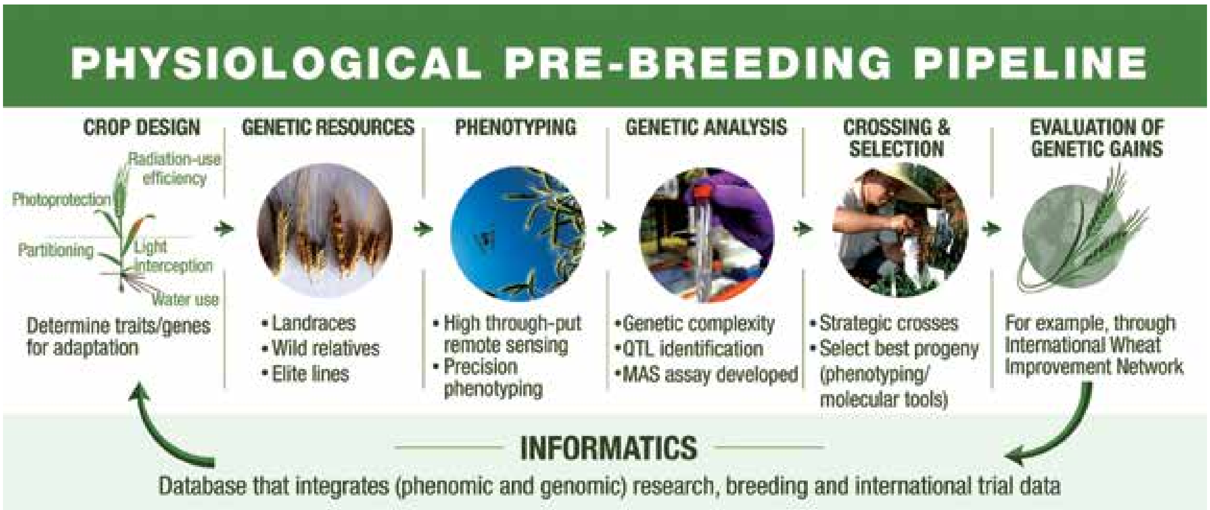

Fig. 1. *Main research steps involved in translating promising technologies into genetic gains (Graphical abstract(Reynolds and Langridge, 2016)). In terms of timing for each step of the pipeline: Crop Design is an ongoing process: Screening Genetic Resources can take a year or two (using Phenotyping and Genetic Analysis); Crossing and Selection typically takes between 3-5 years; Evaluation of genetic gains through international testing is usually conducted in one season through the International Wheat Improvement Network (IWIN). Reprinted under creative commons license https://creativecommons.org/licenses/by-nc-nd/4.0/.*

Reynolds, 2015). Other field studies have identified markers from exotic sources -such as re-synthesized hexaploids (Molero *et al*., 2018; Rosyara *et al*., 2019).

Although diversity for responses to heat and drought stress has been documented in wheat, and numerous genetic mapping studies have been conducted, individual studies are limited in scope and scale and few resilience genes with consistent effect across genetic backgrounds and target environments have been identified (Acuña-Galindo *et al*., 2015; Gupta *et al*., 2017). While some physiological and metabolic factors for resilience have been reported (Gupta *et al*., 2017), they represent just a handful of genotypes and conditions. Due in large part to these knowledge gaps and concerns about linkage-drag and disrupting proven haplotypes/linkage-blocks, most breeders are still wary of crossing with more exotic sources, especially when it comes to genetically complex traits that are harder to track, such as heat and drought tolerance.

Further efforts will require considerable knowledge and expertise to determine which combinations of traits and genes will be required to achieve climate resilience as well as needed genetic gains.

The proofs-of-concept presented here support the case for boosting the scope and scale of this approach, bringing breeding solutions to fruition more quickly in farmers' fields. New resources could also fast-track the application of promising advances from academia, by creating an opportunity for them to be validated in a realistic field-based context.

Based on the proofs of concept already delivered, the approach has significant promise for scale-out, and could serve as a model for cereals and other crops facing unpredictable and harsher climates. Furthermore, translational research and pre-breeding could also achieve a significant boost by linking to upstream discovery research that aims (e.g. via public-private partnerships) to fill significant knowledge gaps that currently limit a more comprehensive understanding of yield and climate resilience in most crops (Reynolds *et al*., 2021).

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Genomics-Assisted Breeding of Climate-Resilient Cultivars Utilizing Traditional Varieties and Wild Rice Genetic Resources

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One of the biggest challenges for 21st century Agriculture is to produce enough food for growing human population from diminishing acreage, deteriorating soil health and environmental stresses induced by global climate change. Rice is arguably the most important crop for global food security but about fifty percent of it is cultivated under rainfed condition. Therefore, it is imperative to develop high-yielding superior quality rice varieties with tolerance to different environmental stresses. Rice became the first crop plant with high quality reference genome available in the public domain (IRGSP 2005). Extensive information on genetic diversity, genetics of agronomic traits, mapped genes and quantitative trait loci(QTL) has accumulated over the last hundred years (Khush and Brar 2001). Rice breeders at International Rice Research Institute, Philippines and national agricultural research system (NARS) institutions in the rice growing countries have developed several hundred rice varieties over the years but most of these have not been popular for long among the farmers for various reasons.On the other hand a few varieties e.g. 'IR64' are highly popular among the farmers even after decades of their release (Mackill and Khush 2018). These varieties are cultivated in millions of hectares for decades due to their superior quality and yield stability due to high adaptability. Such varieties are called mega varieties (MVs) and represent the best available assortments of superior alleles of agronomically important genes as a result of recombination breeding. The MVs provide an ideal base for further improvement byintrogression of validated genes and QTLs usingmarker-assistedselection for accelerated breeding.

The availability of rice genome sequence (IRGSP 2005) and pangenome (Sun *et al*. 2017, Bayer *et al*. 2021) has led to an upsurge in the number of successful QTL mapping studies and cloning of genes underlying these QTLs for agronomically important traits (www.gramene.org). For examples, genes for resistance to bacterial leaf blight, blast, tolerance to soil salinity, drought, flooding, submergence, yield traits including plant height, grain size, grain number, and quality traits like grain shape, aroma and amylose content have already been cloned using a map-based approach. Major effect QTLs have been identified for yield under drought for which fine mapping and gene discovery is in progress. Gene-based functional markers/perfect markers have been developed for foreground selection of the desirable alleles of these traits. More than 18 thousand type I SSR markers and over 4 million SNPs have been described, opening up tremendous opportunities for of DNA markers in diversity analysis and breeding application (www.ncbi.nlm.nih). A subset of these SSR markers,viz. HVSSR have shown much higher level of polymorphism in simple electrophoresis assays and hence are suitable for low cost laboratories lacking sophisticated genotyping facilities (Singh *et al*. 2010). High-density SNP chip arrays are also available for genome wide association studies (GWAS), QTL mapping and background selection (Singh *et al*. 2015). Thus, rice is now at the cutting edge for the application of genomics-assisted breeding. Different marker-assisted breeding approaches include:(i) marker-assisted pedigree selection (MAPS) including gene haplotype-based selection (GHS) [Bhat *et al*. 2021], (ii) marker-assisted recurrent selection (MARS) [Charmet *et al*. 1999], (ii) marker-assisted backcross breeding (MABB) [Singh *et al*. 2016], and (iv) genomic selection (GS) [Hefner *et al*. 2009]. Of these approaches MABB has proven to be the most rapid and successful as most of the MAS-derived rice varieties released to date have been developed through MABB. Other methods are still under development and refinement.

More than 50 rice varieties developed through marker-assisted selection have already been notified for commercial cultivation in South and South-East Asia with IRRI and ICAR playing a pivotal role in marker development and sharing of advance breeding lines with the NARS partners e.g. Swarna-Sub1, Samba Mahsuri-Sub1, IR 64-Sub1, BR11-Sub1, Chehrang-Sub1, Improved Pusa Basmati 1, Improved Samba Mahsuri, Pusa 1637, Ranjit-Sub1, DRR Dhan 50 and Pusa 1847. MABB is oneof the most promising and technically feasible options for introgression of useful genes in the background of MVs which are cultivated in millions of hectares for their high yield potential but are susceptible to one or more of the climate-change induced stresses. Correction of these susceptibilities by introgression of small genomic segments promises high impact on rice production stability because it is very difficult to develop mega varieties by design as these are rare combinations of yield, quality and adaptability traits. However, a major limitation of MAS is the availability of validated markers. Availability of affordable genotyping services within reach is another limitation that requires establishment of genotyping service centres.

Development of near-isogenic lines of mega varieties (MV-NILs) provides a core strategy for further enhancing the value of these already popular varieties. After careful consideration of the feasibility of accumulating useful alleles of large number of genes in a single MV, parallel back-crossing programmes for introgression of individual genes/QTLs in to the MVs appears to be the most efficient strategy. Elimination of linkage drag around the genes/QTLs of interest is the most difficult problem in back-cross breeding that can be effectively tackled by employing DNA markers for foreground, recombinant and background selections coupled with visual phenotypic selection. There are several advantages with the development and deployment of MV-NILs and their derivatives as outlined below:

(a) Direct release of MV-NILsas new essentially derived variety (EDV) with gain in yield, quality or adaptability traits without the need for extensive field evaluation.

(b) Pyramiding of multiple genes/QTLs with additive effect on the trait (Joseph *et al*. 2004). Inter-crossing of MV-NILs will produce MV-NIL pyramided lines (MV-NIL-PLs) with minimum linkage drags and background carryover from the donor varieties.

(c) Strategic deployment of resistance genes against specific strains of diseases and pests prevalent in the region in order to check the development of resistance. A multiline approach can also be adapted using mixtures of MV-NILs having separate resistance genes to delay the onset of resistance development (Browning and Frey 1969).

(d) Location-specific deployment of genes for abiotic stress tolerance. Abiotic stresses like drought, flooding, salinity, temperature are location specific and hence only those QTLs needed for a particular niche area can be deployed with minimum background disturbance. Swarna-Sub1, a submergence tolerant version of the MV Swarna for flood-prone regions of India is a bright example of this (Neeraja *et al*. 2007).

Green revolution (GR) high-yielding varieties (HYV) carrying the *sd1* gene for semi-dwarf plant height have rapidly replaced the traditional climate-resilient high quality rice varieties in most parts of the world. These GR-HIV were selected primarily for yield under high input conditions and therefore are largely sensitive to adverse climatic conditions. Hence, there is need to combine the high yield of these varieties with climate resilience. Knowledge of the complete rice genome and causal genes for tolerance to different abiotic stresses namely heat, drought, flood and salinity has provided us an opportunity to transfer the favourable alleles of these genes into MVs by MABB through multi-institutional networks (Singh *et al*. 2016). We have transferred six consistent QTLs for grain yield under drought; namely *qDTY1.1*, *qDTY2.1*, *qDTY2.2*, *qDTY3.1*, *qDTY3.2* and *qDTY12.1* into flood-tolerant versions of Swarna, Samba Mahsuri and IR 64 to develop two-in-one drought and flood tolerant high yielding rice varieties. Similarly, to address the problem of flash flooding, the*SUB1*QTL for submergence tolerance has been transferred to nine regional rice MVs, namely ADT 46, Bahadur, HUR 105, MTU 1075, Pooja, Pratikshya, Ranjit, Rajendra Mahsuri and Sarjoo 52. Furthermore, *qSALTOL1* QTL for seedling stage salt tolerance and *qSSISFH8.1* for reproductive stage salt tolerance have been transferred into five popular MVs, *viz*. ADT 45, Gayatri, MTU 1010, Pusa 44 and Sarjoo 52. We used foreground selection markers for the presence of desired gene and recombinant selection markers to reduce the linkage drag around the target gene. Selection for phenotypic similarities with the recipient variety (RP) was done throughout the backcross generations and a high-density genotypic background selection was done at BC_3F_2 stage using a 50K SNP chip on a small set of advance breeding lines obtained by phenotypic selection. Finally, MV-NILs with more than 95% similarity to the RP genome have been identified, released after two years of multi-location testing and notified for commercial cultivation. These climate-smart rice varieties are gaining popularity and will provide production stability in the adverse conditions to enhance farmer's income and support livelihood security.

We are exploring wild rice collected from different parts of India for identifying new genes for climate resilience and transferring these into the HYV-MV backgrounds. Crop wild relatives are adapted to wide geographical and climatic conditions and are a rich source of genes and alleles that can be harnessed for developing climate-resilient varieties. Therefore, exploration, evaluation and utilization of fast depleting crop wild relatives gene pool is the need of the day. We have evaluated a large pool (>1000) of wild rice (*Oryzarufipogon* Griff/ *Oryza nivara* Sharma et Shastry) germplasm collected from different agro-climatic zones of India and identified accessions that can withstand drought, flood and soil salinity stresses better than what is available in the cultivated rice germplasm pool (Mishra *et al*. 2016, Singh *et al*. 2018). Precise introgression of novel genes and QTLs for drought, flood and salinity tolerance identified in these wild rice germplasm is in progress using modern genomic tools. Crosses have been made using accessions highly tolerant to anaerobic germination, submergence, drought and salinity stresses. Backcross-1 (BC1) progenies from crosses for anaerobic germination, and salinity tolerance and have been genotyped and phenotyped to identify major QTLs in a bid to simultaneously map and transfer the useful genomic regions using advance backcross QTL (AB-QTL) breeding approach described in tomato by Tanksley and Nelson (1996). In the near future, new genome editing tool for allele replacement (SDN-2) is likely to be used in place of the present backcross breeding approach for high speed precision breeding of new climate-resilient varieties of rice and other crops. Efforts are also underway to combine genes for disease and pest resistance for further enhancing the yield stability of these mega varieties without losing their quality attributes crucial for consumer acceptance.

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Trait Discovery and Deployment through Mainstreaming Landraces and Crop Wild Relatives (CWR) in Legume Breeding Programs

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Globally, food legumes are grown on 92.76 million ha with 88 million tons production. These crops hold vital position in sustainable diversified agri-food systems. During the last five decades, these crops, especially chickpea, lentil, and cowpea have experienced growth in global production, mainly because of their expansion in new areas and enhanced productivity. Despite more than 3500 improved varieties in public domain, the average productivity of legumes is 950 kg/ha which is far below their genetic potential. The annual genetic gain in legume crops is estimated at 0.7% which is not enough to meet the growing demand of plant protein. Narrow genetic base has been identified as one of the constraints for limited genetic gain in legumes. This is due to the bottlenecks during the process of evolution and domestication, which has further been compounded during breeding. Pedigree analysis of chickpea and lentil varieties released globally confirmed the extensive and repetitive use of a handful of germplasm as parents in hybridization. Consequently, many useful alleles have been left behind in landraces and crop wild relatives (CWR). One option to widen the genetic base is to mainstream systematic and targeted use of landraces and CWR in breeding schemes contains a wealth of novel traits/alleles due to their adaptation to diverse habitats. This requires systematic discovery and deployment of useful genetic variation from the global collections using a combination of genotyping, phenotyping, and pre-breeding tools and techniques.

ICARDA genebank holds 50,968 accessions of legume crops including chickpea (15,749), lentil (14,597), faba bean (10,034), peas (6,131) and grasspea (4,457). These holdings also include CWR of lentil (619), chickpea (547) and grasspea (1555). Despite large collections, there are major germplasm gaps at species and genotype levels, and a continuum is required to fill these gaps from the unrepresented areas. A recent mission has expanded the CWR collections of *C. reticulatum* and *C. echinospermum* by over 10-fold (Von Wettberg 2018). Similarly, out of 187 species in the genus *Lathyrus*, global collection represents only 45 species. Phenotyping of CWR and landraces shows significant genetic variability for desired traits especially resistance/tolerance to key stresses including drought, heat, cold, salinity, foliar and root diseases, insect pests, and parasitic weeds in legume crops. Singh (2014) evaluated the global wild *Lens* originating from 27 countries under diverse agroclimatic conditions in India and found useful variations for yield traits including multiple disease resistance. Wild *Cicer* species have great potential for chickpea improvement through genetic base broadening and by providing adaptive traits missing in the cultigen. *Cicer judaicum* has resistance genes for

Ascochyta blight, Fusarium wilt and Botrytis grey mould. Similarly, faba bean landraces have shown tolerance to Orobanche and herbicides and *Lathyrus annuus, L. cicera,* and *L. gorgoni* have shown low ODAP content and resistance to Orobanche.

Plant breeders have long recognized the potential of CWR, but the absence of a simple means to determine which CWR might hold valuable genetic variation has restricted its use. Extreme specificity of adaptation, crossing barriers, linkage drags, long breeding cycle, and perception that wide crosses would disturb favorable combinations and result in inferior recombinants has further restricted their use. With the advent of modern tools and techniques combined with systematic phenotyping, it is feasible to mainstream CWRs and prioritize their use for crop improvement through trait discovery and their deployment to ensure high genetic variance among resultant progenies and maintain long term selection gains by strengthening genetic diversity and unraveling novel genes. ICARDA in collaboration with NARS partners in India has implemented a prebreeding project in lentil and chickpea, which has been instrumental in introgressing useful genes in mainstream breeding. Transgressive segregants for agronomically important traits have been mined from wide crosses, resulting in the release of two lentil varieties (Jammu lentil 144 and Jammu lentil 71) and one chickpea variety (Pusa 1103) in India. Recently, successful use of *Lens orientalis* as a source of resistance to key diseases, phenology, micronutrients, and plant habit has been demonstrated with the development of pre-bred lines of lentil at ICARDA. These pre-bred lines not only performed well with >40% yield over the best check but also rich in micronutrients and fit in short season windows of 80-100 days. Recently, good progress has been made in terms of desirable trait (resistance to cold, drought, heat, and fusarium wilt) introgression from wild species into cultivated chickpea. However, the gain in genetic diversity and identification of novel genes through classical breeding is a time-consuming process. Use of genomics with classical breeding helps to untap the hidden genetic potential of landraces and CWR by accelerating the identification of new alleles that may be absent in cultivars.

Novel alleles can be introgressed into varieties via gene pyramiding/accumulation approach using innovative tools. Application of population genomic scans can detect loci with exceptionally high population Fst values, indicating loci with divergent selection for local adaptation (Baute 2015). Next-generation sequencing (NGS) technologies have accelerated the development of genetic markers such as SNP and InDels, which has greatly facilitated the identification of novel alleles via exploiting in genotyping by sequencing (GBS) or genome-wide association studies (GWAS) approaches. Selection on genome-wide markers can speed the process by reducing linkage drag and increasing the rate of recovery of the elite background. Studies suggest that over 90% of the recurrent genotype can be recovered within two generations when a suitable number of markers and an adequate number of progenies are used for background selection. This represents substantial saving in time compared to conventional backcrossing scheme. The procedure of introgression can further be fastened by integrating speed breeding to advance introgression lines quickly. A recent international collaboration has built a large introgression resource using wild diversity in chickpea (Von Wettberg 2018). Target-induced local lesions in the genome (TILLING) approach have been used in legume crops to identify novel allelic variations for nutritional and stress-tolerant traits.

With rapid advances in embryo rescue techniques, speed breeding, genomic tools and high throughput phenotyping techniques, the prospect of transferring useful traits from landraces and CWR in legume crops has brightened. Wide genetic base of cultivated varieties provides an insurance against the epidemics of diseases and insect pests besides, of course, making the cultivated germplasm more amenable to breeding advances.

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Smallholder Farming and the Role of Youth in Food System Transformation for Sustainable Development

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According to India's 10th agricultural census 2015–2016*, smallholder farmers, or those with less than 2 hectares of land, make up 86.2% of all farmers and occupy 47.3% of the nation's arable land. With an average size of 0.6 hectares, India's over 126 million smallholder farmers collectively possess around 74.4 million hectares of land, making it extremely difficult for the government's extension services to provide them with the relevant technologies and farm support schemes. Additionally, in a variety of smallholder Indian agroecosystems, typical contemporary farming, which is founded on Green Revolution ideas, has limited advantages. This explains why farmer suffering is increasing in India's agricultural sector. It is, therefore, being argued that India has to live with its smallholder farms and devise ways and means to make smallholder farms economically viable for sustainable development[2].

Traditional Indian farming is highly labour-intensive, and the family labour has traditionally been the key factor in a variety of agricultural and joint activities at the community level. However, the lack of economic incentives is forcing the rural youth, the main labour force, to out-migrate to urban areas in search of off-farm employment. Young people in rural areas believe that farming is not worth the efforts. The three interconnected concepts serve as a framework for sustainable farming: being i) economically viable for farmers, (ii) socially just to communities, and (iii) environmentally-friendly. These are the building blocks of sound development that need to be in place to support the expanding population in the coming years.

A sustainable approach to improving local farming systems and nutritional security is suggested through the promotion of traditional food crops. As part of our study, we undertook feasibility studies of the four community-level interventions in four distinct agroecosystems of India: (i) hill and mountain; (ii) hot arid desert; (iii) central plateau; and (iv) north-eastern region, as component of the UNEP-GEF project "Mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability in India" being executed jointly by the Alliance of Bioversity International and the International Centre for Tropical Agriculture (CIAT), and the Indian Council of Agricultural Research (ICAR). The four marketing interventions as better initiatives towards infusing sustainability into traditional farming systems across the country include, (i) Promoting community-supported agriculture (CSA) initiatives; (ii) Linking smallholder farming to the midday meal (MDM) school feeding programmes; (iii) Enhancing market access and value chain development for local plant food resources, and (iv) Enhancing off-farm employment

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*Agricultural Census 2015-16. All India Report on Number and Area of Operational Holdings; DAC&FW, Ministry of Agriculture & Family Welfare, GoI: New Delhi, India, 2018.

opportunities for rural youth at the community level**. Our hope is that these initiatives will help enhance the livelihood security of native farming communities and bring sustainability to farming and food systems. The transition to more sustainable agriculture practices is needed that supports our growing population and also serves as an economic development engine to create jobs and prosperity in the now impoverished and depopulating rural areas. The enhanced job opportunities for rural youth at community level is specifically addressed with regards to organic farming, agro-ecotourism, women-centric non-farm jobs through self-help groups (SHGs), and the community agro-forestry/forestry management interventions. These interventions would engage rural youths fully in farming and related jobs. Restricting outmigration of rural youths is considered very vital for the sustainability of traditional small-holder Indian farming.

Young people had not placed farming as an aspiration while at school; they aspired to move into white-collar professions. Only 7% of the rural youth plan to pursue agriculture as their livelihood. We also found a sharp increase in youth outmigration in recent years. Our main worry is the 20% of rural youth not in education, employment, or training (NEET), who are at risk of becoming socially excluded—individuals with income below the poverty line and lacking the skills to improve their economic situation. Young people represent the most active and energetic age group, and, more importantly, they consume more than any other age group. The role of young people in transforming food systems is therefore considered critical, making food systems more sustainable, resilient, and effective. The policymakers/planners and other concerned parties need to pay attention to what food systems are currently doing to: deteriorating human health systems, high GHG emissions, putting pressure on the sustainability of natural resource use, and not generating enough livelihood opportunities for the coming youth bulge.

There are six major challenges to engaging rural youth in farming and food systems, including poor and inadequate education; limited access to land; inadequate access to financial services; poor employability at the community level, including green jobs for sustainable livelihoods; young people's limited access to markets, and youth's limited involvement in policy dialogues. To increase youth involvement in agriculture and ultimately address the enormous untapped potential of this sizable and growing demographic, it will be critical to address these six key issues.

Youth are calling for three major changes to food systems: (i) ensuring youth are involved in the essential overhaul and widespread transformation of food systems to increase access to safe and nutritious food; (ii) the transformation must focus on improving food system resilience; and (iii) the transformation must drive healthier and more sustainable production and consumption. A vital component of raising living standards is access to healthy food. Eliminating barriers to key resources including, but not limited to, education, access to land, and fair wages, is a crucial first step in supporting youth participation in increasing production of and access to healthy nutritious food. Building resilience to vulnerabilities is vital to securing healthy food system. Food, climate, and nature agendas must be completely linked, and nature-positive production practices must be adopted at scale. The idea that the right to food is a human right for all, we need to build a robust and multi-stakeholder effort to respond to political and environmental crises. Poor and unhealthy diets and the resulting malnutrition are major drivers of non-communicable diseases around the world. All generations must therefore be empowered with access and knowledge to make healthier, climate-positive dietary choices. There is a need to restrict inappropriate marketing of unhealthy food products targeted at youth and provision of nutritious and sustainable meals in schools and universities.

**Bisht IS, Rana JC, Ahlawat SP. The future of smallholder farming in India: Some sustainability considerations. Sustainability, 2020; 12: 3751. DOI:10.3390/su12093751

The sustainability of small-holder traditional farming has been a big challenge in all Indian agroecosystems. We therefore need a system in place where we help small-holder farmers sell their farm products locally within their communities that benefits consumers and farmers alike. In the global food security literature, the development of a local food system that includes organic farms constitutes a key point. This system could enhance a community's health and long-term sustainability through developing local food systems. Formal expansion of organic farming in traditional farming agroecosystems and linking organic farming to CSA initiatives, school meal (MDM) programmes, and value chain development for local organic produce are explored in our recent studies to make the "local" food system a norm rather than a niche. All these marketing interventions, in combination with enhanced jobs at the community level, are likely to bring sustainability and profitability to traditional farming. Local food movements have therefore been regarded as offering new economic benefits for small-holder farms, reductions in the environmental footprint of food, and closer relations between consumers and producers, while also providing good nutrition to consumers.

The alliance is also implementing a project to mainstream the conservation and use of agricultural biodiversity for resilience in agriculture and sustainable production to improve livelihoods and access and benefit sharing capacity of farmer communities across four agro-ecoregions of India. The plans to ensure that crop diversity (both inter- and intra-specific) in India is effectively conserved and used to improve rural livelihoods meeting the challenges of climate change. The Project is developing a number of tested community-based participatory approaches which support the maintenance of existing crop diversity and the introduction and deployment of appropriate new materials of at least 20 crops. The various approaches proposed include awareness campaigns, seed fairs, diversity fora, strengthening seed supply systems and the establishment of community genebanks, and other adaptive technologies that enable farmers to adopt and benefit from diversity rich solutions. In order, to enhance genetic diversity on farm, 4278 native varieties of 20 crops were tested in 759 participatory variety selection (mother) trials and 5028 baby trials have been conducted and farmers identified 233 varieties of different crops as the most potential varieties suitable to their diverse needs. Seed system has been strengthened with 29 community seed banks at 17 project sites, conserving >3000 native varieties. Value chain has been developed and established and products are marked with different brand names such as Native Basket, Dhartee Naturals, Sahalee, Mountain Grains, Hill hatt, Gramouday, Natural Basket etc. at different sites and are being promoted involving 160 Self Help Groups (SHGs) with membership of 2388 of which 1798 women and 590 men farmers are closely working with 25 Farmers' Producer Groups and 23 private companies on value addition and product development for improved adaptation and livelihoods.

We conclude that agroecology is a truly sustainable alternative. There is an urgent need to promote inclusiveness in the production of food; this makes sure the food system is sustainable and reduces the nutrition inequity gap so that everyone can access healthy and nutritious food easily. Producer-consumer relationships are strengthened via shorter food circuits. Applying the concepts of the circular economy to agriculture is expected to increase its capacity for regeneration, build a more diverse and robust food system, protect the integrity of the environment, and promote rural livelihoods and incomes. Blind adherence to increasing food production without considering trade-offs or synergies with other outcomes is now being challenged, enabling India to envision alternative futures that address the needs of farmers, society, and nature. Changing food systems is an intergenerational challenge that requires an intergenerational approach. We have no choice but to empower youth as major stakeholders in the food system, as potential agents of change.

ABS, Nagoya Protocol and Biodiversity Conservation

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We have entered a monumental era in terms of realizing the impact of biodiversity loss on our everyday lives. We suffer from the consequences of biodiversity loss due to overexploitation of natural resources as we continue failing to restore biodiversity. One of the major consequences of biodiversity loss is the emergence of global pandemics. We are in urgent need of realizing the full potential of all of the international legal instruments on creating incentives for biodiversity conservation. Access and benefit-sharing or ABS is an international legal framework implemented with the hopes that it would provide such incentives. Therefore, a legal analysis on whether ABS is designed to achieve biodiversity conservation is of crucial importance in achieving international conservation targets. This lecture will introduce the ABS system from the PGR point of view. It will then move on to identifying the commonly used regulatory mechanisms of ABS which are put in place under provider countries' ABS legislation. The lecture will furthermore analyse the ability of these regulatory mechanisms to attain international ABS goals. Lastly, the adopted text of the Nagoya Protocol will be analysed with the aim of mapping the obligations of Parties to channel benefits into conservation. It is concluded that the design of the Nagoya Protocol does not intrinsically lead to biodiversity conservation but benefit-sharing is a tool that can be directed towards biodiversity conservation

Technologies and Innovations Contributing Towards Food and Nutritional Security in the Era of Climate Change

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The loss of arable lands due to the occurrence of unfavourable environmental conditions has threatened our food security and has increased the risk of malnutrition. Hunger and malnutrition have alarmed us to retain the food quality and quantity *per capita* for the future as an urgent requirement. Among several crops, rice has the advantage to be used as a genetic system for functional analysis due to having a small genome size, synteny with other cereal crops, and diversified source of closely related germplasm. To conquer nutritional and food insecurity, there is a vital need for better-quality and high-yielding varieties of crops that are more elastic to climate change and possess sufficient levels of essential amino acids, minerals, vitamins, etc. Moreover, the invention of genome editing has provided new opportunities for the development of improved crop varieties with the precise addition of beneficial traits or removal of undesirable traits. It allows faster genetic modification than other available techniques at a low cost and with high efficacy. Therefore, considering the complexity of stress response, and its impact on food and nutrition security, we are editing the rice genome to make it lysine-rich and tolerant to abiotic stresses which will retain food and nutritional security in the era of climate change. In the present talk, attempts will be made on presenting the tools and technologies being adopted to improve the yield and nutritional value in diverse crops.

Using New Breeding Techniques and Digital Tools for Crop Improvement

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Multiple technology approaches are needed to sustain genetic gains achieved through plant breeding, and address the major challenges associated with climate change as well as tolerance to biotic stress factors. Incorporating single genes into crops that enable plants to withstand these stresses is a demonstrated approach but one which has faced increasing difficulty in gaining approvals or release. To aid the crop breeder, molecular marker and genomics approaches have been used successfully and now the focus is on predictive breeding models for making decisions in breeding programs. Predictive breeding approaches can reduce time to develop a product as well as save on resources. Integrating doubled haploids has been a proven enhancement in breeding programs with a number of successes in commercial crops. More recently, digital agriculture has offered new methods of assessing crop performance. These include precise phenotyping and yield estimation using artificial intelligence and machine learning approaches. Finally, new breeding techniques have opened a myriad of opportunities to introduce new traits in crop breeding programs. Examples of these approaches along with outcomes and challenges will be discussed.

About Organizers, Co-organizers and Sponsors

The Alliance of Bioversity International and CIAT: Harness Agricultural Biodiversity and Sustainably Transform Food Systems to Improve People's Lives in a Climate Crisis

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Historical background: Bioversity International (now the Alliance for Bioversity International and CIAT) is an International institute governed by the CGIAR Principles on the Management of Intellectual Assets and the CGIAR Open Access and Data Management Policy. In 1974, Bioversity International was established as the International Board for Plant Genetic Resources (IBPGR) to coordinate an international plant genetic resources programme including emergency collecting missions, and building and expanding national, regional, and international genebanks. The Food and Agriculture Organization of the UN (FAO) acted as secretariat. In 1991, IBPGR became the International Plant Genetic Resources Institute (IPGRI) and in January 1994, IPGRI began independent operation as a CGIAR center and at the request of CGIAR, took over the governance and administration of the International Network for the Improvement of Banana and Plantain (INIBAP). In 2006 - INIBAP and IPGRI begin working under the name Bioversity International and started - 'Biodiversity for Food and Nutrition' initiative launched at the Convention on Biological Diversity Conference. In 2015 - Launched three new research initiatives: (i) Healthy diets from sustainable food systems, (ii) Productive and resilient farms and forests and (iii) Effective genetic resources conservation and use.

Bioversity International started to develop an Agrobiodiversity Index for use by countries and the private sector to measure and manage agrobiodiversity across three dimensions: diets, production and genetic resources in 2016 while launched the flagship publication - Mainstreaming Agrobiodiversity in Sustainable Food Systems: Foundations for an Agrobiodiversity Index in 2017. It summarizes the most recent evidence on how to use agrobiodiversity to provide nutritious foods through harnessing natural processes. In 2018 Bioversity International and the International Center for Tropical Agriculture (CIAT) signed a Memorandum of Understanding to create an Alliance that delivers research-based solutions that harness agricultural biodiversity and sustainably transform food systems to improve people's lives. The Alliance focuses on the nexus of agriculture, nutrition, and environment. We work with local, national, and multinational partners across Africa, Asia, Latin America, and the Caribbean, and with the public and private sectors and civil society. With novel partnerships, the Alliance generates evidence and mainstreams innovations to transform food systems and landscapes so that they sustain the planet, drive prosperity, and nourish people

An Alliance for Accelerated Change - Food System Solutions at the Nexus of Agriculture, Environment, and Nutrition

Our planet faces four interconnected global crises: climate change, biodiversity loss, environmental degradation, and malnutrition. Food systems are both a significant driver of these crises and a victim. Food systems can, and must, be part of the solution. Climate change is adversely affecting global agricultural productivity, while 23% of total anthropogenic greenhouse gas emissions derive from agriculture, forestry, and other land use. Agriculture is also a main driver of land degradation and biodiversity loss, accounting for 70% of freshwater use, 80% of deforestation and negatively affecting life on Earth. Biodiversity loss and climate action failure are in the top three risks facing the world in the next ten years. At the same time, our food systems are not meeting nutritional needs. One person in nine is hungry. Worldwide obesity has nearly tripled since 1975. More than 2 billion people lack the essential vitamins and minerals they need for proper growth and development.

The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) brings a dynamic, new, and integrative approach to research for development, addressing the food system as a whole – not merely its component parts and individual symptoms. We do this by working at the nexus of agriculture, environment, and nutrition to deliver impact at scale. Our combined work adds up to more than 100 years of experience of applying science to address global challenges, long before they started to make headlines. Our expertise covers the whole gamut from landscape-level environmental restoration and enhancement, to market systems, health and nutrition, and agricultural biodiversity characterization, conservation, and use. The Alliance has a unique capacity to make a difference. Alliance solutions support the achievement of the 2030 Agenda for Sustainable Development, the Global Biodiversity Targets, the 2016 Paris Climate Agreement, and the Bonn Challenge, among other international initiatives.

Strategic objectives: To achieve its vision of food systems and landscapes that sustain the planet, drive prosperity and nourish people, the Alliance of Bioversity International and CIAT delivers research-based solutions that harness agricultural biodiversity and sustainably transform systems to improve people's lives through four strategic objectives

1. People consume diverse, nutritious, and safe foods
2. People participate in and benefit from inclusive, innovative, and diversified agri-food markets
3. People sustainably manage farms, forests, and landscapes that are productive and resilient to climate change
4. Communities and institutions sustainably use and safeguard agricultural biodiversity

Novel approaches to transform food systems: How we do things is just as important as what we do. Our approach expands our role beyond research and ensures that solutions we generate lead to wider development frameworks. We are agile in responding to demands, challenges and opportunities but always guided by and true to our core principles, vision, mission, and objectives.

Strengths of the Alliance: The Alliance of Bioversity and CIAT brings a total of 100 years of institutional experience applying science to address global challenges around agriculture, biodiversity, environment, food security, and nutrition. Our research spans from blue-sky agenda-setting research to novel on-the-ground institutional innovation and participatory approaches to deliver combinations of social, economic, and environmental benefits. Our scientists have been working on the front lines of many global issues long before they started making headlines:

recognizing the importance of biodiversity for food and agriculture, pioneering genetic resource conservation practice and policy, looking beyond yield in agriculture to resilience, nutrition and sustainability. We were some of the first in the arena on themes related to agriculture and climate change, and big data in agriculture. Through our collaborative work, the Alliance has a track record of delivering impact on the ground. It has an extensive network of partnerships that span global, regional, and national research and development organizations, universities, CGIAR centers, farmers' organizations, the private sector, and other development actors. The Alliance is an integral part of the CGIAR system and is actively engaged in One CGIAR and the coordinated actions that it delivers.

Global reach: The Alliance has a global presence across four continents and has a collective human capital of more than 1,300 staff members, about 600 of whom are scientific staff.

Genebanks: The Alliance holds global collections of banana, cassava, common beans, and tropical forages. Future Seeds, a state-of-the-art genebank facility in Colombia, builds on and expands the Alliance's work on crop diversity, research, capacity building, and public engagement. The International Musa Germplasm Transit Centre in Belgium, which holds the world's largest collection of banana germplasm, is a world leader in cryopreservation.

Use and conservation of agricultural and tree biodiversity: The Alliance is a pioneer in on-farm conservation and conservation in the wild, documenting and understanding why farmers and land managers continue to use local species and varieties, and supporting and connecting their efforts to reduce loss of diversity. This work is closely linked to enhancing the use of biodiversity for better nutrition, expanded livelihood opportunities, and resilience. We have spearheaded genetic resource policy dialogues and related access and benefit-sharing mechanisms, including perspectives of local communities and indigenous people.

Climate-smart agriculture: The Alliance is home to world-class programs working on climate-change adaptation and mitigation, among the greatest challenges facing agriculture. The Alliance is the lead climate center of the CGIAR system, in the vanguard of efforts to develop climate-smart technologies and practices, low-emission agricultural systems, and enabling policy environments to unlock climate finance for scaling of interventions. Its research on climate change is a reference point and has shaped policies for climate action in agriculture at global, national, and subnational levels.

Nutrition: The Alliance is a major player in nutrition in CGIAR, leading work on biofortification, dietary diversification, dietary choices, and nutritional quality of a wide range of crops, both traditional and underutilized. Work on value chains links nutrition objectives with value-adding interventions at all stages of the value chain, from producer to consumer. The Alliance promotes dietary diversity by generating evidence for the nutritional value of such an approach, influencing policies to support its adoption, and raising awareness of its nutritional importance

Digital agriculture: The Alliance leads CGIAR work on the use of big data for agricultural research and development. In doing so, we translate complex data into accessible, user-friendly information to support decision-making. Cutting-edge work on artificial intelligence for crop disease detection and management and big data techniques for climate and agricultural forecasts has benefited small-scale farmers by improving decision-making.

Participatory research and gender approaches: The Alliance has long experience working with local communities to co-develop innovations, strengthen capacities for critical reflection and collective action, and enhance social inclusion. This is achieved using gender-responsive, engaged, community-based approaches, such as participatory action research methodologies, and through development of and support to farmer networks and platforms to allow local people to have a voice in policy processes.

Crop improvement: The Alliance breeding programs have a solid track record of developing and delivering superior varieties of numerous crops by unlocking the potential of plant genetics and building on farmers' knowledge. Breeding networks and work on seed systems represent a model of how continent-wide crop networks can function to improve the capacity of national systems and farmers. Crops with improved yield, increased nutritional value, and resistance to biotic and abiotic stresses have generated economic benefits to the tune of billions of dollars.

Leveraging Change in Food Systems

The Alliance has identified six 'levers for change' that will, applied judiciously, transform food systems and landscapes to meet the challenges of the burgeoning demand for more-nutritious food while maintaining and improving our environment and addressing climate change. These are pressure points where Alliance research can play a catalytic role, where our intervention can trigger multiplier effects for positive change, and where:

- the Alliance has comparative advantage
- an entry point generates beneficial knock-on effects through the system
- our catalytic role is recognized by partners
- we work at the nexus between the agricultural, environmental, and nutrition sectors

Six Levers for Change at the Nexus of Agriculture, Environment, and Nutrition

1. Food environment and consumer behavior

In all countries of the world – rich and poor – billions of people are suffering from malnutrition in all its forms: undernutrition, overnutrition, and micronutrient deficiencies. Diets are the essential link between food systems and nutrition and health outcomes, and poor diet quality is a core driver of the triple burden of malnutrition. Poor dietary quality calls for development of more-nutritious crops, safer foods, and better policies to harness inclusion, equitable outcomes, economic returns, protection of the environment, and productivity in food systems. Specifically, we need to identify healthy, culturally appropriate, locally available, affordable, and acceptable diets for specific contexts, and in the process contribute to shaping the behavior of producers, market actors, and consumers.

Strategies to achieve these objectives:

- Profiling the supply system, the food environment, and consumer behaviour to understand the political, economic, and institutional environment, including social norms shaping dietary choices, capacities, drivers, and points of entry for sustainable policies and programs
- Documenting, characterizing, and assessing wild and cultivated agricultural biodiversity and its role in food and nutrition security and healthy and sustainable diets.
- Designing and testing interventions, behavior-change communications, and policy incentives to drive consumer behavior toward healthier diets, including greater use of neglected and underutilized species, fruits, and nuts.

- Investigating and providing solutions to reduce the environmental footprint of different diets and dietary components and seeking to incorporate interventions to mitigate or adapt to climate change risks at different stages of the food system.
- Evaluating implementation and impact of policies and program interventions, including potential institutional mechanisms, needed capacities, and resources (e.g. the relationship between access/affordability and consumption, sustainability and price, resilience and diversity, forms of multisectoral and multi-stakeholder dialogue).

2. Multifunctional landscapes

The agricultural choices that governments and businesses have supported over the last 50 years have successfully increased harvests, decreasing the proportion of the world's population that goes hungry. But it is an agricultural model that also stores up problems for people and the planet, driving climate change, pollution, deforestation, land and water degradation, and undermining people's livelihoods. The Alliance has a long history of promoting sustainable agriculture and landscape management and restoration. We have a unique combination of scientific expertise on soils and water management, ecosystem services, landscape restoration, the use of biodiversity for food and agriculture, inclusive socio-ecological systems, and economic incentives. Based on this track record, the Alliance deliver innovations that improve ecosystem services, biodiversity conservation and use, and overall system productivity, profitability, and benefits to marginalized groups. We develop approaches that increase the resilience and multiple benefits of agricultural landscapes by diversifying their components, support services, and incentives.

Strategies that the Alliance use to achieve these objectives:

- Documenting, assessing, and integrating local agroecological knowledge and practices, differentiated by gender and age of originators and beneficiaries, that produce multiple benefits in a landscape
- Developing sustainable intensification practices that increase land and water productivity, minimize contaminants in food and the environment, maximize synergies between productivity, ecosystem services, and soil and plant microbiomes, and enhance resilience of agriculture to external shocks.
- Identifying and promoting incentives, institutional arrangements, and business models that encourage uptake of practices and principles that lead to safer food, lower environmental impacts, and resilient and diversified agricultural landscapes.
- Forging integrated agricultural systems that maximize the economic, social, and environmental benefits of integrating biodiversity for food and agriculture (crops, forages, and trees) with improved water, soil, agronomic, and tree management practices.
- Creating communication strategies and digital and modeling tools to accelerate diffusion and cost- efficient application of solutions for sustainable intensification and restoration of landscapes that are fit for purpose for, and accessible to, marginalized groups
- Connecting food produced sustainably (responsible production) with consumers (responsible consumption) to contribute to the uptake of healthy diets

3. Climate action

Addressing the climate crisis is undoubtedly a top global priority of the twenty-first century. Agriculture is a risky business for producers and value chain actors and is getting riskier in the face of climate change, land degradation, and conflict. Climate risk contributes to low investment in agriculture by governments and businesses, which slows technological innovation, leaves the livelihoods of many farming households on a knife edge, and threatens food and nutrition security. Risk has different impacts on different people depending on gender, age, socioeconomic status, and resources available; this needs to be considered in efforts to address risk. Building on its global leadership on climate change in the context of agriculture and food systems, the Alliance foment climate action in a number of strategic areas in the food system, with the goals of addressing the immense adaptation and mitigation challenge and supporting governments and partners in their efforts to deliver their commitments under the Paris Agreement while providing improved food and nutrition security. Particularly novel in our approach apply a climate-risk lens and, through innovative partnerships with the finance and agribusiness sectors, facilitate greater and better investment in agriculture to address the climate crisis.

Strategies that the Alliance employ on climate action:

- Characterizing risks from plot/household to country level to quantify risks better and to understand social vulnerability patterns and the potential impact of innovations.
- Characterizing and developing economically viable climate-smart technologies and practices, including building on local knowledge and traditional practices, designing diversified portfolios of crop varieties and species; farm activities to balance risks and increase availability of diverse, nutritious diets; and policies that promote their uptake.
- Developing risk-aware agricultural extension approaches, including deployment of climate information services, site-specific agriculture, household-tailored advice, a portfolio planning approach, and use of crowdsourced citizen-science approaches to facilitate adaptive management through digitally supported feedback from farmers.
- Leveraging sustainable finance to develop new instruments to incentivize and support adaptation and mitigation efforts in agriculture and food security.

4. Biodiversity for food and agriculture

The industrialization of food and seed systems and globalization of trade and supply networks have led to less plant diversity globally in people's diets, in markets, in farmers' fields, and in the wild. The immediate effect is a reduction in the diversity of what we eat and in our landscapes. Together, the loss of plant diversity means that people's diet quality is getting worse, farmers are exposed to greater climate risks, and ecosystem services to people are being lost and degraded. Loss of plant diversity has negative impacts on water catchment and purification, nutrient cycling and carbon sequestration, pollinators such as bees, and the crop diversity that helps control the build-up and spread of pests. Reversing these trends calls for efforts to boost the use of biodiversity for food and agriculture. We need to start by creating and responding to consumer demand for diverse, nutritious foods, and ensuring that farmers and land managers have access to the diversity they need to manage climate risks and stresses like pests and diseases.

Strategies that the Alliance use to achieve these objectives:

- Building an enabling environment for conservation and use of biodiversity for food and agriculture through support for national-level implementation of the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture's multilateral system of access and benefit sharing and key policy interventions such as seed laws and incentives for growing nutritious, resilient crops
- Promoting integrated conservation, characterization – including health and nutrition characteristics and DNA sequences – and availability of information to farmers, breeders,

and other users of biodiversity for food and agriculture across the spectrum from ex situ in genebanks to in situ in farmers' fields and in the wild, and at global, national, and community scales

- Measuring biodiversity for food and agriculture across markets, consumption, and production systems, and in genetic resource conservation to identify leverage points for change
- Strengthening and advocating for appropriate, economically viable, and inclusive seed systems for a wider range of crops and tree species to promote use of a wider range of diversity by farmers, breeders, land managers, and restoration practitioners
- Working with local, national, and international stakeholders to increase the use of biodiverse commodities in local food systems by linking producers, value-chain participants, and consumers.

5. Digital inclusion

Digital innovations and technologies are revolutionizing agriculture. Remote-sensed data on land, crops, and weather can provide up-to-the-minute information to help farmers manage their land and their crops. Apps on mobile phones and tablets help farmers, traders, and consumers connect, creating a level playing field where all actors are equally informed of market issues, and giving smallholders access to inputs, finance, and extension advice. Blockchain, the Internet of Things, and artificial intelligence are transforming the sector from farm to fork, helping consumers choose a more-nutritious and diversified diet. The digital revolution has the potential to create jobs for young people in particular – so-called 'digital natives' – and to encourage them to get involved in the agriculture sector by providing digital services and support. While this is an exciting innovation space, there is a risk that many people are not benefiting from it because of where they live and work or their socioeconomic status, gender, or age. Women, for instance, are 14 per cent less likely to have access to a mobile phone than are men, and Alliance research shows that only 16–28 per cent of farms of less than one hectare are currently served by 3G or 4G services, compared with 75–83 per cent for farms greater than 200 hectares. There is a danger that the digital revolution will not be inclusive and will increase the digital divide and information asymmetry between the haves and have-nots in the food system.

Strategies the Alliance employ to stimulate digital inclusion:

- Developing digital innovations that tackle exclusion through analysis of the specific constraints associated with context, gender, generation, and socioeconomic group, in relation to infrastructure, resources, capacities, social norms, and targeted interventions (e.g. building capacity for local entrepreneurship and innovation around the digital innovation space).
- Developing, testing, and promoting different inclusive models of digital advisory services (digital extension systems, farmer-to-farmer peer networks, etc.)
- Brokering knowledge from global to local, local to global, and horizontally (across networks of farmers, digital innovators, consumers, and others) to learn from each other and support collective action.
- Developing innovations around market intelligence and greater traceability in the food system (e.g. environmental, social, and governance safeguards, linking consumers to farmers)
- Enhancing food-system surveillance to reveal food-system flows between diverse actors (e.g. mapping informal markets).

- Employing crowdsourcing and citizen-science approaches to deliver locally appropriate seeds, inputs, and advice to improve food and nutrition security in a heterogeneous world.

6. Crops for nutrition and health

Diets are one of the main factors contributing to the triple burden of malnutrition affecting billions of people. Diet-related factors are now the number one risk factor for disease globally. The key features and components of a healthy and balanced diet are well known. However, one challenge is to produce the right kinds of foods matched to local tastes and production capacities in the context of climate change. Crop improvement has an impressive track record of increasing yields, and tackling pests, diseases, and climatic constraints. More recently, it has also successfully increased the content of specific micronutrients needed for human health, such as iron and zinc, in some major crops. We can accelerate crop improvement using new precision breeding technologies combined with participatory approaches.

Strategies that the Alliance use to achieve these objectives:

- Improving the nutritional quality of key staples through biofortification and through identification of nutrient-dense varieties
- Applying nutrition and health lenses to breeding programs for key staples to improve their nutritional quality and their contribution to health (e.g. reducing incidence of diet-related diabetes and cardiovascular diseases).
- Integrating gender-responsive participatory elements into crop improvement to address consumer preferences in new varieties.
- Employing precision breeding to accelerate development of traits related to productivity and diet, especially to eliminate compounds that interfere with the absorption of nutrients (antinutritional factors).
- Diversifying the Alliance's crop improvement programs to make available a more diverse set of locally and regionally important crops, adapted to changing climate conditions, to complement the food basket

Bioversity International contributed to the growth and development of Indian agriculture – a summary:

1. Conservation of Tropical Fruit Diversity: Promoting Sustainable Livelihood, Food Security and Ecosystem Services

This project was implemented from 2009 to 2015 as part of regional project (India, Malaysia, Indonesia, and Thailand). Work was undertaken on Mango, Citrus and Garcinia species. Silent outcomes include: conservation and use of mango, citrus Garcinia diversity and their wild species; establishment of 168 SHGs, 48 farmers, groups and community biodiversity management fund and recognition to 28 custodian farmers; development of DUS Guidelines for Citrus and registration of 67 mango farmers' varieties with PPVFRA; three GIs obtained (Nagpur-Mandarin, Malihabadi- Dasheri & Sirsi-Appemidi) and 104 scientific publications with ICAR scientists.

2. Reinforcing the Resilience of Poor Rural Communities in the Face of Food Insecurity, Poverty and Climate Change through On-farm Conservation of Local Agrobiodiversity

This project was implemented as part of regional project (India, Nepal, Bolivia) from 2011 to 2015 and worked on small millets. Project sites in India were Kolli Hills in Tamil Nadu, Mandla in Madhya Pradesh and Almora in Uttarakhand. Salient outcomes were: 11 value-added products produced and marketed by *'Kolli Hill Agrobiodiversity Conservers' Federation'* across Tamil Nadu under the brand of "*Kolli Hill Natural Foods*"; strengthening 15 Village Millet Resource Centres and community seed banks; nine traditional rice varieties given to the CSBs and 13 threatened rice varieties shared with farmers; establishment of on-farm network of custodian farmers and use-enhancement actions for small millets; promote conservation and use of millets and establishment of on-farm network of custodian farmers.

3. Seeds for Needs: A Citizen Science Approach for Climate Change Adaptation in India:

This project was implemented for genetic base-broadening of current farming system using crowdsourcing (CS) and Participatory Varietal Selection trials (PVS) approaches to look for the "best set" of genotypes those can perform well even under the changed hydrothermal regime. The major focus was on wheat and rice farmers across 4 states (Bihar, Chhattisgarh, UP and MP), where a set of selected varieties of wheat (44) and rice (34) released from the National Agricultural Research System (NARS) were promoted with 15000 and 7000 wheat and rice farmers. Before the intervention, the farmers usually used only two to three varieties, but now they know > 15 varieties of rice and wheat, and their response to different climatic conditions. To improve the access to good seeds 23 community seed banks were established at community level involving KVKs and Self Help Groups in remote and tribal areas of the country. In addition to promote the 'Dry Chain' storage technique for community CSBs, Bioversity also low energy *ex situ* gene bank established at ICAR-IIVR Varanasi for the conservation of ~9000 accessions of vegetable crops

4. Conservation of Neglected and Underutilised Species of Tropical Fruits

Bioversity International has created and established one of finest genetic gardens of Neglected and Underutilised Species of tropical fruits at University of Horticultural Sciences Bengaluru. The total collection now stands at 265 varieties belonging to 118 species, 67 genera and 35 families. It has many unique accessions for desirable fruit and quality attributes and few of these such as Jackfruit, 10 varieties, Chempadec, 4 varieties of Jamun, 3 genotypes of water apple (green, white and red) annona, (three species), peanut butter fruit, rose apple, carambola, lasoda, surinamcherry, straw berry guava, red guava and mulberry were mainstreamed. So far 3,200 plants were produced and supplied to 120 farmers.

5. Studies on Certain Ecosystem Services in Multi-varietal Orchards of Mango

The findings showed high population of beneficial microorganisms like nitrogen fixers, Phosphate solubilizers and Zn solubilizers ($ZnCO_3$), enzyme activities (dehydrogenase, acid phosphatase and alkaline phosphatase), and pollinators diversity was higher in multi-varietal orchards. Fruit yield was 21245.67 kg/ha under multi-varietal compared to 11407.65 kg/ ha and as a result income from multi-varietal orchard was INR 240250.49/ ha while it was INR 79853.55 from mono-varietal orchard (based on two-year data).

6. Studies on Ecosystem Services at Godavari basin

Studies on Quantitative Assessment of Ecosystem Services were carried out along the river Godavari to make a quantitative assessment of the impact of agriculture on terrestrial and aquatic ecosystem services to assist in developing alternate scenarios. The fish and aquatic insect diversities, water quality viz. pesticides, heavy metals & antibiotics content, socio-economic status and sediment retention/loss were studied. Overall results showed that water quality has affected significantly due to increased pollution load. As a result, fish diversity has declined significantly.

7. Mainstreaming Agricultural Biodiversity Conservation and Utilization of the Agriculture Sector to Ensure Ecosystem Services and Reduce Vulnerability

The project has been implemented across four agro-ecoregions viz., Western Himalayas including the cold arid tract; North-eastern region and the Eastern Himalayas; Western arid/semi-arid region, and Central tribal region covering 17 Districts across nine states and 20 important food crops. The project is proposed to be carried out in a fully participatory and integrated interdisciplinary approach. The expectation is that the farmers (25,000) across four agro-ecoregions covering 120,000 ha in India will maintain and use an increased diversity of 20 crops through improved availability of traditional local varieties, many of which were lost or degenerated due to non-cultivation and poor maintenance, and enhanced access to new adapted and resilient diversity. So far >2000 native varieties have been tested in >25000 farmers' participatory selection trials in 153 villages. Around 800o farmers have been trained through farmers' field days, biodiversity fairs, interaction meetings and farmers' exchange visits and cross-learning. 19 community seed banks conserving >3000 native landraces and farmers' varieties have been established.

8. Facilitation in Germplasm Import

Bioversity International facilitated the import of 24 improved parthenocarpic diploids and hybrids of Banana at NRCB, Trichy. Out of these, two varieties *viz*. 'Kaveri Kanya' and 'Kaveri Saba' were developed and released by the Central Variety Release Committee. These are dual purpose, dwarf, tolerant to soil moisture deficit stress, suitable for saline sodic and marginal soils and has extended green life of 7-8 days. More than 20,000 plants and 1.00 lakh clumps of this variety have been distributed to farmers in the states of TN, Kerala, Andhra Pradesh. Soybean germplasm (2000 germplasm accession) from USAID are imported and at being tested at NBPGR. 208 accessions of 22 temperate fruit crops from Uzbek institutes, Bambara groundnut and cowpea germplasm from Africa are under import

A dynamic vision: The Alliance brings a dynamic, new, and integrative approach to agricultural research for development, addressing the food system as a whole and not merely its component parts and individual symptoms. It advocates for agriculture as part of the solution to pressing issues, such as environmental degradation, climate change, and the food and nutrition crises, including tackling the triple burden of malnutrition, not, as is so often portrayed, as part of the problem. The Alliance will achieve this new, holistic vision by employing approaches such as innovation networks and communities of practice and by fostering new alliances and partnerships with investors, the private sector, disruptive innovators, and the like that build on our existing networks. We will also create novel ways to integrate our scientists and our partners in result-oriented teams that will deliver the outcomes this strategy envisages. Join us in accelerating our efforts towards a food and nutrition secure future that protects and enhances the environment in all its aspects.

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Indian Society of Plant Genetic Resources–35 Years of Contribution Towards Science and Policy in Plant Genetic Resources Management*

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Introduction

The Indian Society of Plant Genetic Resources (ISPGR), New Delhi, came into existence in the year 1987, as a multidisciplinary scientific body dedicated to the area of plant genetic resources (PGR). The Society was established by the scientists at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, under the leadership of Dr R.S. Paroda, the then Director of NBPGR. The idea for creation of ISPGR was conceived during the 'National Symposium on Plant Genetic Resources' organized by NBPGR, on March 3-6, 1987 to commemorate completion of a decade of NBPGR's establishment. The symposium was attended by 300 scientists from India and 20 from abroad, including those from International Centres like International Rice Research Institute (IRRI), Philippines, International Maize and Wheat Improvement Centre (CIMMYT), Mexico and International Centre for Research in Semi-arid Tropics (ICRISAT), India. During the symposium, Dr R.S. Paroda proposed the creation of ISPGR, which was welcomed by all the delegates of the symposium. Therefater, suitable action was taken to draft a constitution of ISPGR and most of the NBPGR scientists became founder members.

Objectives of ISPGR

The primary objective of the Society is to provide a forum to various workers in the field of PGR to express their views, publish their findings and interact with different stakeholders. The Society aims at the following:

1. To promote research in the field of PGR and related disciplines such as plant exploration/ collecting, characterization, evaluation, conservation, utilization, introduction and exchange, quarantine and data documentation and information management. Broadly, it will involve in an integrated way various disciplines, viz., Economic Botany, Ecology, Genetics, Plant Breeding, Ethnobotany, Taxonomy, Biosystematics, Biotechnology, Plant Physiology, Horticulture, Seed Science, Chemistry, Agronomy, Plant Pathology, Entomology, Nematology, Agricultural Statistics, Information Technology and allied disciplines.
2. To provide a forum to the scientists for expressing their critical views based on the scientific knowledge and rational thinking on important national policies and programmes related to PGR research and development.
3. To collect, collate and disseminate information on PGR.

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4. To encourage and promote close association/collaboration among members belonging to various disciplines.
5. To work in association and collaboration with other national and international societies/ organizations having similar objectives.
6. To publish a journal at regular interval, as decided by the Executive Council (EC), as an official publication of the Society.

Society Registration and Constitution

The Society was formally registered under the Indian Societies Act (1860) on November 3, 1987 with the Registrar of Societies, Delhi (Registration No. S/18336 of 1987). The Society is also registered under section 12A and 80G of the Income Tax Act of 1961, for tax exemption on any surplus funds of the ISPGR and for donor's tax exemption, respectively. Its headquarter is located in the NBPGR, Pusa Campus, New Delhi. The Constitution of ISPGR was drafted under which the General Body (GB) comprising all members of the Society was designated the supreme authority and elected an Executive Council (EC) biannually for management of all the activities. The Constitution was revised in 2007 and in 2017, under which EC tenure is three years. The GB determines the general policies and programmes of the Society in conformity with the constitution and bye-laws. The administration, direction and management of the activities/functions of the Society are carried out by the EC, which comprises President, two Vice-Presidents, one General Secretary, one Editor-in-Chief, one Joint Secretary, one Treasurer, and two Councillors from each zone demarcated by the EC. All Office Bearers are required to be members of the Society. Two *Ex-Officio* members of the Society are the imediate Past President, ISPGR and Director, ICAR-NBPGR.

The membership of the Society is open to any research worker/scientist or other person interested in PGR activities in India and abroad. The categories of members include life members, ordinary members, institutional members, student members and donor members.

Life Members are entitled to participate in all the seminars, symposia, conferences etc. organzied by ISPGR at subsidized rates, are entitled to apply for awards and become Fellows of ISPGR, as per guidelines, and receive copies (hard copy or PDF) of all issues of Indian Journal of Plant Genetic Resources (IJPGR). Annual/Life members can submit manuscripts for publication in IJPGR. Currently ISPGR has more than 900 members, both from within and outside India.

Notable Presidents

The EC of ISPGR is headed by President. Dr R.S. Paroda became the Founder President for two consecutive tenures (1987-88 and 1989-92) and later for another tenure during 1996-98. During 1993-95, Dr R.S. Rana, the then Director of NBPGR was the President, whilst in 1999-2000, Dr Mangala Rai, the then DDG (Crop Science), Indian Council of Agricultural Research (ICAR), New Delhi, became President. Dr P.L. Gautam took charge as President in 2001-2002, when he was National Coordinator, National Agricultural Technology Project (NATP), ICAR. In the subsequent two tenures (2003-04 and 2005-06), Dr B.S Dhillon, the then Director, NBPGR, served as President. During 2007-09, Dr Bhag Mal from International Plant Genetic Resources Institute (IPGRI, later rechristened as Bioversity International), Sub-regional Office for South Asia was the President. Later Dr S.K. Datta, the then DDG (Crop Sciences), served as President for the period of 2010-2014. Since 2015 onwards, ISPGR is headed again by Dr R.S. Paroda as President, who is Chairman of Trust of Advancement in Agricultural Science (TAAS) also. Thus, over the years the Society has greatly benefitted by being led by scientists who have contributed immensely in the areas related to PGR including the policy matters at national and international level. Further, it has been blessed by patronage from luminaries like Dr M.S. Swaminathan and the late Dr A.B. Joshi, two doyens of Indian Agriculture.

Scientific Activities Undertaken

In the last 35 years of its existence, the ISPGR has organized several dialogues, conferences, symposia, meetings that have contributed directly and indirectly in formulation of international and national policies and action on agricultural biodiversity, especially PGR. A few important events organized by ISPGR are shown in Table 1.

Table 1. Major events organized by ISPGR.

	Title of Conference, Symposium, Workshop, Brainstoring etc.	Co-organizer(s)	Date and venue
1.	National Dialogue on *'Plant Genetic Resources in India- Developing National Policy Option'*	NBPGR	December 1-2, 1993, New Delhi.
2.	National Dialogue on *'Issues in Management of Plant Genetic Resources'*	NBPGR	December 1-2, 1998, New Delhi
3.	Symposium on *'Plant Genetic Resources Management:Advances and Challenges'*	NBPGR	August 1-4,, 2001, New Delhi.
4.	National Conference on *'Transgenics in Indian Agriculture'*	ICAR and NBPGR	March 9-10, 2004, New Delhi
5.	International Symposium on *'Introduction Achievements and Opportunities in South Asia'*	NBPGR	February, 15-17 2005, New Delhi.
6.	National Symposium on *'Recent Global Developments in the Management of Plant Genetic Resources'*	NBPGR	December 17-18 2009, New Delhi
7.	Brainstorming session on *'Access and Benefit Sharing (ABS) - Striking the Right Balance'*	NBPGR, NBA	October 22, 2016, New Delhi
8.	**Ist International Agrobiodiversity Congress 2016- Science, Technology, Policy and Partnership**	Bioversity International, ICAR, PPV&FRA, NBA, TAAS, NAAS, MSSRF, ISGPB. CIMMYT, ICRISAT, ICARDA, GCDT, CABI, GIZ, APAARI etc.	November 6-9, 2016, New Delhi
9.	**Brainstorming**		
10.	Satellite Symposium on *'Dryland Agrobiodiversity for Adaptation to Climate Change'*	Bioversity International, APAARI	Feb. 13, 2019, Jodhpur
11.	National Webinar on *'Implementation of Access to Plant Genetic Resources and Benefit Sharing (ABS)'*,	Alliance of Bioversity International and CIAT, ICAR-NBPGR, NBA, PPV&FRA, TAAS	August 27, 2020 (virtual mode)
12.	Virtual Brainstorming on *'Digital Sequence Information and Germplasm Sharing'.*		March 2021 (virtual mode)
13.			
14.	National Consultation on *'Plant-based Local Food Systems for Nutrition and Health'*		Oct 22, 2021 (virtual mode)
15.	Peer Group Meeting on *'Biological Diversity (Amendment) Bill, 2021'*		Jan. 22, 2022 (virtual mode)

Besides the above, ISPGR actively contributed as a coorgizers in following events:

1. Second 'Crop Science Congress' wherein a Satellite Symposium was organized by ISPGR, November ,1996, New Delhi
2. Society was a member of the confederation that jointly organized the 'International Conference on Managing Natural Resources in the 21st Century' held during 14-18 February, 2000, at New Delhi and organized a Session and Keynote Address on PGR/Agrobiodiversity.
3. In the first Indian Science Congress of the New Millennium (88th session), held in January, 2001, New Delhi, ISPGR made significant impact on the deliberations on household Food, Nutrition and Environmental Security.
4. ISPGR celebrated the Birth Centenary of Late Dr. B.P. Pal by joint organization of the Symposium on Search for New Genes held on September 1-3, 2006, at National Academy of Agricultural Science, New Delhi.
5. National Symposium on 'Crop Improvement for Inclusive Sustainable Development', organized by Indian Society of Genetics and Plant Breeding, ISPGR, Crop Improvement Society of India and MTAI, 17-18 December 2009.
6. National Seminar on 'Crop Breeding for Wider Adaptation' was organized by Ranchi Chapter of Indian Society of Genetics and Plant Breeding (ISGPB) in collaboration with ISGPB, New Delhi and ISPGR, New Delhi at Birsa Agricultural University (BAU) from Dec. 12-13, 2020.
7. '2nd International Agrobiodiversity Congress (IAC)' hosted by the Government of Italy and Alliance for Bioversity International & CIAT, Nov 15-18, 2021.
8. A National Symposium on "Food, Nutrition and Environmental Security: Towards Achieving SDGs" organized by TAAS, ICAR, NAAS and ISPGR in collaboration with BI & CIAT, ICRISAT, CIMMYT and IRRI, 29-30 August 2022, New Delhi.

All the above activities have led to great visibility of the ISPGR and its members. In the recent past, the IAC2016 initiated by ISPGR has become a rolling event at internatioal level, with the 2nd IAC held in Rome in 2021 and the next one expected to be held in China, with support from the Allaince of Bioversity International & CIAT. The 'Delhi Declaration on Agrobiodiversity', a visionary document developed for pathway and action points on the sustainable management and use of agrobiodiversity through interdisciplinary exchange of ideas and opinions among various stakeholders has been much appreciated. It provides a roadmap to enhance food, nutrition and health security by optimal utilization of agrobiodiversity while protecting agro-ecosystems and landscapes, and also mainstream agrobiodiversity related issues into global discussions to ensure fair access, benefit sharing and sustainable use.

Awards and Recognitions

The ISPGR annually bestows several awards and recognitions to its members to encourage and motivate dedicated researchers working in the area of PGR management. following awards are instituted:

1. **Dr Harbhajan Singh Memorial Award:** This prestigious award has been instituted by the ISPGR in the memory of Late Padma Shri Dr Harbhajan Singh, referred to as the Indian Vavilov and Father of PGR in India. It carries a sum of Rs 1,50,000 in cash, a citation and a plaque. The seed money was a contribution made by M/s Mahrashtra Hydrid Seeds Co., Jalna. The award is a lifetime achievement award, given biennially to eminent scientists who have made outstanding contribution in the field of PGR with special

reference to India.

2. **Dr S.K. Vasal Award for Efficient Use of PGR :** Dr Surinder Kumar Vasal, World Food Laureate (2000) and Distinguished Scientist (Retd) of International Maize and Wheat Improvement Center (CIMMYT), Mexico, contributed a corpus of Rs 10 lakhs to ISPGR fin 2021 for instituting an award to recognize those who have shown professional excellence in the utilization of PGR, including areas of pre-breeding, genetic enhancement, use of germplasm or crop wild relatives for breeding, widening genetic base of crops etc. The award is carries a sum of Rs 1,00,000, a citation and a plaque to be given annually to a scientist (or team of 2-4 scientists) who have dedicatedly used PGR for developing advanced materials, that have impacted agricultural growth/ sustainability.
3. **Dr B.R. Barwale Award for Application/ Excellence in PGR** was instituted by ISPGR in 2017 to recognize the work of scientists/researchers who have significantly contributed in any area of PGR science or application, including collecting, characterization, evaluation, conservation, use (e.g. development of varieties) and other matters for its management. The award is supported by generous contribution made by the family of late Dr B.R. Barwale. It carries a sum of Rs 1,00,000, a citation and a plaque to be given annually to mid-level scientists working in the PGR domain.
4. **Dr R.S. Paroda Young Scientist Award:** Dr R.S. Paroda, an outstanding scientist, administrator and policy maker, donated the cash prize received by him in 2001 on account of Dr Harbhajan Singh Memorial Award and some corpus fund to ISPGR. The award is carries a sum of 50,000, citation and plaque and is given annually to recognize the outstanding contributions of young scientists in area of PGR.
5. **Dr R.K. Arora Best Paper Award.** This award has been instituted in 2008 by the ISPGR out of the cash prize donated by the late Dr R.K. Arora to ISPGR on account of Dr H.B. Singh Memorial award of 1998-99. The award carries a cash prize of Rs 10,000 and a plaque. This award is given annually to author(s) who contribute(s) best work in the form of publication in Indian Journal of Plant Genetic Resources.
6. **Dr K.L. Mehra Memorial Award for the Best PGR Student:** Dr K.L. Mehra was the first Director of NBPGR. Mrs Mehra donated seed money to institute an award in name of Dr Mehra in the year 2009. This award is given annually to best M.Sc. PGR student of IARI Post-Graduate School to motivate and encourage PGR students to excel in area of PGR. It carries Rs 20,000 cash prize and a plaque of honor.
7. **'Fellows' of ISPGR.** The process was initiated in 2007 wherein 52 Founder Fellows were selected. Five fellows are selected each year, and so far the Society has recognized valuable contributions of more than 75 Fellows in the areas of PGR research. In addition six Honorary Fellows include Prof M.S. Swaminathan, Late Dr A.B. Joshi, Prof G.S. Khush, late Prof. S Rajaram, Prof. R.B. Singh, Dr H.D. Upadhyaya, Prof. Emile Frison, Late Prof H.Y. Mohan Ram, Dr S.K. Dutta, Dr R.R. Hanchinal, Dr J.S. Sandhu, late Dr K.S. Gill, Dr S.K. Vasal and Prof. Kamal Bawa.

Publications by ISPGR

In accordance with objectives of the Society, a triennial journal, 'Indian Journal of Plant Genetic Resources (IJPGR, ISSN 0971-8184), is being regularly published to disseminate/update knowledge on PGR activities. The IJPGR comprises full-length papers or short communications of original scientific research in the field of PGR. Review articles summarizing the existing state of knowledge in topics related to PGR are also published. In addition, it also notifies the trait-specific germplasm/genetic stock 'registered' by the ICAR. The current NAAS rating of IJPGR is

5.54 (2022) while Indian Citation Index – Research Impact Indicator is 0.096. The PDF copies of all issues from 1988 till date are available at http://www.indianjournals.com/. Efforts are underway to make IJPGR a fully open access journal, to increase its visibility. The latest issue of IJPGR (Vol 35 issue no 3, 2022) is special issue commemrating the 80th birth anniversary of the founder and current President of ISPGR, Dr R.S. Paroda. The issue consists of 80 articles by eminent experts in agrobiodiversity, on achievements and way forward in variuos facets of genetic resource management. The articles can be accessed from the link http://ispgr.nbpgr.ernet.in/80.html

Besides the IJPGR, the Society publishes books, proceedings and other information leaflets related to its activities. The details can be accessed from the ISPGR website (http://ispgr.nbpgr.ernet.in/Default1.aspx)

Miscellanous Activites

The ISPGR hosts lectures and meetings on relevant topics under the series of 'Dr A.B. Joshi Memorial Lecture', Dr Dilbagh Singh Athwal Memorial Lecture', which normally coincide with the annual award function of the Society. Further, need-based technical inputs are provided on policy matters to ICAR, NAAS, and Ministries etc. Regular meetings of GB and EC are held and elections of Society are conducted as per rules, every three years.

Conclusion

ISPGR has been serving the PGR research community for the last 35 years in various ways. Under the able guidance of past and current Presidents and EC, Society has been serving its purpose very effectively. However, the emerging issues related to PGR are enormous, which need the attention of researchers, teachers, policy makers and farmers time to time. It is the endeavour of ISPGR to provide a platform for open discussion and provide the way forward for sustiable management of agriculture through effective use of agrobiodiverity.

Mahyco Grow

Founded in 1964 by Dr. B. R. Barwale, Mahyco Private Limited, popularly called as **Mahyco** is the flagship company of the **Mahyco Grow**, formerly known as Barwale group. Mahyco was founded with a vision to bring science based solution to address farming challenges through Seeds. Today, Mahyco Grow has three business verticals – Hybrid seeds, Engineering, and Fresh produce.

1. Hybrid Seeds

Mahyco Private Limited is focused on research and development, production, processing, and marketing of seeds for India's farming fraternity. Founded in 1964, Mahyco is the pioneer of high quality hybrid and open pollinated seeds. Headquartered in India, the company was founded with the objective of strengthening Indian food sovereignty and is now one of the country's best established seed companies. Following a business restructuring two years ago, its seed business in India is now organised under Mahyco Pvt Ltd. The company has expanded its operations in South-East Asia and in Africa over the recent years through its group company Mahyco International Pte Ltd with a vision to take its experience and expertise to serve the small holder farmers in these regions.

Ranking fourth in the 2021 Access to Index study by World Benchmarking Allinace for South and South-East Asia, Mahyco Grow demonstrates leading performance across the majority of measurement areas, particularly in research and development and also governance and strategy. Germplasm development forms a core activity of the company, and Mahyco maintains a large centralized germplasm collection at its main R&D centre near Jalna, Maharashtra. The seed collection is maintained and rejuvenated as per standard practices by crop. Working stocks of seeds are also maintained at satellite germplasm storage units at regional breeding stations.

Mahyco adheres strictly to the provisions of the Govt. of India enacted 'The Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001' adopting a sui generis system. This Act was established in order to provide for the establishment of an effective system for the protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants. The legislation recognizes the contributions of both commercial plant breeders and farmers in plant breeding activity and also provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions, and farmers. Mahyco began registration of its varieties in 2007and continues to actively engage with the Authority as needed.

Mahyco is widely respected for its strict adherence to quality. In keeping with its vision of being a pioneer in agricultural innovation, Mahyco was the first Indian company to introduce hybrid seeds for Wheat, Sorghum, Pearl Millet, and Sunflower, and many vegetables in India. It was also the first to introduce GMS /CMS based Cotton Hybrids in the world. Mahyco actively produces, processes and markets over 115 hybrids in 30 crop species, including cereals, oilseeds, fiber crops and vegetables. Mahyco also introduced India's first biotech crop Bt Cotton in collaboration with Monsanto in 2002. This technology helped transform the cotton sector in India, by increasing the domestic cotton production from 13.6 million bales in 2002 to nearly 40 million bales by 2015, making India the largest producer of Cotton in the world.

2. Engineering

The vision of the Engineering Businesses of Mahyco Grow is to provide modern and scientific solutions to agricultural processing and storage, with a view to minimize the post harvest losses, and help in adequate value addition to agricultural production.

Westrup is an Engineering company of the group based in Denmark providing Engineering solutions on project basis for agricultural produce processing in EU and America. This company started as a seed cleaning equipments company in Europe about six decades back, was acquired by Mahyco Grow during last decade. Today, Westrup is the leading company in Europe providing pre-engineering consultancy to complete project management in handling and processing of grains and other agricultural productions.

Fowler Westrup is the Engineering company of the group based in Bangalore ,India providing engineering solutions for cleaning, grading, sorting- including colour sorting, Processing, and Silo storage of Agricultural produce. Fowler Westrup is the only such engineering company in India providing comprehensive end to end solutions to post harvest management of agricultural produce. This was also the business that the Mahyco Grow acquired during the turn of this century. It has technical collaboration with many global engineering companies specializing in different parts of post harvest value chain.

3. Horticulture Genetics and Fresh Produce

Seven Star Fruits Pvt Ltd, a group company of Mahyco grow is a leading exporter of fruits from India. Its product range covers Grapes, Mangoes, Pomegranate, and Banana. It works with horticulture farmers closely to help in producing quality fruits by providing technical support. Seven star has also entered the domestic market recently for supplying fruits and vegetables to retail chains, and direct to home delivery in select cities.

Seven Star also supplies elite planting materials for select horticultural crops in India. It is working on improving genetics of some of the fruit crops like Apple, through its exclusive licensing arrangement with leading Apple rootstock research institutions in USA, along with elite club varieties of scion, in order to improve the yield and the quality of fruits produced and marketed in India.

Grow Indigo Pvt Ltd and **Fytomax Nutrition Pvt Ltd** are emerging businesses of the group. Grow Indigo, a joint venture between Mahyco Grow and Indigo Ag of USA is focused on Creating value for smallholder farmers and protecting the environment with regenerative agricultural practices . Fytomax Nutrition is focused on making available the affordable plant based proteins for ensuring nutritional security of the nation.

Role of FSII in Providing Sustainable Solutions to Farmers

Environmental sustainability is the need of the hour for managing climate change. Agricultural sustainability is both a boon and a bane for the farmers. Farmers can be major contributors as well as beneficiaries of sustainable practices. However, they can negatively impact the environment by not following the best practices and severely suffer the consequences.

Most technologies are delivered through seeds, be it genetics, traits, or seed treatments, therefore seed industry in concordance with the farmer can significantly contribute towards sustainability. Continuous innovation in seeds being brought forward using technology by the breeders has been providing short- and long-term solutions to the various problems faced by the farmers in the field. The issues have been pre-dominantly climate change driven for the past few years and have been getting more severe lately.

Federation of Seed Industry of India (FSII) is an association of research-based seed companies that provide high-performance, high-quality seeds and technological solutions for the benefit of Indian farmers. The association is driven by the fundamental value of investing in research to create value for the farmer and in respecting the intellectual property of each other. FSII members contribute approximately 70% of research & development-based expenses of the seed Industry in India and are committed to long term investment in research infrastructure and skill development. Alliance for Agri Innovation, a special interest group of FSII focuses on agricultural biotechnology industry.

FSII members have been regularly bringing forward high yielding crop hybrids, varieties that have ensured higher productivity with lower inputs. The cultivation of input efficient crops lowers the strain on the input resources, conserves water, soil quality and contribute towards sustainability. Similarly, the higher productivity nullifies the need for land conversion to farms as a matter of fact some instances of reverse conversion have been observed due to better productivity. Lower land conversion contributes not only to better carbon capture, conservation of soil and natural water bodies but also diversity of flora and fauna that together manage long-term sustainability in the region.

United Nations' Intergovernmental Panel on Climate Change (IPCC) has warned that the rise in global average temperature is going to have a serious negative impact on Indian agriculture. We experienced this with the wheat crop this year as well as unseasonal heavy rains that marred a good harvest of Kharif crops. In 2021, over five million hectares of crop area was destroyed due to extreme events driven by climate change. Severe weather conditions like prolonged drought, flooding, unpredictable rain patterns, frequent cyclones, increase in salinity have destroyed standing crops. FSII members have been using marker assisted breeding to develop climate resilient crops that can withstand restricted resource availability like poor soils and paucity of water. These new varieties and hybrids are being developed using prior knowledge and the latest molecular techniques, including GM technology.

Another aspect of climate change is the increased infestation by pests and disease with many pests widening their spread across agro-climatic regions and infecting newer hosts. Pest resistance is also being tackled at the stage of seed, be it with improved native or GM traits or seed treatments or providing support to the farmer in managing the resource or pest stress. The success of insect resistance trait in cotton (Bt cotton) that transformed the cotton cultivation and associated industries is a stellar example of technology providing solutions to modern day issues.

Germplasm diversity is the most critical resource for new hybrid/variety development and developers spend a lot of resources in preserving and characterising the available germplasm. Therefore, these developers be it public institutions or seed companies develop the infrastructure for conservation and characterization of varies accessions of crops from across the country including wild and ancient varieties and contribute towards biodiversity conservation and sustainability in the long term. FSII members along with national agencies are custodians for an array of accessions for multiple crops.

FSII members are also working towards lowering greenhouse gas (GHG) emissions since conventional agriculture is responsible for 18% of total GHG emissions in the country. Plant breeders are developing photosynthetically efficient varieties that will better capture carbon, varieties amenable for no-till cultivation as well as resource efficient cover crops so that soil carbon is increased and GHG emissions are reduced. FSII members companies have also been working with the farmers to create awareness about the latest available varieties, technology, and agronomic practices to improve productivity, farmer's income, and sustainability for both short- and long-term gains.

FSII is an association of research based plant science industry committed to deliver quality seeds for farmers.

Alliance for Agri Innovation, a special interest group of FSII, promotes technology innovations in agriculture.

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Imperial Life Sciences (ILS) has been an exclusive representative of many leading global players in India. The objective of the company is to provide complete solutions in the field of Genomics, Molecular Diagnostics, Cell Culture, Drug Discovery and Bio-production labs and contribute towards advancement in the field of Science in India. ILS aims to simplify the research process by providing a cornucopia of quality and cost effective products, prompt Sales, Service and Technical Support and timely deliveries through an all India distributor network. ILS envisions to provide world class service and support to the customers and become their valuable partner in life. ILS became Imperial consulting member for Indian Govt. Draft on National Biotech Policy – 2005. ILS has been appointed as body member of FICCI Biotech Delegation to USA (June, 2005).

ILS creates a benchmark in the research space by being a "one stop solution" to the life science industry. Having partnered with major principals like Affymetrix, Nanostring Technologies, Agena Biosciences, Perkin Elmer; ILS offers ground breaking technologies to Indian scientific community. With strong hold in genomics & small animal imaging, ILS also delivers unmatched range of Genes2me's molecular biology reagents including restriction enzymes, polymerases etc. and CST's primary & secondary antibodies.

ILS has its own State-of-the-art Laboratory Facility at Gurgaon with High end instrumentations including Affymetrix Gene Titan MC high throughput Genotyping Microarray System, GeneChip 3000 7G Microarray System, Agena BioScience MassArray System, Nanostring Analysis Platform and Sequencer from BGI for Services, Demonstrations, Trainings and Proof of concept studies by our Application Scientists.

ILS contribution in agricultural research, education and extension in India is routed into deep level and well known for its multidisciplinary research programs and services in crop conservation and management. The company provides cutting edge technologies in Agriculture research covering all relevant fields related to crop management and conversation and development. ICAR institutes like NIPB, IARI are one of our premier customers and under the leadership of one of the leading scientist from NIPB, ILS has developed India first custom Array for Rice 50K Markers which has been presently used by many users across India. Apart from this there are many other crops based arrays which has been developed and customized by ILS Application team in collaboration with the user groups such as Rice 50K Chip, Rice 90K Chip, Wheat Breeder Array, Pigeon Pea, Chick Pea, Ground nut, Mango etc. which are being used by Indian Scientific Fraternity for their respective crop analysis and development.

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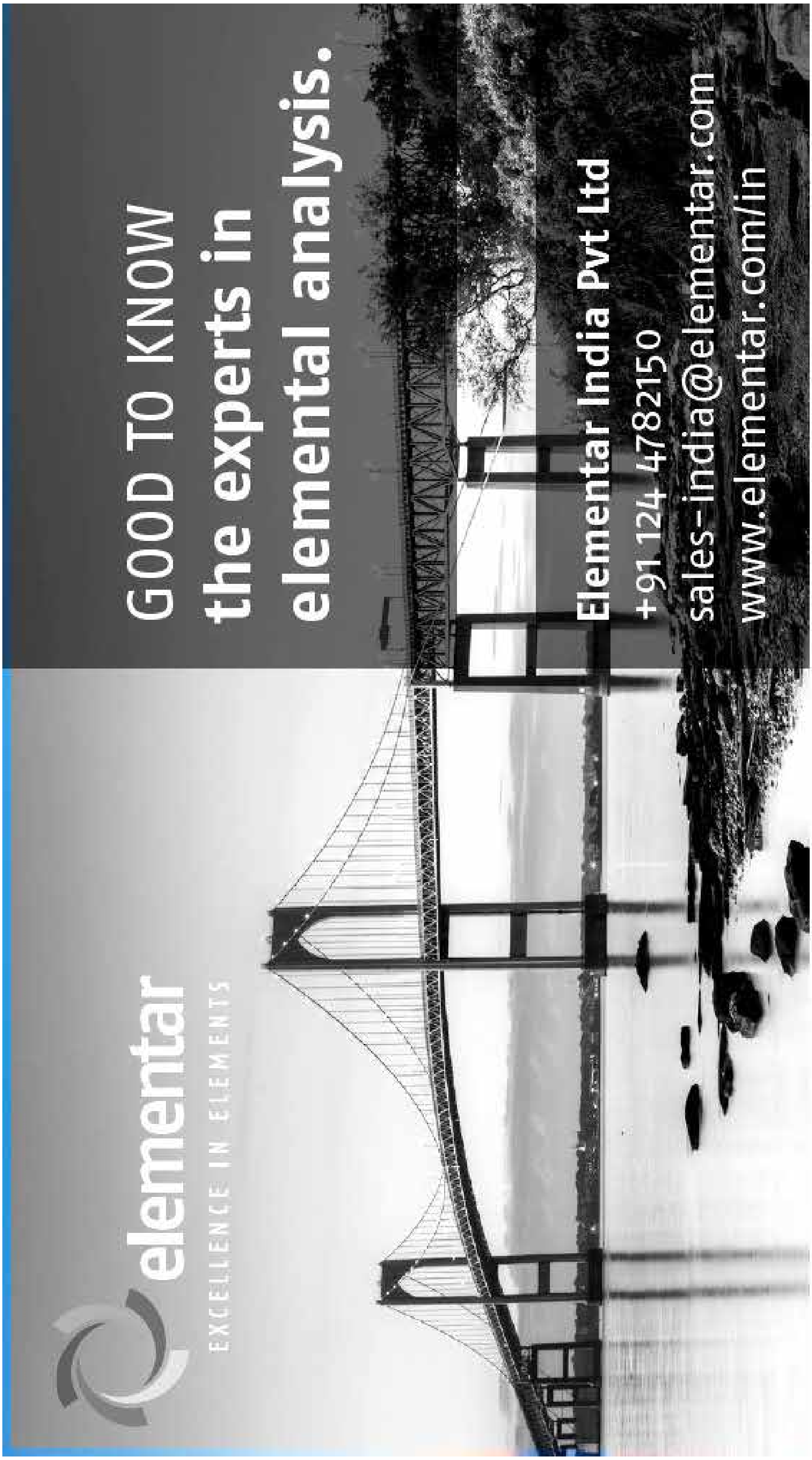
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