1st INTERNATIONAL AGROBIODIVERSITY CONGRESS

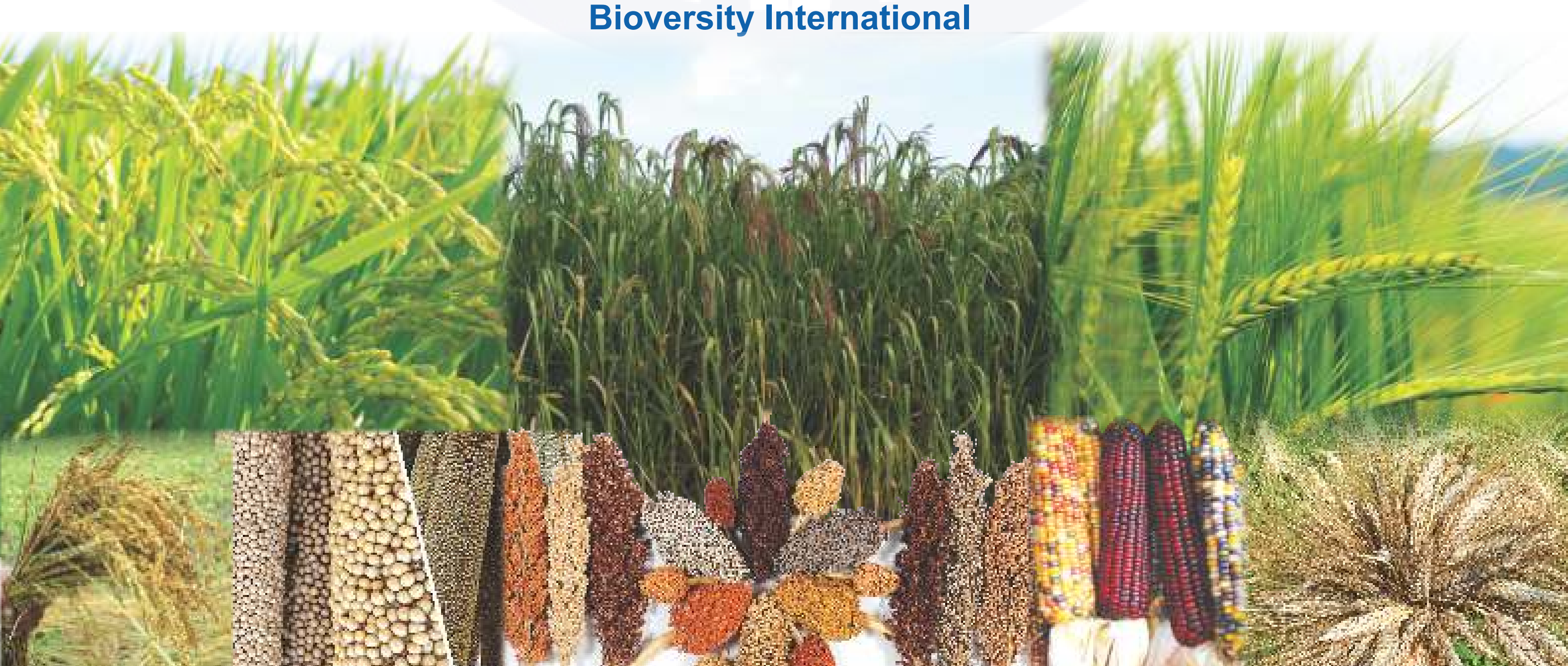
Science, Technology, Policy and Partnership

November 6-9, 2016, New Delhi, India

Souvenir

Organizers

Indian Society of Plant Genetic Resources
Bioversity International



Co-Organizers

भाकृअनुप ICAR

National Biodiversity Authority, India

taas Progress Through Science

National Academy of Agricultural Sciences New Delhi

MSSRF Science for Sustainable Development

APAARI Asia-Pacific Association of Agricultural Research Institutions

CIMMYT International Maize and Wheat Improvement Center

BISA Borlaug Institute for South Asia

german cooperation DEUTSCHE ZUSAMMENARBEIT

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1st INTERNATIONAL AGROBIODIVERSITY CONGRESS

Science, Technology, Policy and Partnership

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Souvenir

Organizers

Indian Society of Plant Genetic Resources
Bioversity International

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Compiled and Edited by:
R. K. Tyagi
Anuradha Agrawal
Sunil Archak
P. N. Mathur
Bhag Mal

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Congress Secretariat

Bioversity International
G-1, B-Block, NASC Complex, DPS Marg, Pusa Campus, New Delhi - 110012, INDIA
Tel: +91 11 25849000/1/2, Fax: +91 11 25849002
Email: info@iac2016.in, Web: web.iac2016.in

Professional Conference Organiser & Destination Management Company
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B-128, Sector-5, Noida 201301, National Capital Region-Delhi, India
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Email: info@iac2016.in, Web: www.tui.ice.in

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Website: www.mph.net.in

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Deputy Press Secretary
to the President of India

सत्यमेव जयते

राष्ट्रपति सचिवालय,
राष्ट्रपति भवन,
नई दिल्ली-110004.
PRESIDENT'S SECRETARIAT,
RASHTRAPATI BHAVAN,
NEW DELHI - 110004.

MESSAGE

The President of India, Shri Pranab Mukherjee, is happy to know that the Indian Society of Plant Genetics Resources (ISPGR) and Bioversity International in collaboration with Indian Council of Agricultural Research, Protection of Plant Varieties and Farmers' Right Authority and National Biodiversity Authority is organising the 1st International Agrobiodiversity Congress: Science, Technology, Policy and Partnership (IAC 2016) from November 6-9, 2016 at New Delhi.

The President extends his warm greetings and felicitations to the organisers and participants and sends his best wishes for the success of the event.

Date : 17 October 2016

Deputy Press Secretary to the President

Tel. (O) : 91-11-23793528 (Direct), 91-11-23015321 Extn. 4442 , Fax : 91-11-23010252
E-mail : message-rb@rb.nic.in

MESSAGE

प्रधान मंत्री

Prime Minister

I am happy to learn that the first International Agrobiodiversity Congress: *Science, Technology, Policy and Partnership* is being organized from 6th to 9th November, 2016 in New Delhi.

Our agrarian economy is blessed with rich biodiversity and natural resources. Conserving and nourishing this natural wealth is the key to achieving sustainable development goals. I am sure, this Conference will help evolve new strategies towards this end.

On this occasion, I convey my best wishes to the organizers and participants.

(Narendra Modi)

New Delhi
Date : 04 November, 2016

MESSAGE

राधा मोहन सिंह
RADHA MOHAN SINGH

D.O. No. 2448 /AM

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
MINISTER OF AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA
14 OCT 2016

I am extremely happy to know that the **1st International Agrobiodiversity Congress 2016 (IAC2016)** is being organized in New Delhi, India, from 6-9 November) 2016. India is rich in agrobiodiversity in form of plants, animals, fish, microbes and insects, which are extremely important for livelihood security of farmers. India has robust and dynamic National Agricultural Research System including genetic resources management system for conservation and sustainable use of genetic resources in development of agriculture and to increase income of the farmers.

I am confident that the IAC 2016 will provide the opportunity to share the experiences of scientists participating from various countries for their mutual research benefits to serve the farmers.

I congratulate Indian Society of Plant Genetic Resources, Biodiversity International, Indian Council of Agricultural Research, Protection of Plant Varieties and Farmers' Rights and other organizations for jointly organizing the IAC2016.

I wish the IAC 2016 a grand success.

Date : 14 October 2016

(Radha Mohan Singh)

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129

डॉ. हर्ष वर्धन
DR. HARSH VARDHAN

मंत्री
विज्ञान और प्रौद्योगिकी एवं पृथ्वी विज्ञान
भारत सरकार
नई दिल्ली - 110001

MINISTER
SCIENCE & TECHNOLOGY AND EARTH SCIENCES
GOVERNMENT OF INDIA
NEW DELHI - 110001

MESSAGE

I am happy to know that the **1st International Agrobiodiversity Congress (IAC 2016)** is being organized in India; in New Delhi from 6-9 November 2016. Science led innovations in agriculture in the past century have led to new openings and capacity building all over to harness biotechnologies for solution-finding research. India endeavours to work in partnerships with other countries and private sector on a sustainable basis to help maintain the rich agrobiodiversity evolved by the generations of farmers and also use it diligently with the newer tools of science and technology. In this context, the regulation of genetically modified organisms (GMOs) including their trans-boundary movements and biosafety/biosecurity; and handling of the environmental, public order and morality/ethical issues is critical. I will be happy to receive any futuristic recommendation emerging from the in-depth deliberations on germplasm-centric science led innovations as well as Quarantine, Biosafety and Biosecurity Issues during IAC 2016.

I congratulate Dr. M.S. Swaminathan and Dr. R.S. Paorda for the initiative and all the organizers of IAC and convey my best wishes to all the participants for purposeful deliberations.

Date : 5 October 2016

(Dr. Harsh Vardhan)

209, अनुसंधान भवन, 2, रफी मार्ग, नई दिल्ली–110001 दूरभाष : +91–11–23316766, 23714230; फैक्स : +91–11–23316745
209, Anusandhan Bhawan, 2, Rafi Marg, New Delhi-110001 Ph.: +91-11-23316766, 23714230; Fax: +91-11-23316745

S S AHLUWALIA
Minister of State, Agriculture & Farmers Welfare
Minister of State, Parliamentary Affairs
Government of India

एस एस अहलुवालिया
कृषि एवं किसान कल्याण राज्य मंत्री
संसदीय कार्य राज्य मंत्री
भारत सरकार

MESSAGE

The Government of India is making concerted efforts in improving the lives and livelihood of farming community, through various prosecution of interventions and schemes that encourage diversification in different sectors of agriculture development i.e. animal husbandry, fruit and vegetable production, goat rearing, poultry farming, fisheries, etc., alongwith farmers centric conventional farming. The main aim of these efforts is to eradicate rural poverty by increasing food production that underlies use of agro-bioresources and related technologies. Scaling-up and scaling-out grass-root level innovations to conserve, manage and use agrobiodiversity (including the crops, animals, poultry, fish and other agriculturally important biota) in the diversity rich rural areas. Increasing agricultural output requires a sustained scientific back-up, both in terms of new research and technology adoption. In India, the National Agricultural Research Systems (NARS) needs to be further strengthened for a more robust and dynamic germplasm management system, for long-term sustenance of its genebanks and genetic resources bureaux for plants, animal, fish, insects and microbes. At the same time, capacity building and human resource to employ new tools for optimal agrobiodiversity use require adequate attention.

In light of the above, I am happy to note that Indian Society of Plant Genetic Resources and Bioversity International have planned to host the 1st International Agrobiodiversity Congress (IAC2016) at New Delhi. The agenda of the Congress has been carefully set to cover most of above-mentioned and related issues. I hope the outcome of this event would be beneficial for both agriculture and people who are engaged in its practice. The IAC2016 can be a good platform to resolve some of the conflicting and contentious issues related traditional knowledge, exchange and benefit sharing of genetic resources in current regimes of IPR and WTO. My best wishes to the Organizers and participants for a successful conduct of IAC 2016.

Date : 5 October 2016

S.S. Ahluwalia

Office : 199Q, Krishi Bhawan, New Delhi - 110 001, India
Office : Room No. 56, Parliament House, New Delhi - 110 001, India
Residence : 10, Gurudwara Rakabganj Road, New Delhi - 110 001, India
Tel.: 91-11-23782343 (KB), 23034638 (PH), 23720747 (Res.), Fax: 23074190 (KB), 23731977 (PH)
e-mail: ssamin@gov.in, ssa@10grg.com

परशोत्तम रूपाला

PARSHOTTAM RUPALA

कृषि एवं किसान कल्याण और
पंचायती राज राज्य मंत्री
भारत सरकार

Minister of State For Agriculture & Farmers Welfare and Panchayati Raj Government of India

D.O. No. ..2(8)...MoS(AC&FW)/PR/VIP/2016/235

MESSAGE

The 1st International Agrobiodiversity Congress: Science, Technology, Policy and Partnership (IAC 2016) being organized at New Delhi, is a very aptly and timely event, as far as planning the security and sustainability of agriculture is concerned. Conventional breeding methods coupled with modern biotechnology tools are expected to play important roles in the generation of higher yielding, pest and stress resistant varieties of crops and breeds. The availability of genetic innovations will depend on continued high levels of investments in agricultural research, both at the international and the national levels. Unhindered access to germplasm to breeders worldwide is absolutely crucial to the rapid dissemination and adoption of improved germplasm. This movement and the dissemination of modern biotechnology innovations to developing countries are hampered by increased patent protection and increased legal regimentation. I am hopeful that the discussions in the IAC 2016 would lead to a roadmap to resolve the complex issues of access to germplasm, access to technology and benefit sharing amongst various stakeholders. The ultimate target is to develop a strategy that would ensure increased livelihood of farming communities and assured food and nutrition security for the masses.

My best wishes for a successful organization of the IAC 2016.

Date : 19 October 2016

(Parshottam Rupala)

Delhi Office : Room No. 322, 'A' Wing, Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110001
Tel. : +91-11-23383975/76 Fax: +91-11-23383971, E-mail : mosrupala@gmail.com, p.rupala@sansad.nic.in
Gujarat Office : Plot No. 219, Sector-20. Gandhinagar, Gujarat-382020, Telefax: 079-23260013

सुदर्शन भगत
SUDARSHAN BHAGAT

कृषि एवं किसान कल्याण
राज्य मंत्री
भारत सरकार
MINISTER OF STATE
FOR AGRICULTURE &
FARMERS WELFARE
GOVERNMENT OF INDIA

D.O.No. 219 /VIP/MoS(A&FW-SB)/Message

MESSAGE

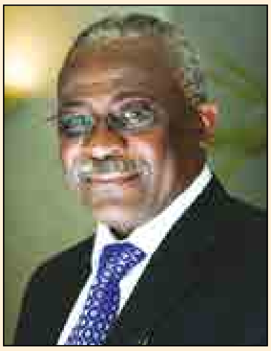
Traditionally, farmers, pastoralists and fisher folks are the primary users, generators and conservers of genetic resources. They have an intricate knowledge of genetic resources and use a variety of strategies to manage them to suit their needs. For resource-poor farmers in difficult ecosystems, this knowledge provides livelihood security, since mainstream hybrids and varieties often fail in harsh conditions. With such immense importance of genetic resources, it is very heartening to know that the Indian Society of Plant Genetic Resources and Bioversity International has planned to host the 1st International Agrobiodiversity Congress: Science, Technology, Policy and Partnership (IAC 2016) in collaboration with other partners. India is an agrarian country with an extremely rich legacy of agrobiodiversity. I do hope that the outcome of this event would result in a roadmap that would enrich the lives of farmers and addressing the pressing issue of food and nutrition security of the ever-increasing global population in an era of climate change.

I wish the organizers great success and extend my best wishes to all the delegates of IAC 2016.

Date : 21 October 2016

(Sudarshan Bhagat)

Office : Room No. 199-J, Krishi Bhawan, Dr. R.P. Road, New Delhi - 110001
Tel. : 011-23388859, 23388879, Fax : 011-23388827, Email : s.bhagat@sansad.nic.in office.sbhagat@gmail.com
Residence : 6 GRG Road, New Delhi-110001, Tel. : 011-23317352, Fax : 23317351



IFAD
INTERNATIONAL FUND FOR AGRICULTURAL DEVELPMENT

MESSAGE

Kanayo F. Nwanze
President

I would like to congratulate Dr. R.S. Paroda, Prof. M.S. Swaminathan and other organizers of the 1st International Agrobiodiversity Congress (IAC 2016) for this important initiative. The theme of “Science, Technology, Policy and Partnership” goes to the heart of the need for a concerted global effort by all stakeholders to end poverty and hunger while preserving the planet’s natural resources, thereby ensuring a sustainable future.

The International Fund for Agricultural Development (IFAD) is a unique organization, both an international financial institution and a United Nations agency. It is the only development institution exclusively devoted to eradicating poverty and hunger in rural areas. It does so by investing in rural people. IFAD finances agricultural and rural development projects that help rural people grow more food, increase their incomes, gain access to markets and financial and other resources, and direct their own development. Rural people make up three-quarters of the world’s hungry and poorest people, and are also on the cutting edge of climate change.

Rural people are also stewards of much of the world’s natural resources. Therefore, they are key partners in preserving agrobiodiversity. Rural people-including indigenous communities-can make valuable contributions thanks to their traditional knowledge and their understanding of ecosystem management. IFAD’s Adaptation for Smallholder Agriculture Programme (ASAP) is the largest global financing source dedicated to supporting the adaptation of poor smallholder farmers to climate change. In channeling climate finance to rural peoples, ASAP also supports local agrobiodiversity promotion and diversification as a means to adapt to climate change.

A key aspect of sustainable development will be to scale up grassroots-level innovations to conserve, manage and appropriately use agrobiodiversity, including crops, animals, poultry, fish and other agriculturally important biota in the richly diverse rural areas of developing countries. I am happy that the agenda of the Congress will cover these and other important issues, and will provide an opportunity for participants to share knowledge and experiences that contribute to sustainable rural development. I wish the congress every the success.

Date : 8 June 2016

Kanayo F. Nwanze

MESSAGE

United Nations Decade on Biodiversity 2011-2020

Braulio F. de Souza Dias
Executive Secretary

It is with great pleasure that I note that the 1st **International Agrobiodiversity Congress (IAC 2016)** is being organized in New Delhi, India, from 6-9 November 2016.

The Convention on Biological Diversity (CBD) is a global agreement that addresses all aspects of biological diversity, including agrobiodiversity. It also covers agreed provisions for community rights, biotechnology and intellectual property rights.

The objectives of the Convention are: the conservation of biological diversity; the sustainable use of its components (including agrobiodiversity and genetic resources for food and agriculture); and, the fair and equitable sharing of benefits arising out of the utilization of genetic resources. Shared benefits may include appropriate access to resources and transfer of relevant technologies, taking into account equitable rights over resources and intellectual property rights over technologies involved, as well as appropriate funding.

The Convention's protocols on biosafety and access and benefit-sharing and its supplementary protocol on liability and redress for damages caused due to trans-boundary movement of living modified organisms provide an additional framework for handling issues linked to agrobiodiversity management. Partnerships and linkages with other related institutions for trade, agriculture and environment also help promote the cause of agrobiodiversity management and use at large.

I am pleased that the Congress is providing participants with an opportunity to share experiences and concerns in this regard. The National Focal Points of the Parties to the CBD also endeavour to provide transparent information with regard to the implementation of national policies, plans, and programmes to meet the objectives of the Convention.

I would like to offer my congratulations to the organizers of IAC 2016, and I wish all participants of the Congress fruitful deliberations and a successful meeting.

Date : 14 July 2016 **Braulio F. de Souza Dias**

Secretariat of the Convention on Biological Diversity
United Nations Environment Programme
413 Saint-Jacques Street, Suite 800, Montreal, QC, H2Y 1N9, Canada
Tel : +1 514 288 2220 Fax : +1 514 288 6588
secretariat@cbd.int www.cbd.int

MESSAGE

M.S. Swaminathan
Founder Chairman
MS Swaminathan Research Foundation, Chennai

MSSRF
Science for Sustainable Development

Agrobiodiversity is the feedstock for sustainable food, nutrition and livelihood security. Some of the major components of agrobiodiversity are cultural, culinary, curative and ecosystem diversity. If today there is adequate food for 7.4 billion men, women and children, it is because of the intelligent use of agrobiodiversity through both mendelian and molecular genetics. It is surprising that agrobiodiversity which is the anchor of our food production has not yet received multidisciplinary and multi-national attention at an international conference. Therefore, the 1st International Agrobiodiversity Congress which will pay special attention to science, technology, policy and partnership is a path breaking event. I am confident that as a result of the interaction at the Congress, there will be increased opportunities for biohappiness arising from the sustainable and equitable use of genetic resources. I wish the Congress great success in helping to achieve the goal for food of all and forever.

Date : 7 October 2016

M.S. Swaminathan

Trust for Advancement of Agricultural Sciences

Avenue-II, Indian Agricultural Research Institute, New Delhi - 110 012
Phone: 011-65437870 Telefax: 011-25843243
E-mail: taasiari@gmail.com Website: www.taas.in

taas
Progress Through Science

MESSAGE

On behalf of the Indian Society of Plant Genetic Resources, I am pleased that we jointly with Bioversity International, are organising the *1st International Agrobiodiversity Congress from 6-9 November 2016* in New Delhi. It is encouraging that several national and global organisations such as ICAR, NBA, PPV&FRA, DST, ISGPB, MSSRF, NIF, TAAS, ACIAR, CIMMYT, ICRISAT, ICARDA, BISA, CABI, APAARI, EcoAfrica, FAO, GCDT, GIZ, JIRCAS, Kirkhouse Trust and some seed companies are co-sponsoring the congress.

Considering the importance of agrobiodiversity for human welfare and for achieving the sustainable development goals (SDGs), the congress is expected to deliberate for the first time important issues concerning scientific, technical, policy, and the legal matters affecting the management, conservation and sustainable use of agrobiodiversity.

It is highly encouraging to see an overwhelming response for the participation in the congress. More than 100 invited key speakers and around 800 delegates from 45 countries are expected to attend. It is expected that the deliberations would help us in defining a clear 'Road Map' for the sustained management and use of agrobiodiversity for over all betterment of humankind.

New Delhi is a beautiful capital representing both traditional and modern culture and known for its warm hospitality. It is our expectation that the delegates would find time to enjoy its flavour especially during pleasant weather at this time of the year.

I wish the 1st IAC 2016 a great success and look forward to see that it eventually becomes a rolling event and provides a neutral platform to deliberate most emerging issues concerning sustainable agricultural development and for global food, nutrition and environmental security through efficient management and use of agrobiodiversity.

Date : 14 October 2016

(Raj S. Paroda)
President, ISPGR, Chairperson, TAAS
and
Co-Chair, IAC 2016

MESSAGE

Ann Tutwiler
Director General, Bioversity International

Welcome to New Delhi and to the International Agrobiodiversity Congress!

I'm proud and pleased that my organization has joined hands with the Indian Society of Plant Genetic Resources (ISPGR) in organizing this Congress. We could not have done it without the support from various national and international organizations.

Agricultural biodiversity – or agrobiodiversity – is the foundation of sustainable agricultural development and is an essential natural resource to ensure current and future food and nutrition security. Increasing the sustainable use of agrobiodiversity in production and consumption systems plays an important role in solving today's challenges: reducing global malnutrition, adapting to climate change, increasing productivity, reducing risk and increasing shrinking food security. As the Director General of Bioversity International – which envisions that agricultural biodiversity nourishes people and sustains the planet – I am happy that agrobiodiversity is increasingly attracting attention of international and national communities, as endorsed by this International Agrobiodiversity Congress.

The International Agrobiodiversity Congress (IAC 2016) will gather more than 850 delegates from over 40 countries across the world who will present the results and stories of progress of agrobiodiversity research they are involved in. The Congress will provoke discussion and knowledge-sharing on issues for the effective and efficient management of genebanks; science-led innovations in the field of genetic resources; livelihood, food and nutrition security though crop diversification; issues relating to quarantine, biosafety and biosecurity; and Intellectual Property Rights and Access and Benefit Sharing in the context of exchange of germplasm; and many other related themes.

An important objective of IAC 2016 is to initiate and encourage a dialogue among relevant stakeholders – including farmers – to better understand everyone's role in agrobiodiversity management and the conservation of genetic resources. At Bioversity International, we believe that agricultural biodiversity, and information on how to use it, must be readily available across various sectors – including governments, intergovernmental bodies, plant breeders, the agri-food sector, farm households and rural communities. In this way, priority agricultural biodiversity can be monitored and safeguarded, seed systems can operate effectively, production systems can adapt to rapidly changing circumstances and consumers can have more diverse and nutritious diets. It is time for agrobiodiversity to be in the spotlight and the International Agrobiodiversity Congress is the perfect venue.

I would like to offer my congratulations to the organizers of the International Agrobiodiversity Congress and wish all participants of the Congress fruitful deliberations and a successful meeting.

Date : 14 September 2016

Ann Tutwiler

A CGIAR Research Centre

CGIAR

Bioversity International is the operating name of the International Plant Genetic Resources Institute (IPGRI)
Headquarters: Via dei Tre Denari, 472/a - 00054 Maccarese, Rome, Italy
Tel.: (+39) 0661181 - Fax: (+39) 0661979661 - Email: bioversity@cgiar.org
www.bioversityinternational.org

Martin Kroff
Chief Executive Officer

It gives me immense pleasure that the 1st International Agrobiodiversity Congress (IAC) is being organized in New Delhi, India during November 6-9, 2016. I am sure the Congress will be an excellent forum to bring together different stakeholders engaged in genetic resource conservation and management towards a common goal for food security and environmental sustainability. The rich experience of the scientists, students and farmers from public and private organizations will provide a real contribution to the sustainable management and utilization of agrobiodiversity around the world.

I wish the organizers a grand success in organizing this Congress.

With warm regards

Date : 14 October 2016

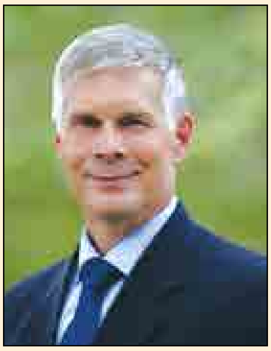
Dr. Martin Kropff

International Maize and Wheat Improvement Center
National Agricultural Science Centre Complex (NASC), DPS Marg, New Delhi -110012, India

International Maize and Wheat Improvement Center
Carretera México-Veracruz Km. 45, El Batán, Texcoco, Edo. de México, C.P. 56237 MEXICO

Email: cimmyt@cgiar.org
www.cimmyt.org

MESSAGE



ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

It gives me immense pleasure to write a message for the First International Agrobiodiversity Congress. For me it has special significance as ICRISAT is collaborating with the Indian Society of Plant Genetic Resources to organize this important event.

This Congress is timely, as today the world is facing unprecedented challenges in the form of shrinking availability of agricultural land coupled with the adverse effects of climate change on natural resources, including agricultural biodiversity. Further, climate change will likely exacerbate the situation as increased temperatures result in reduced productivity, increased diseases and pests incidence, and adverse effects on nutritional quality. The seriousness of the situation can be gauged by the fact that currently about 800 million people suffer from food insecurity and malnutrition. To overcome these multiple challenges, agrobiodiversity is an insurance that nature has bestowed upon the global community.

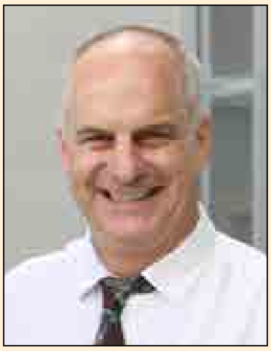
The Congress will offer an opportunity to enhance knowledge through an exchange of views, ideas and experience among the participants ranging from scientists and students to farmers and representatives of government, civil society and industry. Experts in genetic resources, genetics, breeding, biotechnology, genomics, information management, bioinformatics, conservation biology, policy etc. will actively deliberate to find solutions. A holistic approach which includes both *in-situ* and *ex-situ* conservation and more importantly greater use of genetic resources in crop improvement programs is urgently required.

ICRISAT has over 124,000 accessions of six mandate crops (sorghum, chickpea, pigeonpea, pearl millet, groundnut, and finger millet) and five small millets from 144 countries conserved in our genebank at Patancehru in Telangana, India. Besides the central gene bank we have three regional genebanks in Africa, at Kenya, Zimbabwe and Niger, to support our regional partners. ICRISAT genebanks have provided over 1.44 million samples of germplasm to scientists in 148 countries. This has had significant global impact whereby 109 germpalsm accessions have been released as 146 cultivars in 51 countries contributing significantly to food and nutritional security. Our national agricultural research system partners have released over 800 cultivars from breeding materials supplied by ICRISAT. Several countries which had lost their germplasm have recovered them from the ICRISAT genebank through repatriation of over 55,000 accessions to nine countries in Asia and Africa. We are focusing on identifying gaps in our collections and filling them through assembly, collection and enhancing the use of germplasm through the development of mini-core collections which represent just 1% of the entire collection. Extensive evaluation of mini-core collections and their molecular characterization has helped to identify genetically diverse trait-specific germplasm for use by the breeders to develop high yielding, climate resilient and nutritionally dense cultivars with a broad genetic base.

I wish this Congress great success in achieving its goals and in contributing to ensuring food and nutritional security for the global community by creating and an enabling environment to better maintain and utilize agro bio-diversity to support sustainable, nutritious and equitable agri-food systems.

David Bergvinson
Director General, ICRISAT

Date : 5 October 2016



Australian Government
Australian Centre for International Agricultural Research

GPO Box 1571
Canberra ACT 2601
ACIAR House, 38 Thynne Street
Fern Hill Park, Bruce ACT 2617
T (61 2) 6217 0500
F (61 2) 6217 0501
E aciar@aciar.gov.au
ABN 34 864 955 427

Andrew Campbell
Chief Executive Officer

MESSAGE

ACIAR was pleased to be invited by the Indian Society of Plant Genetic Resources (ISPGR), and Bioversity International in collaboration with Indian Council of Agricultural Research (ICAR), Protection of Plant Varieties and Farmers' Right Authority (PPVPFRA), National Biodiversity Authority (NBA), Trust for Advancement of Agricultural Sciences (TAAS), National Academy of Agricultural Sciences (NAAS), MS Swaminathan Research Foundation (MSSRF) and ICRISAT, CIMMYT, GCDT, JIRCAS, GIZ, to be involved with the **1st International Agrobiodiversity Congress** (IAC 2016), November 6-9, in New Delhi.

ACIAR supports the primary objective of the conference. Examining issues of global importance, especially the effective use of agrobiodiversity for food, nutrition, environmental security and climate change are crucial in our work to support agricultural research for development.

I am sure that the Congress will deliver some important outcomes and I wish you well with your deliberations.

Yours sincerely

Andrew Campbell

Date : 29 September 2016

ACIAR
Research that works for developing countries and Australia
aciar.gov.au

MESSAGE

ICARDA Science for Better Livelihoods in Dry Areas

ICARDA is a member of the CGIAR consortium and leads the CGIAR Research Program on Dryland Systems

Mahmoud Sohl
Director General

ICARDA is very pleased to participate to this important event which stresses the importance and benefits of saving and using the agrobiodiversity in sustaining the livelihoods of rural communities and in continuing to supply adaptive genes to overcome actual and future challenges to food security under the changing climate. ICARDA focus on the non-tropical drylands lays over four major Vavilovian centers of diversity for crops and forages of global significance, is playing a crucial role in promoting the conservation and sustainable use of dryland agrobiodiversity. I hope this Congress will emphasize further the needs to support concerted national, regional and global efforts for enhancing the conservation, the use and exchange of genetic resources for food and agriculture along with benefit sharing.

Date : 16 September 2016

Mahmoud Sohl

World Agroforestry Centre

Transforming lives and landscapes with trees

MESSAGE

I am very pleased that the Indian Society of Plant Genetic Resources (ISPGR), and Bioversity International in collaboration with Indian Council of Agricultural Research (ICAR), Protection of Plant Varieties and Farmers' Right Authority (PPVPFRA), National Biodiversity Authority (NBA), Trust for Advancement of Agricultural Sciences (TAAS), National Academy of Agriculture Sciences (NAAS), and MS Swaminathan Research Foundation (MSSRF) is organizing the 1st International Agrobiodiversity Congress from 6-9 November, 2016 at New Delhi, India.

ICRAF's research around the world has documented the multiple benefits for smallholders of agrobiodiversity – especially where they have chosen to plant quality trees. We expect this Congress to help spread the message of the importance of quality germplasm - its identification, delivery and conservation – for agricultural development. The importance of agrobiodiversity – in ICRAF's case tree species diversity – for resilient and productive agricultural landscapes cannot be under-estimated.

It is for this reason that I compliment the organizers for having chosen agrobiodiversity as a focus for this Congress and I look forward to hearing about its important outcomes.

I convey my best wishes for the success of the Congress.

Date : 11 October 2016

(Prof. Anthony Simons)
Director General

United Nations Avenue, Gigiri | PO Box 30677-00100 Nairobi, Kenya | Ph: 254 20 7224000 or 1 650 833 6645
Fax: 254-20- 7224001 or 1 650 833 6646 | Email: icraf@cgiar.org | http: www.worldagroforesty.org
INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY (ICRAF)

S.K. PATTANAYAK
SECRETARY

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

MESSAGE

It is a matter of great pleasure that **1st International Agrobiodiverty Congress (IAC 2016)** is being organized in New Delhi, India from 6-9 November, 2016. India is an agrobiodiversity rich country where farmers are engaged in diverse agricultural systems and farming situations to meet the local demand and also cater to the domestic and international market. Government is promoting both on-farm and off-farm activities, including farmers' rights and public-private partnerships for pushing a dynamic evolution of Indian agrobiodiversity *vis-à-vis* trade in agriculture. I am happy that the Congress will provide opportunity to also share corresponding experiences and concerns of other countries.

I am happy to note that eminent researchers like Prof. M.S. Swaminathan and Dr. R.S. Paroda are the torch bearers of this important initiative. I compliment the Indian Society of Plant Genetic Resources, the Bioversity International, ICAR, PPV&FRA and all other agencies jointly organizing the 1st Agrobiodiversity Congress.

I wish IAC 2016 a grand success.

Date : 22 September 2016

S.K. Pattanayak

त्रिलोचन महापात्र, पीएच.डी.
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAE
SECRETARY & DIRECTOR GENERAL

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
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAWAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

I am happy to know that the Indian Society of Plant Genetic Resources, Bioversity International, Indian Council of Agricultural Research, Protection of Plant Varieties and Farmers' Rights Authority, and National Biodiversity Authority are jointly organizing the 1st International Agrobiodiversity Congress: Science, Technology, Policy and Partnership during November 6-9, 2016 at New Delhi.

The natural resources, both physical and biological, provide food, fodder, fuel, fiber, medicine and industrial products. Over a period of time, these natural resources have been over-exploited that has resulted in the reduction of biological diversity. Developmental activities have also contributed significantly for the loss of biodiversity. This has warranted conservation of valuable bio-resource through gene/seed bank, field level germplasm collection and cryo-preservation enabling *in situ* and *ex situ* conservation and management.

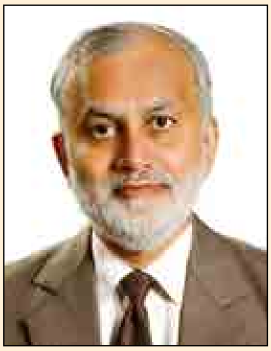
Globally, concerns are being expressed over alarming rate of loss of biodiversity. However, the existing biological richness in this planet still provides the opportunities for exploring newer species. Envisioning this, the Indian Council of Agricultural Research started exploring plant genetic resources way back in 1976. Eventually, the National Gene Bank at National Bureau of Plant Genetic Resources (NBPGR), New Delhi, has a collection of 4.29 lakh accessions of crops, of which, nearly 1.9 lakh accessions have been characterized and more than 2000 cultivars have been DNA fingerprinted. A significant milestone in agrobiodiversity conservation is characterization of 22,000 accessions of wheat and 18,500 accessions of chickpea during the last five years. So far, India has imported over 3 million samples of seed/planting materials, as germ plasm collection from 147 countries, and has distributed about 0.4 million samples of germplasm to various research organizations following the germplasm exchange protocol. Further, the germplasm collections are being screened and evaluated for bringing climate resilience in agriculture. While sustainable agricultural development is attributed to biodiversity conservation, the agro-ecosysterns are also to be emphasized for their species richness that is linked to the food chain. Realizing this, the ICAR has also established National Bureaux for genetic resources of animals, fish, agriculturally important insects and microorganisms widening the horizon of agrobiodiversity conservation.

The International Agrobiodiversity Congress would enable sharing of global experiences in agrobiodiversity management. I am sure, the Congress would also dwell upon issues regarding gemplasm exchange, plant quarantine, GMOs, equitable access to biodiversity, benefit sharing etc. and evolve strategic recommendations along with a framework for conservation and utilization of agrobiodiversity for ensuring sustainable agricultural development.

I wish the Congress a grand success.

Date : 30 June 2016

T. Mohapatra



National Academy of Agricultural Sciences

MESSAGE

Dr. S. Ayyappan
President

My greetings for the *1st International Agrobiodiversity Congress: Science, Technology, Policy and Partnership* (IAC2016) in New Delhi, India, from 6-9 November 2016. In India, consistent efforts by National Agricultural Research System have led to a robust and dynamic germplasm management system by establishing the genetic resources bureaux for plant, animal, fish, and agriculturally important microbes and insects. A large research infrastructure and human resource have been developed over the past decade to employ biotechnological tools for germplasm characterization and use. IAC 2016 will provide a common platform for scientists, researchers, policy makers, students and farmers to deliberate the various issues related to agrobiodiversity management and their sustainable use for ensuring food and nutritional security. The opportunity provided by IAC 2016 for sharing the experiences will also be unique to develop future research collaborations at national and international level.

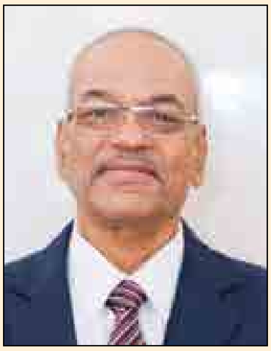
I wish the Congress a grand success.

Date : 14 September 2016

S. Ayyappan

NASC
DPS Marg, P.O. Pusa
New Delhi-110 012

Tel.: 91-11-25846055
91-11-25846051
91-11-25846052
Fax : 91-11-25846054
Email : naas@vsnl.com
Web.: www.naasindia.org



Asia-Pacific Association of Agricultural Research Institutions

FAO Annex Building, 202/1 Larn Laung Road, Pomprab Sattrupai
Bangkok 10100, Thailand

Email: apaari@apaari.org
Website: www.apaari.org

Tel: +66 (02) 282 2918
Fax: +66 (02) 282 2919

MESSAGE

Raghunath Ghodake
Executive Secretary

Agrobiodiversity, including plants, animals, insects, aquatic and microbial, is the foundation for sustainable agricultural development and is rather more crucial resource than even land, water and environment. In recognition of the value of agrobiodiversity for the society, and also in view of the concerns of its loss, resolute efforts need to be made towards conservation, access, sustainable use and advancement of this resource as that can contribute to the realization of the Sustainable Development Goals (SDGs).

The Asia-Pacific region is the primary center of origin/diversity of many important species of crops and livestock and secondary center of diversity of several species. Resource poor producers in the region are largely dependent on the agrobiodiversity of minor crops, their wild relatives and species of plants and animals for their food security and livelihood. Such a vast diversity needs to be effectively utilized and conserved for posterity and future use.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI), had been playing an invaluable role in conservation and use of agrobiodiversity in collaboration with its members, partners and stakeholders, the Suwon Agrobiodiversity Framework being a major initiative. Under its vision 2030, APAARI has planned systematic programs and activities in strengthening agri-food research and innovation systems in Asia and the Pacific. An integral part of these contributions have been the effective partnership and networking to manage, utilize, conserve and promote agrobiodiversity in the region.

I wish the first International Agrobiodiversity Congress a great success.

Date : 20 September 2016

Raghunath Ghodake

डॉ. जीत सिंह सन्धू
उपमहानिदेशक (फसल विज्ञान)

Dr. Jeet Singh Sandhu
Deputy Director General
(Crop Science)

भारतीय कृषि अनुसंधान परिषद्
कृषि भवन, डा. राजेन्द्र प्रसाद मार्ग, नई दिल्ली - 110001

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI BHAWAN, DR. RAJENDRA PRASAD ROAD, NEW DELHI-110001

MESSAGE

I am very pleased to be part of the 1st International Agrobiodiversity Congress (IAC2016), a unique occasion where researchers working on crop genetic resources, animal genetic resources, aquatic genetic resources, insect and microbial genetic resources relevant to food and agriculture. It is high time we all realize the importance of utilization of agricultural biodiversity to overcome challenges posed by food insecurity and climate change. A specific road map on the germplasm sharing and use on a sustainable basis within the framework of access and benefit sharing guidelines is expected from the IAC2016.

Breeders are fighting against abiotic and biotic stresses affecting the production and productivity of major crops. IAC2016 needs to delve on the significance and modes of employing crop wild relatives in breeding programs. The participants also need focus on in situ on farm conservation strategies and how to involve grassroot stakeholders in a workable model of conservation of genetic resources without affecting the livelihood security.

I congratulate the organizers for conceiving “Farmers' Forum” and “Genebank Round table” from which I have great expectations. I wish all the success to the IAC2016 and look forward to be part of the daily scientific deliberations.

Date : 19 October 2016

(J.S. Sandhu)

Ph. : (Off.) 23382545 Fax : 23097003 E-mail : ddgcs.icar@nic.in

भारतीय कृषि अनुसंधान परिषद्
कृषि भवन, डा. राजेन्द्र प्रसाद मार्ग, नई दिल्ली-110001
Indian Council of Agricultural Research
Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110001

डा. हबिबर रहमान
उपमहानिदेशक (पशु विज्ञान)
Dr. H. Rahman
Deputy Director General
(Animal Science)

MESSAGE

It is a matter of great pleasure to know that prestigious Indian Society of Plant Genetic Resources (ISPGR) and Biodiversity International of Indian Council of Agricultural Research, Protection of Plant Variety and Farmer's Rights Authority, National Biodiversity Authority, Trust for Advancement of Agricultural Sciences (TAAS) National Academy of Agricultural Sciences (NAAS), and MS Swaminathan Research Foundation (MSSRF) are organising 1st International Agrobiodiversity Congress (IAC 2016) from Nov 6 to 9, 2016 in New Delhi. India is known for its richness in agrobiodiversity that includes plants, animals, fisheries, and microorganisms, etc. The objective of the Congress is to provide an international platform to all the stakeholders engaged in conservation and management of genetic resources. I hope there will be in-depth deliberations on all the thematic issues of global importance on natural and effective use of all forms of agrobiodiversity for food and nutritional security and environmental safety.

I have great pleasure in extending my best wishes for the souvenir and success of the 1st International Agrobiodiversity Congress (IAC 2016) being inaugurated by Hon'ble Prime Minister of India, in bringing recommendations on issues related to agrobiodiversity for Indian and global Applications.

14/09/16

Date : 14 September 2016

H. Rahman

Phone : (O) 23381119, 23388991-7 Extn. : 200, Res. .... Fax : 0091-11-23097001
E-mail : ddgas.icar@nic.in

MESSAGE

डॉ. जे. के. जेना
उप महानिदेशक (मत्स्य विज्ञान)
Dr. J. K. Jena
Deputy Director General (Fisheries Science)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन-II, पूसा, नई दिल्ली 110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II, PUSA, NEW DELHI - 110 012
Ph. : 91-11-25846738 (O), Fax : 91-11-25841955
E-mail: ddgfs.icar@gov.in

Agro-biodiversity conservation and management today has not only remained as the subject of discussion for the researchers, agri-planners, policy makers, farmers and all those stakeholders associated with the agricultural sector, but also it warrants attention of each and every one of the Society in the contexts of ever-increasing population pressure, growing concern of malnutrition and hunger, and above all alarming situations being experienced due to climate change. It is indeed a great honour and privilege for me to be a Member of the National Steering Committee and having got opportunity to be associated in organization of the 1st International Agro-biodiverisity Congress (IAC 2016) to be held at New Delhi, India during November 6-9, 2016. I am sure, the Congress would provide an appropriate platform for greater deliberation by the experts associated in different segments of agro-biodiversiry management from allover the globe and come out with advisories/action plans which would greatly help in enriching the available Road Maps/Action Plans made for effective management of agro-biodiversity in different countries/regions, including that of India.

I wish the Congress a great success.

Date : 7 October 2016

(Joykrushna Jena)

Agrobiodiversity Needs Dynamic Change Management[1]

R.S. Paroda[2]

Chairman, Trust for Advancement of Agricultural Sciences (TAAS), and President, Indian Society of Plant Genetic Resources (ISPGR); Former Secretary, Government of India, Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research (ICAR), New Delhi - 110012

1. Preamble

World landscape and biodiversity profiles have been changing fast with forest cover shrinking, agricultural lands being shadowed by ambitious urban and peri-urban developments, genetic vulnerability of crops and genetic erosion on account of greater spread of high yielding varieties, and the threat of climate change. In three millennia during 1700-2000, there has been more than 500 per cent increase in the world area under agriculture with corresponding global forest land reducing by over 20 per cent. Almost 100 million hectares of agricultural land increased in just two decades (1980-2000) of which around 55 per cent was estimated to have been added from the forest cover.

Exponential population increase and demand for more food, feed and fibre had been the main causes for over exploitation of our natural resources. Every morning, the world requires extra food for additional >0.2 million people. Globally, half the food produced today comes from 1.5 billion small holder farmers. Subsistence farmers mainly depend on landraces in their cropping systems, and they use nearly 60 per cent of total agricultural land. Hence, awareness of smallholder farmers towards conservation and rational use of our agrobiodiversity is a critical pre-requisite for global sustainable development. In fact, time is running out and business as usual may be inadequate to salvage the rich genetic diversity that is being eroded gradually due to human intervention and climate change. In the processes of development as well as depletion of natural resources, we are either on the verge of losing or have actually lost important agrobiodiversity in different regions. Unfortunately, such realization often comes late for any recourse to reverse the processes but then this is the reality that we face today. We hardly do as much as is needed to be done about both conservation and replenishment of natural resources where feasible.

We started thinking globally in Stockholm in the UN Conference on Environment and Development 1972 (UNCED) to *inter-alia* care for and protect our agrobiodiversity landscapes, and conserve and use the dynamic gene pools of agricultural species and their wild relatives, for overall sustainable development. In 1983, the UN FAO provided a non-legally binding platform as per the International Undertaking on Plant Genetic Resources (IUPGR) to act locally on the principle of 'germplasm is common heritage of mankind' to maximize international free flow of germplasm and its use in crop improvement. Subsequently, in 1992 the Convention on Biological Diversity (CBD); in 2001 the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and in 2010 the Nagoya Protocol on Access and Benefit Sharing (NP-ABS) have set the legal standards for facilitated access and benefit sharing.

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[1]Article to commemorate the 1st International Agrobiodiversity Congress, 2016 (IAC 2016), New Delhi, India.

[2]E-mail Address: raj.paroda@gmail.com

However, the responsibility of implementing the conservation and access and benefit sharing (ABS) is broadly left up to countries without much international commitment for their requisite financial and institutional capacity needs. Nevertheless, actions at local and regional levels are crucial to harness the desired genes/attributes for better adaptabilities, fitness and higher source-sink relationships from the available gene-rich agrobiodiversity. Inescapable interdependence of countries and people around the world in terms of meeting each other's needs, preferences and tastes has significantly changed our food baskets. Therefore, it is important and urgent to manage and maintain on-farm at least the current level of genetic resources in diversity-rich pockets for hay day; for which new, innovative approaches, ways and means must be devised.

2. Agrobiodiversity Conservation

Agrobiodiversity dates back to the settlement and domestication era, over ten millennia B.C., whereas the centres of origin and diversity of crop plants were conceptualized only in the past century, mainly in the late 1920s. The knowledge regarding centers of origin and richness of available genetic resources and the evolution of technological approaches for germplasm use did change the paradigm for agricultural research from direct selection to systematic plant breeding and use of biotechnology over the past nearly six decades. Again, it is also well argued that while importance of agrobiodiversity and genetic resources will have to be understood globally, the specific actions to conserve and protect them for posterity will have to be managed locally. Hence, it is critical that we try to minimize the gap between the needs and the developments relating to agrobiodiversity management at all (global, regional, and national) levels. Bigger countries with diverse agro-ecologies have to also focus such attention on a zonal level.

2.1 Global Initiatives

The widespread genetic resource collection efforts in the 1950s across the world, followed by the establishment of national gene banks for *ex situ* conservation of seeds of plant germplasm, led to the beginning of plant genetic resource (PGR) conservation movement in the 1960s[3]. The change management around genetic resources for food and agriculture (GRFA), as contemplated by the international agencies, especially FAO, helped in investing on PGR management and institutionalizing processes for collecting available diversity to be conserved and used by future generations of farmers and to meet the existing crop breeding needs across the world. It is also appropriate to pay rich tributes to the international community of farmers who shaped agrobiodiversity through their conscious selections and sub-conscious interventions over the generations; and also to the pioneers like Albert and Gabriella Howard, N.I. Vavilov, B.P. Pal, and many more like Sir Otto H. Frankel, E. Bennett, J.G. Hawkes, J.H.W. Holden and J.T. Williams among others who shaped or joined the global germplasm movement for agrobiodiversity augmentation, conservation and use.

The global mechanisms led by the Food and Agriculture Organization of the United Nations (FAO) and the Consultative Group on International Agricultural Research (CGAIR) successfully catalyzed and nurtured the germplasm conservation movement. In the process, the CG Centers including International Plant Genetic Resource Institute (IPGRI), which emerged from erstwhile International Board of Plant Genetic Resources (IBPGR) and later became Bioversity International (BI) and other CG centers like IRRI, CIMMYT, ICRISAT, ICARDA, IITA, CIP, etc. laid considerable emphasis on sharing and using the available agrobiodiversity resources for much needed genetic enhancement for yield, stress tolerance, and quality etc. In the process, both *ex situ* and *in situ* on farm approaches were aggressively promoted.

[3]FAO, 1967: (i) created a department of Crop Ecology and Genetic Resources, led by Erna Bennett and R. J. Pichel, and (ii) organized the first Technical Conference on the Exploration, Utilization and Conservation of Plant Genetic Resources in Rome, Italy

Box 1.

Commentary: New knowledge such as biotechnology, nanotechnology, ICT, GIS, etc., must be promoted and used as supplementary tools or decision support systems to sustainably promote the traditional knowledge or the conventional approaches. Adaptabilities, fitness, resilience, hardiness and immunity or long-term resistance to various pest menaces, some of which are illustrated in various photographs above taken by me during my career, have evolved in agrobiodiversity through divergent evolutionary pathways. The question is; how long the tree in desert with roots without soil stratum would stand uncared? Or; how long new varieties would endure floods or diseased or drought unless bred and developed for specific manifestations with validated genes. The only way out is; Must conserve agrobiodiversity by all ways and means to feed and nurture the present and next generations, and for posterity.

Photo Descriptions: Clock-wise from Left above: 1. *Khejri* (*Prosopis cineraria*) the most prominent agroforestry tree species of the Thar Desert showing utmost hardiness; standing firm despite that more than 1.6 meter soil layer from its root zone has gradually blown away due to desert storms over the years; 2. Fully submerged rice plants under water in reproductive phase, showing panicles; 3. Clean (immune or highly resistant) and fully infested with brown rust varieties of wheat growing side by side; 4. Amber wheat variety C-306, released in 1965, highly tolerant to drought conditions, which is still grown by farmers in some rainfed pockets of the major wheat belt.

As regards sustainable use of plant genetic resources (PGR) held *ex situ* in CG gene banks, and the in-situ on farm available in farmers' fields in diversity rich areas, the process for multilateral access of GRFA with equal emphasis on Farmers' Rights got triggered through ITPGRFA. In the negotiation process leading to the Treaty, I was actively involved as Chairman of the FAO working group that defined and adopted the definition on Farmers' rights, agreed for the creation of a Gene Fund, and also finalized the agreed list of 64 crops incorporated as Annexure I of the Treaty. Later, I was also actively involved in an important initiative to establish a Global Crop Diversity Trust (GCDT) while being the Chairman of the Global Forum on Agricultural Research (GFAR). Also, during the first Global Conference organized by GFAR, the Global Forum then came out with a 'Dresden Declaration' on Biotechnology and Management of Agrobiodiversity. It is indeed most satisfying to see that these initiatives finally got culminated in a long term, safe collection of genetic diversity available with all CG Centers, as FAO designated collections for multilateral access under ITPGRFA, conserved in a permafrost facility at Svalbard created by GCDT.

The FAO initiatives through first and second Technical Reports on 'State of the World's Plant Genetic Resources' and subsequently the 'State of the World's Animal Genetic Resources' also catalysed various NARS in different parts of the world to initiate National Action Plans for managing their genetic resources. At the same time, the World Information and Early Warning Systems (WIEWS) and many CG center Gene Banks organized and provided valuable information on GRFA relating to plants, animals, fish, insects, microbes, etc. that drew needed attention for their scientific evaluation, conservation and use.

While the initiatives in the context of agrobiodiversity conservation, management and use were significant, some other major initiatives taken worldwide by different nations include putting in place their plant variety protection or *sui generis* systems in place to harmonise with the global WTO-TRIPS regime. In the process, flow of germplasm exchange at the national, regional and global levels received a set-back mainly due to uncertainties arising from issues like ABS, determination of mutually agreed terms (MAT), material transfer agreements (MTA), ensuring effective protection and enforcement of IPRs, etc. Public awareness on these issues and institutional capacity to handle the same became more prominent concerns. In many cases, the processes for sharing of genetic resources even for research or direct human welfare got complicated with more and also petty legal issues surrounding the IPR-ABS domains being flagged every now and then.

The institutions responsible for implementing the biodiversity and *sui generis* IPR laws had to resort to more and more awareness creating activities, and correspondingly solution finding to resolve the conflicts on real terms basis could not get as much importance or priority. Obviously, as a result, the on-going processes and speed for germplasm exchange and benefit sharing have got adversely affected. This trend for relatively slow or even no movement of germplasm otherwise so critical for genetic advancements in various crop plants and animal species needs to be reversed with determined international push and appropriate financial commitment for germplasm enhancement and use at local levels.

2.2 Regional Initiatives

Major regional initiatives on germplasm exchange and use were taken by most of the CG centers located in different regions; mainly in view of their core activity as well as major mandate for accelerated pre-breeding activities in different mandated crops/species. In the process, significant progress took place, including the realisation of Green Revolution in South Asia. These developments mainly in the last 50 years catalysed the process for faster agricultural growth, and ensured poverty reduction and increasing food security in all regions. The CG centers also facilitated networks of germplasm exchange benefitting mainly the weaker NARS thus ensuring availability of International Public Goods in the form of new high yielding varieties and hybrids.

In the process, some regional associations like APAARI, ARINENA, FARA, CACAARI, etc. got actively involved in facilitating such networks in partnership with various NARS of respective regions. I was fortunate to have got involved in accelerating the process of germplasm exchange through these networks like INGER by IRRI, CLAN by ICRISAT, Asian Vegetable Network by AVRDC etc.

Also APAARI worked closely with IPGRI [now Bioversity International (BI)] in establishing three sub-regional networks on genetic resources; in South Asia, SE Asia and the Pacific. As Executive Secretary of APAARI for 22 years, and also of CACAARI for 5 years, efforts were made especially to accelerate the process of germplasm exchange and strengthening of National Gene Banks involving developing country NARS, including the adoption of Suwon Declaration on Agrobiodiversity Management in Asia Pacific, which laid a clear Road Map for action by all stakeholders.

Unfortunately, most of these networks are currently non-functional mainly due to funding constraints and lack of commitment by the CG centers that existed before. Also pre-breeding initiatives seem to have become a casualty at most of the crop research centers in the process of funding through CRPs and the lack of core funding under windows 1 and 2. Even scoping study of BI to focus mainly on *in situ* conservation strategies seemed to have not received due priority for a standalone CRP by the CGIAR. In the process, the whole process of agrobiodiversity management seems to have received a set back during the last two decades.

It is high time that the whole issue of retarded exchange and use of agrobiodiversity across the regions is now revisited as an emerging threat to correct the priorities for needed change management of valuable agrobiodiversity so critical for future sustainability of global agriculture. For the last fifteen years, as Chairman, TAAS, I have been making efforts by providing a platform to interested stakeholders to deliberate on the rising issues and concerns, and suggest way forward to concerned agencies to systematically push forward the agenda for agricultural research and innovation for development (ARI4D) in general and in the present context promote the dynamic conservation and use of available agrobiodiversity.

2.3 National initiatives

In India, the process of identifying, assessing and augmenting the landrace diversity of amber wheats and other crops especially in the Indo-Gangetic plains[4] had started a century ago mainly by the economic botanists resulting in single plant selections of best amber grain quality Pusa wheat varieties (Pusa-4, -6, -12 etc.) that served a useful cause subsequently as donors for grain quality. For example, use of Type 8A and 9D selections in early twentieth century resulted in breeding very popular varieties like C-591 in 1930s and C-306 in 1960s. Further, during 1940s, the plant breeding efforts were accelerated through rational use of agrobiodiversity by Dr BP Pal, as defined in his famous article entitled 'the search for new genes'[5]. Subsequently, the dedicated efforts of pioneers like Drs. Harbhajan Singh, M.S. Swaminathan, A.B. Joshi, K.L. Mehra, R.S. Paroda, R.K. Arora, R.S. Rana, K.P.S. Chandel among others led to the establishment of a unique institutional mechanism by ICAR, called "National Bureau of Plant Genetic Resources (NBPGR)", which is one of the prominent examples of national genetic resource management systems in the world, with the most modern Gene Bank facility inaugurated in 1996 that got built through great efforts and funding support of USAID.

Having a current holding of nearly 0.49 million seed accessions and with a holding capacity of one million base collections in the long term storage, the NBPGR Gene Bank also has cryo and in-vitro gene banks, and a back up of well knit network of active collections in medium term storage modules and field collections in different parts of the country. Lately, the genomic resources are also being augmented at

[4]Howard and Howard, 1911
[5]Pal, B.P. 1942

the Bureau, and the system is supported by ICAR's world class, advance computing system to develop the field of bioinformatics. I am indeed fortunate to have been associated with the administration of NBPGR, including the planning and construction of its Gene Bank, in the late eighties and nineties.

Later, it was a great satisfaction personally to me to have been responsible for the creation of a Network of National level Genetic Resource Bureaux such as those on animals, fish, agriculturally important micro-organisms and also one on insects. Side by side, to provide the opportunity to agricultural scientists and other stakeholders to come together from all across and deliberate all about ARI4D under one roof, I could also conceptualise and build the National Agricultural Science Centre (NASC) Complex in New Delhi, which is now also the venue for IAC 2016. This prestigious resort in Pusa Campus also houses the regional or India offices of various CG Centres, CABI, important National Authorities (NRAA, PPV&FRA), National Academy of Agricultural Sciences (NAAS), National Agricultural Science Museum and an International Guest House besides auditorium, board rooms, meeting halls, lecture halls and splendid lawns to provide due ambience for serious dialogues.

In the past few years, as Chairman of National Advisory of Management Board of Genetic Resources, constituted by ICAR, it was highly satisfying for me to address some key policy issues needing priority attention by the national network of institutions engaged in the area of agrobiodiversity management, especially needing efforts for effective coordination and convergence of various on-going activities, policy directions and concerted efforts for ensuring effective use and sharing of available germplasm for continued and accelerated growth of agricultural productivity.

Also I was fortunate to have got an opportunity to establish/ renovate eight national Gene Banks in Central Asia and Caucasian countries that became independent from Russia. In the process, I am indeed grateful to those who decided to associate my name with the Gene Bank at ICRISAT, Hyderabad, and the one at Plant Breeding Research Institute, Kisnavadopad in South Kazakhstan.

National germplasm management system efforts also include special mention of Plant Introduction Unit of IARI headed by Dr HB Singh, which gradually expanded its activities under the guidance of stalwarts like Dr MS Swaminathan and Dr AB Joshi, to later on develop into a full fledged ICAR institute, the NBPGR[6]. Private seed industry was given initial boost though these germplasm introduction efforts since the 1950's and later on public policy support under the New Policy on Seed Development in 1987, which provided them access to breeder seed of varieties and hybrids developed by the public research system – ICAR institutes and state agricultural universities.

3. Regulatory Domain

In the post-CBD era, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) holds the key to system of multilateral access and benefit-sharing (MLS) for crop germplasm of identified food, forage and other agricultural species among the contracting parties. However, the national biodiversity laws were enacted mainly in harmony with the CBD. Thus, currently there are many grey areas in these laws particularly with regard to prescribed procedures and processes for germplasm flow of food and agricultural commodities requiring further attention of legislators, regulatory agencies and executive machinery of the governments. Not only corrective steps or their simplification are needed but it is also required to expand the scope of ITPGRFA beyond the Annex 1 coverage at the national levels depending upon their strengths in other commodities for trade and commerce or for sustainable food and nutritional security etc.

Thus to elaborate, further means and processes to improve access to PGRFA for use in breeding, research and training must be addressed quickly by the national systems. For this, the national institutional capacities will have to be further developed, the roles of national focal points elaborated

[6]NBPGR, 2000. 20 Glorious Years of NBPGR (1976-1996). 333p.

and explained to the concerned stakeholders, and awareness/promotion activities are well supported and financed as a matter of national policy priority. For an effective implementation of the multilateral system of access and benefit-sharing at the country level, the regulatory authorities must bring out common literature with explanatory notes to help the candidate beneficiaries and potential stakeholders meet a number of core and/or supplementary requirements expected to be fulfilled by them. Elaboration of such requirements should clearly spell out the prescribed procedures and processes under the Treaty as well as those laid out according to the needs of the respective countries.

In India, some steps have already been taken in this direction. The central government has recently notified that there is no need to seek prior permission of the National Biodiversity Authority (NBA) by foreign applicants accessing the germplasm materials covered under ITPGRFA. Similarly, guidelines for the implementation of the provisions of ABS under the Nagoya Protocol have been notified to implement the protocol in letter and spirit. However, the implications of the relevant Gazette Notifications by the Ministry of Environment, Forests and Climate Change must be clearly understood in conjunction with other relevant extraneous situations or interpretations from other laws in case-specific manner to avoid undue litigations or public ire.

Also, time has now come for all those countries that are Party to the Treaty to move forward beyond just raising the awareness about ITPGRFA or just developing Road Map for its fast and effective implementation including the acceptance and adoption of SMTA procedures. In order to encourage countries to adopt measures for the smooth implementation of ITPGRFA, the Governing Body of the Treaty should also recommend to FAO to recognize and highlight/document the specific national contributions of country parties in the international collections already in circulation by the international centres and national systems for public and private use through multilateral exchange under SMTA. This arrangement may eventually better help in developing and adopting some good, long term equitable benefit sharing arrangements among the gene-rich and technology-rich countries of the world as well as their farmers and innovators correspondingly.

4. Understanding the Dynamism

In the 1993 ISPGR Dialogue for National PGR Policy Options, held in New Delhi, which commemorated the establishment of the Convention on Biological Diversity (CBD), I had summarized the international developments concerning agrobiodiversity and PGR, from Stockholm Conference on Human Environment, 1972 to Rio Earth Summit, 1992. It emerged that the CBD had drawn as much world focus on the need to institutionalize ABS as the conservation of biodiversity through *in situ* means for sustainable use. The ex-situ collections were being mainly covered by the FAO Global System under IUPGR already, which were subsequently governed under the ITPGRFA. Thus, for ABS matters both CBD and ITPGRFA domains would be critical for countries to match with.

My learning about PGR has started as a student of genetics when there were no such summits or conventions. We were taught three important things about genetic resources, i.e., these are; (i) building blocks for improving productivity using new genes in plant breeding, (ii) common heritage of (hu)mankind, and (iii) to be freely exchanged for research and breeding for human welfare. These principles, however, have become history as we have seen evolution of alternatives such as; (i) genetic modification technology (transgenics and molecular marker aided selection for the quicker problem-solving manipulations in crop improvement), (ii) free to facilitated access regimes, and (ii) benefit sharing options to be anticipated and explored prior to material transfer through informed consent on mutually agreed terms. Now that the global debate on conservation and sustainable use of PGRFA has partly settled under ITPGRFA, it is high time that the regulatory regimes at the national levels are voluntarily reviewed in the interest of peace and prosperity through agriculture. At this stage, I would also like to pay my greatest tributes to Nobel Peace Laureate Dr Norman E. Borlaug due to whom agriculture was seen as the most potent sector responsible for sustainable peace on earth. His critical breeding and selection strategy in wheat had led to the greatest ever Green Revolution. Indians and agricultural scientists will always feel proud to portray him as a part of their fraternity, and his name is associated with countless commemorations in south Asia.

In the past, Indian national agricultural research system (NARS) had strong national breeding programmes in many crops, which included the national crossing blocks, regional co-operative trials by ICAR institutes and state agricultural universities (SAUs), and/or the multi-location testing for identification of superior varieties under the All India Coordinated Research Projects (AICRPs), on almost all crops for food and agriculture. Several improved varieties and hybrids were developed under these projects using native or exotic germplasm without restriction. Today, most of the national programmes seem to have become more dependent on the pre-breeding materials provided and/or international nursery trials constituted by many of the international centres/institutions, which is a concern. To re-build the national capacities in enhancement of GRFA and thus enhance the probabilities of generating more diverse international commons through collaborative research, more participatory activities within and across the regions must be organized and financially supported. Innovation must be encouraged and rewarded in the first place to push the global ARI4D agenda for farmers' welfare *vis-à-vis* development paradigm.

The CBD relates to all components of biological diversity which broadly concern all sectors (health, industry, agriculture, rural development, etc.) but PGRFA are of immediate necessity for the food and nutritional security and the well being of humankind. These must receive priority attention and fast-track handling by the regulatory bodies. The concern of farmers' rights raised under the International Undertaking on Plant Genetic Resources for Food and Agriculture (IUPGR) is equally important. But both these concerns remained as 'outstanding issues' at the time of finalizing the text of the CBD[7]. Accordingly, these two outstanding issues had to be renegotiated, which took over seven years to settle for agreement in the form of the ITPGRFA[8].

During this phase, I was actively associated with a wide range of debates concerning farmers' rights and the multilateral system of access to international collections. At that time, there was no consensus for even the definition of farmers' rights and other definitions now provided under the treaty. I chaired the FAO Working Group on Farmers' Rights, which took almost two years to arrive at a clear definition. It also emerged then that not only plant breeders should have rights on new varieties developed by them but also farmers' rights over the varieties evolved and perpetuated by them should be recognized. Eventually, farmers' rights became a part of the international law under ITPGRFA[9] and also India became the first country to internalize it in their legal and policy systems. Many other developing countries mostly look forward towards Indian experience in this regard with a view to develop their own national systems. The IAC 2016 will provide opportunity to such other countries[10] through the participation of their delegates for sharing the information arising out of such developments in agrobiodiversity domain through structured technical sessions and panel discussions as well as the larger opportunity through networking and informal discussions during the entire 4-day event.

5. Change we must pro facilitated ABS

Studies clearly show how nations have historically been dependant on each other for diversification of their food baskets or meeting their needs of genetic resources for increased productivity of agricultural

[7]Under Article 4 of the Nairobi Final Act

[8]http://planttreaty.org/ content/texts-treaty-official-versions

[9]Article 8 of International Treaty on PGRFA

[10]Participants from nearly 60 countries have either already enrolled as delegates or have confirmed their participation as invited speakers

commodities. This dependence is predicted[11] to increase more in future, given the current trends of climate change, emerging needs for expanding food basket and changing consumer preferences for more healthy foods. Obviously, therefore, the future determinations about how access is to be provided and when and what benefit sharing will be agreed upon would hold the key to sustain such interdependence; wherein a judicious interpretation of international and national legal obligations and processes under which exchange is to be governed will dictate the terms. In this context, the administrative, structural, and political compulsions are not uniform across the countries, and this has already rendered the exchange of agro-bioresources/PGRFA much more complex and sometimes even uncertain.

Further, instead of easing out the process of facilitation ITPGRFA had indirectly led to reduced exchange of germplasm between nations, despite clear recognition of multilateral system (MLS) for exchange, and now the Nagoya Protocol of the CBD has increased the complexity in real time handling situations. Experience shows that neither the MLS has functioned at the anticipated level nor it has helped in generating financial benefits through the proposed international Benefit-Sharing Fund (BSF). In India, there is still unsettled debate concerning exchange of germplasm even with the local private seed sector organizations engaged in plant breeding. Even SMTA has not yet been put into practice for want of procedural clearances and lack of understanding.

As already mentioned, ICAR as a policy allowed free access to the parental lines of hybrids bred by the public system since mid-1980's recognising well that seeds of these hybrids would otherwise not reach the end users i.e., the smallholder farmers. This policy decision then not only accelerated the coverage under hybrid seeds in the country resulting in increased crop productivity but it also helped in strengthening the existing limited Indian private seed sector. On the contrary, with the pronouncement of Plant Variety Protection and the rise of IPR regime in agriculture and biotechnology, there is hesitation particularly in the developing countries to share their germplasm accessions due to unfounded uncertainties and fears over the possible effect of ABS and IPR. There is definite concern for lack of much needed trust-building and partnership. This would obviously require enabling policy environment to help foster the sharing of germplasm as well as information between public and private sectors.

In many cases farmers are custodians of traditional varieties in different diversity rich regions. In India, their rights are now being protected under the *sui generis* PPV&FR Act. The system of genome saviour awards and recognition has evolved considerably with government funding, and farmers are being made aware through ICAR's *Krishi Vigyan Kendras* (Farm Science Centres) and extension units of state agricultural universities. The PPV&FR Authority needs to be commended for implementing the farmers' rights and creating the awareness. The Authority has been assured of Government support to build initially an Indian Gene Fund of INR 50 crore (around USD 7.5 million) in order to ensure for the long term, the recognitions, rewards and incentives to farming communities engaged in conserving valuable genetic resources. It is also expected that the evolution of benefit-sharing mechanism along with funding support from the seed sector will help in future in building up the Gene Fund at around USD 20 million. Simultaneously, there is need for a call to develop a clear mechanism to benefit directly the farmers in future for their invaluable service for PGRFA to the society.

6. Turning Youth into Catalysts of Change

Rural youth around the world are undoubtedly the future of food security, agricultural sustainability, and innovativeness in farm enterprising with quality outcomes. Yet hardly few young persons in a village would see a future for themselves in agrobiodiversity management, agriculture or farm enterprises. It is understood that for sustainable rural development farmers, especially smallholders, must be in the

[11]Galluzzi *et al.*, 2016

centre of all policy decisions. Their younger generation must be approached and groomed for assessing and addressing all agrobiodiversity related concerns that can be potentially handled at the local levels. Priorities and funding should be explored from the existing central government schemes in agriculture, rural development, and environment and forests sectors to reach the rural youth with right message and viable options.

Some interlinked imperatives for sustainable agrobiodiversity management in the gene-rich rural areas would be: safeguarding the available natural resources; sharing the available knowledge (both traditional and formal); building local PGRFA inventories, local access processes and capacity to harmonise with existing policies and laws; promoting conservation ways and means for sustainable PGRFA use; and, developing linkages and partnerships at local/district, state and country levels. Let the rural youth be sensitized, trained, and supported up to the level of sustainable self-dependence to cruise through the dynamic agrobiodiversity and manage it more effectively on immediate basis and also for the future.

7. Conclusions

Human interventions in the agro-ecosystems have helped in agriculture-led development. Globally, humans are deemed to have made conscious selections in estimated 7,000 edible plant species that are either cultivated by them or harvested from the wild. Of these, only about 150 species have gained significant commercial importance; two-third of which produce 90 per cent of the world's food. But the intensity and options of continued human intervention have remained confined to just five staples, including three food grains – rice, wheat and maize, and two roots and tubers – potato and tapioca, which together produce two-third of the world's food. Hence, we need to be scientifically clear and receptive, professionally vigilant, and legally unambiguous for a smooth regulation and productive execution of germplasm exchange to once again set the ball rolling vis-à-vis meet the PGRFA needs world-wide for the present and future generations. Agrobiodiversity also requires our focused attention and conscious efforts to stimulate further inter-dependence and ensure multilateral access of diversity to identify crops and varieties of future potential in different agro-ecologies under climate change.

Agricultural expansion and intensive cultivation have considerably reduced the existing agrobiodiversity. Tradeoffs for increasing the food grain production have contributed to decline and degradation in other ecosystem services like clean water, recycling and carbon foot-prints. All this has jeopardized our existing sustainability as well as the replenishment potentials. At the same time, everyone is concerned by the degradation of agricultural soils and environment, and unknown threats of climate change. The emerging scenarios have posed further management challenges of all sorts, especially the assessment of potential new genes to manifest adaptability and productivity under severe abiotic and biotic stresses.

Most redeeming feature of the existing agrobiodiversity is that it offers great scope to adapt to or mitigate the climate change effects in future. Nonetheless, to achieve this, we shall need greater research and development efforts to harness available potential using new science before it is too late. In this context, new tools of research and accelerated germplasm use have been developed with increased sophistication and precision to attain both efficiency and targeted purposefulness. The cost of research has also increased tremendously, whereas the corresponding policy support and donor interests are diminishing, which needs to be reversed before it is too late.

Thus, funding in research, capacity development and training, especially of rural youth and women, for enhancing their analytical and decision making capabilities, have emerged as additional challenges for managing the change relating to conservation and rational use of agrobiodiversity. The pressing need for a quick system-wide reorientation with the international regimes concerning the biodiversity and GRFA (i.e. CBD, its protocols dealing with biotechnology, biosafety and ABS, and ITPGRFA) must be realized with collective introspection and much needed diligence. Researchers must discover, invent and innovate with new zeal to evolve more productive and resource use efficient varieties and breeds/ strains on a regular basis to better connect future agriculture with unpredictable environment.

Besides intensification of research and regulatory systems at the national level, a concerted effort for international cooperation for managing agrobiodiversity would be critical – both in terms of knowledge-sharing in cutting-edge of science and for sharing and effective use of germplasm through well understood and accepted material transfer arrangements. Also, countries would need to make specific recurrent efforts in documenting and notifying their available rich agrobiodiversity. In the process, also the conserver-farmers be incentivized as a matter of government policies irrespective of their mode of operation (own cultivation arrangements or participatory activities or contract farming). Of course, all this would need policy support, experience and material sharing, and global cooperation in the field of agrobiodiversity management. It is my sincere expectation that the IAC 2016 platform would enable us jointly adopt an agreed Action Plan (Road Map) for managing effectively our agrobiodiversity for posterity.

Indian Agrobiodiversity System

Trilochan Mohapatra

Secretary, DARE and Director General, ICAR, Krishi Bhawan, New Delhi - 110001, India

Agrobiodiversity occupies a distinctive place within biodiversity. It recognises that agriculture evolved from bioprospecting, selection and development of few species from plant and animal kingdoms, to meet human needs of food, fibre and fuel. All biotic factors related to agriculture, such as, plants, animals, fish, reptiles, insects, birds and microbes are components of agrobiodiversity. The conservation, management and sustainable use of these organisms (and their wild progenitors/relatives) require specific attention. The Indian Council of Agricultural Research (ICAR) addresses the issue of management of genetic resources through its five Bureaux, namely, National Bureau of Plant Genetic Resources (ICAR-NBPGR), National Bureau of Animal Genetic Resources (ICAR-NBAGR), National Bureau of Fish Genetic Resources (NBFGR), National Bureau of Agriculturally Important Microbes (NBAIIM) and the National Bureau of Agricultural Insect Resources (ICAR-NBAIR) for the management of their respective genetic resource. The respective Bureau coordinates the management of its genetic resource involving various stakeholders in its functional area.

Effective conservation and use of agrobiodiversity is of immense importance in the current scenario which will witness more disruptive climate shocks in the future, and in which food-deficit regions would be increasingly dependent on food-surplus regions. This means that there is an urgent need for managing genetic resources for food and agriculture in ways that promote the evolution and conservation of agrobiodiversity, and to ensure that they are available to all stakeholders for use to adapt to changing environment by developing new climate resilient varieties/species to ensure the food and nutritional security. Climate change will also increase the importance of minor or under-utilized crops and plant species. Therefore, it is essential that all forms of agrobiodiversity are conserved through suitable characterization and evaluation, and to ensure their availability for improvement programmes of food and agriculture. The following section provides brief account of the activities, achievements and new initiatives taken by each of the five Bureaux:

I . ICAR-National Bureau of Plant Genetic Resources, New Delhi

The ICAR-NBPGR was established under the Crop Science Division of ICAR in 1976 as a nodal institute for assembly of global collection of plant genetic resources (PGR). The PGR comprise diversity among and within plant species that are of direct or indirect value to humans.

Since its inception, ICAR-NBPGR has played an important role in crop improvement and diversification, and management of PGR and related activities at national and international level. It has 10 Regional Stations in different agro-ecological zones of the country and a network of 58 National Active Germplasm Sites (NAGS). It is an ISO 9001:2008 certified organization. The component activities include PGR collection through exploration, characterization, evaluation, safe conservation using both conventional storage and biotechnological approaches for *in vitro* conservation and cryopreservation; generation and conservation of genomic resources. Besides, it is a nodal institute authorized by Government of India to facilitate international exchange of germplasm for research purposes and to undertake the quarantine. DNA fingerprinting of agri-horticultural crops, conservation and use of genomic resources and GM detection are also important activities at ICAR-NBPGR. The PGR information has been duly documented in user friendly databases.

The mandate includes management and promote sustainable use of plant genetic and genomic resources of agri-horticultural crops and carry out related research; coordination of capacity building in PGR management and policy issues governing access and benefit sharing of their use, and molecular profiling of varieties of agri-horticultural crops and GM detection technology research. A brief account on its achievements over the past four decades is as follows:

PGR Exploration and Collection

- The institute has so far undertaken 2,644 explorations and collected about 2.67 lakh accessions of crop species and their wild relatives.
- Mapping of collected diversity followed by gap analysis using GIS tools was done in some crops. In rice, more than 35,000 accessions; in maize >8,000 accessions and in sesame over 2,500 accessions collected from different states of the country were georeferenced.

PGR Exchange

- Annually, ~25,000 accessions of PGR and ~75,000 samples of trial material are introduced in India for use in crop improvement programmes. Till date about >7 lakh germplasm accessions of various crops including the transgenic planting material have been introduced/ imported into the country. Exchange carried out with >100 countries and CGIAR institutes under bi-or multi-lateral agreements.
- 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 Himachal Pradesh.
- Online application for import permit facility is available at http://www.nbpgr.ernet.in/gep/.

Plant Quarantine

- ICAR-NBPGR has been empowered under the Plant Quarantine (Regulation of Import into India) Order 2003, issued under Destructive Insect s and Pests (DIP) Act 1914 of the Government of India to carry out quarantine of germplasm including transgenics meant for research purposes. ICAR-NBPGR also undertakes quarantine processing of germplasm meant for export and issues the Phytosanitary Certificate.
- The quarantine has resulted in the interception of several pests of high economic significance including (>50) those not yet reported from the country. Such interception signify the success of quarantine as otherwise these pests could have entered the country and played havoc with the plant biodiversity and Agriculture.
- Engaged in development of protocols for diagnostics for detection of various pests and quarantine treatments for salvaging of infested/infected germplasm.

PGR Characterization and Evaluation

- Approximately 10,000 accessions are characterized/evaluated per year at ICAR-NBPGR and its regional stations. Till date, about 2.40 lakhs accessions of different agri-horticultural crops have been characterized and evaluated.

- Mission-mode mega programme on characterization and evaluation of Wheat and Chickpea germplasm under the National Initiative for climate Resilient Agriculture (NICRA) executed in collaboration with SAUs for 21,822 accessions of wheat and 18,775 of chickpea conserved in National Genebank. These were characterized and evaluated for various biotic and abiotic stress tolerance traits. Core sets of wheat (2, 226 accessions) and chickpea (1, 103) were developed. Wheat characterization and evaluation experiment conducted by ICAR-NBPGR (2011-12) entered the Limca Book of Records 2013.
- Pre-breeding and genetic enhancement efforts in lentil and chickpea identified sources with specific traits. One representative set of global wild *Lens* accessions was developed by extracting 96 accessions using PowerCore approach.
- Core sets have been developed in four crops viz., okra, mungbean, sesame and brinjal, wheat and chickpea to facilitate the enhanced utilization of germplasm. Pre breeding, to widen the genetic base was undertaken in chickpea and lentil including their wild species.

PGR Conservation

- The Indian National Genebank (NGB) was established at ICAR-NBPGR to conserve the national heritage of PGR in the form of seeds, vegetative propagules, *in vitro* cultures, budwoods, embryos/ embryonic axes, genomic resources and pollen.
- The NGB consist of four kinds of facilities, namely, Seed Genebank (-18°C), Cryogenebank (-170°C to -196°C), *in vitro* Genebank (25°C), and Field Genebank, to cater to long-term as well as medium-term conservation.
- Indian Genebank with a capacity to conserve about one million germplasm in the form of seeds is currently conserving about 0.426 million accession belonging to nearly 1,800 species. Over 11,000 accessions of seed, dormant buds, pollen and genomic resources are cryopreserved in liquid nitrogen in cryogenebank and about 1800 accessions in the *in vitro* genebank. Also, horticultural crops are conserved in the form of *in vitro* cultures (~40,000 cultures of 130 plant species). Newly identified genes (952 in number) are also conserved in the form of DNA libraries, etc.

DNA Fingerprinting and Conservation of Genomic Resources

- About 2300 varieties in > 35 crops have been fingerprinted. Also, new varieties are being DNA fingerprinted to avoid biopiracy by any unauthorized person or country.
- National Genomic Resources Repository has been established to collect, generate, conserve and distribute genomic resources for agricultural research in the country. The aim is to promote deposition, sharing and utilization of enormous amount of genomic resources generated in the country and elsewhere. All forms of genomic resources including clones, gene constructs, large DNA fragment libraries as well as genomic sequence information in soft copy form can be deposited in this repository.
- All depositions or requests are to be made along with material transfer agreements in order to protect the interest of the depositor and the sovereignty of the Nation over the genetic resources. The IP rights (if any) shall remain with the depositor.
- GM detection technologies developed and transferred include rapid/cost-effective assays based on visual and real-time LAMP targeting commonly employed eight transgenic elements, which can also be used on-site. Multi-target real-time PCR system, simultaneously targeting 47 targets, including 21 GM events of five crops. GMO matrix for 141 GM events of 21 crops with 106 genetic element targets as decision support system. PCR-based diagnostics developed for 12 GM crops.

Germplasm Utilization

- ICAR-NBPGR was also involved in the release of about 100 varieties in the past in different agri-horticultural crops either through direct introduction or by selection from the introduced germplasm and popularized several such introductions for commercial cultivation.
- Also, many temperate fruits including kiwi, hops and several medicinal and aromatic plants like rose, geranium introduced by ICAR-NBPGR are getting increasingly popular in Himalayan states, Uttarakhand and HP.
- Several indigenously supplied germplasm accessions have helped to develop improved varieties in various national programmes. These include rice variety (Maruteru sannalu), sorghum variety (Parbhani Moti), red okra (Aruna), Chinese potato (Nidhi), coriander variety (Sudha), and yam variety (Indu).

PGR Documentation and Dissemination of information

- A PGR Portal has been hosted on ICAR website and ICAR-NBPGR website, which is a gateway to information on PGR conserved. The Portal contains information on about 0.4 million accessions belonging to about 1800 species.
- Germplasm field days held regularly for important crops for selection of promising germplasm by breeders and researchers.
- Participation in national and local fairs, radio and TV shows to create awareness about importance of PGR. Encouraging visits of students, teachers, farmers and scientists at ICAR-NBPGR headquarters as well as regional stations.

Germplasm Registration

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. About 1250 potentially valuable germplasm of over 204 species of various crops are registered.

All India Coordinated Network Project on Potential Crops

This network programme located at ICAR-NBPGR, New Delhi has 13 main centers in different parts of the country. The major functions are introduction, evaluation, conservation, breeding and popularization of new potential and useful plant species for acclimatization to local condition. Grain amaranth, buckwheat, ricebean, Jatropha and Simarouba have been developed and popularized under this project.

National and International Linkages

- ICAR-NBPGR has close collaborations with Bioversity International, ICARDA, IRRI, CIMMYT and other countries on genetic resources management and utilization
- Collaborations are also there with all ICAR institute, SAUs, CSIR institutes, DBT, DST, DRDO etc. for trait-specific evaluation and utilization of germplasm.
- Memorandum of Understanding (MoU) has been signed between ICAR and the Royal Botanic Gardens (RBG), Kew, UK on 13th February, 2014 to enhance capacities of both the institutions in research on conservation biology.
- The National Permafrost Facility (prototype) has been created as a result of joint initiative of ICAR and DRDO with the involvement of the Bureau at Leh, Ladakh (Chang-La) for conservation of safety duplicates at a very low-cost.

Future Thrusts for ICAR-NBPGR

- Characterization of *ex situ* conserved germplasm and detailed evaluation of prioritized crops for enhanced utilization.
- Assessment of impact of on-farm conservation practices on genetic diversity.
- Genome-wide association mapping for identification of novel genes and alleles for enhanced utilization of PGR.
- Identification and deployment of germplasm/ landraces using climate analog data.
- Validation of trait-specific introduced germplasm for enhanced utilization.
- Enhancement of germplasm holdings in the National Genebank (avoiding duplicates).

II. ICAR-National Bureau of Animal Genetic Resources, Karnal

Animal husbandry plays a significant role in national economy and is an important sector of Indian agriculture. Livestock and poultry provide a range of products and services to their keepers like milk, meat, egg, fibre, transport and fuel. Large animals provide important inputs to crop production, including manure and draught power. Presently, there are 160 livestock and poultry breeds which includes 40 cattle breeds, 13 buffalo breeds, 42 sheep breeds, 26 goat breeds, 6 horse breeds, 9 camel breeds, 6 pig breeds, 1 donkey breed and 17 poultry breeds in addition to many more not characterized and accredited so far, besides populations/breeds of other species like mules, yaks, mithuns, ducks, quails etc. which are yet to be classified in to well descript breeds. A large range of agro-ecological zones in India has helped to evolve this large number of breeds of various livestock species. This diversity of domesticated livestock and poultry breeds is the result of human intervention: they have been consciously selected and improved and have co-evolved with economies, cultures, knowledge systems and societies. This has endowed them with unique qualities: tolerance to high heat and humidity; resistance to diseases; and ability to adapt/survive under severe nutrient stress. These breeds now represent unique combinations of genes.

ICAR-NBAGR was established on September 21, 1984 at Bangalore and later shifted to Karnal in 1985. The Bureau is working for the enhancement of indigenous livestock and sustainable utilization of AnGR. It is divided in to three divisions Animal Genetics, Animal Biotechnology and Animal Genetic Resources, and also works with various agencies involved in livestock improvement through a Network Programme on Animal Genetic Resources. It is an ISO 9001:2008 certified organization. The Bureau has a Mandate of "Identification, Evaluation, Characterization, Conservation and Utilization of Livestock and Poultry Genetic Resources" with objectives as

- To conduct systematic surveys to characterize, evaluate and catalogue farm livestock and poultry genetic resources and to establish their National Data Base.
- To design methodologies for ex situ conservation and in situ management and optimal utilization of farm animal genetic resources.
- To undertake studies on genetic characterization using modern molecular biological techniques.
- To conduct training programmes as related to evaluation, characterization and utilization of animal genetic resources.

Research achievements including technology/methodology developed are

- Survey methodology for AnGR characterization- Widely used for breed documentation
- *In-situ* conservation model-Used by SAUs, SAH departments and development agencies
- Digitized database on AnGR-Widely used in decision support

- Test for fecundity gene in sheep used for identification of prolific animals
- Standard karyotypes of livestock species- Used widely to screen chromosomal abnormalities as diagnostics for detecting genetic disorders in breeding bulls
- Molecular diversity analysis-Standardized protocol for establishment of genetic relationship among different breeds of a species has been developed
- Breed assignment based on microsatellite genotyping-Assignment of individuals to breeds/ populations
- New single universal sex determination methodology in 6 bovid species by single universal duplex PCR
- Parentage verification kits: Developed for cattle, buffalo, goat and camel while one kit can resolve parentage and related issues in all ruminant livestock species-cattle, buffalo, goat, sheep yak and mithun
- Non-invasive tool to study molecular aspects of lactation biology in buffalo and native cattle
- Isolation of mammary epithelial cells (MECs) from milk of cattle and buffalo
- PCR based differentiation of cattle and buffalo meat and milk
- PCR-RFLP and tetra-ARMS PCR based genotyping of novel SNPs identified in TLRs and other functional genes for association studies in buffalo and goats

Majority of the indigenous breeds of various species have been characterized phenotypically as well as genetically.

Genomics

- Large number of candidate genes of growth, production, reproduction, immune response and heat regulation has been characterized in various livestock species. Indigenous breeds of different species revealed polymorphisms at nucleotide level. A number of SNPs have been identified at different gene loci in different farm species which are specific to our indigenous breeds.
- Buffalo draft genome assembly constructed using the cattle genome (Btau 4.0 assembly) as a reference. The assembly has read depth of 17-19X. The buffalo assembly represents ~ 91%-95% coverage in comparison to the cattle assembly Btau 4.0.
- Establishment of transcriptome signature of buffalo mammary gland during lactation, involution and heifer physiological stages and identification of stage specific genes and pathways.
- Milk transcriptome profile of Sahiwal cows.
- Transcriptional profiling of fecundity related genes and folliculogenesis in FecB carrier and non-carrier ewes as well as FecB carrier sheep under high and low nutritional regimes.
- Tissue distribution profiling of selected genes in buffalo and goat.
- EST libraries from buffalo mammary gland- about 1200 sequences generated
- RNASeq based sequences from different tissues- (More than 20 lakhs); Dromedarian camel- 5.8 lakhs, Bactrian camel- 3.6 lakhs; Buffalo- 6.0 lakhs; Goat- 4.6 lakhs
- QTLs- Buffalo growth related, milk composition and milk yield QTLs identified on eight different chromosomes.
- Around 8.5 lakh SNPs generated from 12 breeds of buffalo.

Conservation of AnGR

Ex-situ Conservation

- About 1,1,30,000 cryo-preserved semen doses representing important and endangered breeds of seven species (Cattle, Buffalo, Goat, Sheep, Camel, Equine and Yak) are being maintained in the National Gene Bank.
- Animal Genomic Resource Bank is established which has collection of DNA samples of more than 90% of the Indian breeds of various livestock species besides some embryos.

In-situ Conservation

- *In-situ* model of conservation has been developed by providing technical inputs and incentives to the farmers/breeders in the breeding tract of respective breeds and has been adopted under Network Project through the State Agricultural and Veterinary universities/ State Animal Husbandry Departments/ ICAR Institutes and NGOs.
- Under in situ conservation project, gaushalas located in Haryana, Gujarat, Rajasthan and Uttar Pradesh were studied for conservation of indigenous cattle breeds. A new model 10P was developed to produce young bulls from purebred cows in an open nucleus manner within the gaushalas.

Future Thrusts for ICAR-NBAGR

- Comparative and functional genomic research for improvement and conservation of animal genetic resources.
- Identification of molecular basis for various adaptive traits such as heat tolerance, disease resistance, drought tolerance etc.
- Registration of animal germplasm to protect and check biopiracy of indigenous AnGR.
- Development of farm animal germplasm repositories.
- Documentation of AnGR and preparation of National Watch list.
- Identification and characterization of genes/biomolecules associated with functional traits in livestock species.
- Computing methodologies for AnGR.
- Development of Geographic Information System (GIS) for AnGR.
- Manpower development programmes for characterization, evaluation, conservation and utilization of AnGR.
- Sensitization and awareness programmes at different level.
- IPR and commercialization of technologies.

III. ICAR-National Bureau of Fish Genetic Resources, Lucknow

The National Bureau of Fish Genetic Resources (ICAR-NBFGR) was established in 1983 with the mandate of collection, classification and cataloguing of fish genetic resources of the country, maintenance and preservation of fish genetic material for conservation of endangered fish species and evaluation and valuation of indigenous and exotic fish species. The Bureau has created excellent infrastructure and expertise in several research areas including development of fish databases, genetic characterization, gene banks, fish germplasm and habitat inventory, risks analysis of exotic species, diagnostics for OIE notified pathogens, aquatic microbes and other areas of germplasm conservation with special focus on threatened, prioritized and exotic fish species. Significant achievements have been made by the Bureau and plan of activities in coming years is as given below as per the mandate of the institute.

Cataloguing and classification of fish genetic resources of India

Cataloguing and classification of fish genetic resources of India is one of the important programmes of the Bureau. A database on Fish Diversity of India, containing information on about 2936 indigenous fish species (936 freshwater, 113 brackish water and 1,887 marine species) and 462 exotic species, has been developed. The Bureau has prepared fish diversity checklists for eight states, *viz*. Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Rajasthan, Kerala, Karnataka, Tamil Nadu and Maharastra and three ecosystems such as Western Ghats, Gulf of Mannar and Vembanad lake. In addition, a check-list of over 500 exotic fishes, including variants, of India has been prepared for passport information.

Explorations of aquatic germplasm resources

Under the exploration of aquatic germplasm of the country, surveys of different river basins and two important hotspots, *viz*. Western Ghats and Northeastern States have been undertaken for documentation of fish diversity. A Collaborative Programme on 'Exploration and characterization of fish germplasm resources and indigenous knowledge in North Eastern Region of India' involving collaborators from various institutions of the NE region has been initiated. The programme is being implemented in the states of Assam, Arunachal Pradesh, Meghalaya, Sikkim, Mizoram, Tripura and Manipur with encouraging results.

The Bureau has discovered 40 new species during explorations from North-eastern States and Western Ghats in collaboration with other partner organizations. Some of the new records include gobiid fish *Redigobius bikolanus* and *Schismatogobius deraniyagalai*, and minnows *Laubuka laubuka* were found in the Sharavathi river basin. An endemic fish, *Labeo rajasthanicus* (Cypriniformes: Cyprinidae) from western Rajasthan, as a valid species and designation of its neotype has been re-described.

Ecological risk and impact assessment of exotic fish species in India

Document on import risk analysis of *L. vannamei* (in collaboration with ICAR- CIBA, Chennai) and impact assessment of *P. hypophthalmus* was submitted to the, Department of Animal Husbandry, Dairying and Fisheries (DADF), Ministry of Agriculture and Farmers Welfare, New Delhi. In addition, two documents, *viz*. 'National Strategic Plan for Aquatic Exotics and Quarantine' and 'Aquatic Exotics and Quarantine Guidelines' were prepared. Both the documents were approved by DADF. Furthermore, guidelines for import and culture of *L. vannamei, Oreochromis niloticus, P. hypophthalmus* and ornamental fishes were developed in collaboration with other ICAR Fisheries institutes. In addition, Bureau provides technical backstopping to DADF on import of exotic fishes.

Species profiling and taxonomic validation

The cytogenetic profiling of over 70 fish species mainly from freshwater and marine systems, collected from various part of the country including biodiversity hot-spots, like North-Eastern part and Western Ghats, Kerala, has been accomplished. The fluorescence *in situ* hybridization (FISH) markers have been generated in over 17 species which has been utilized in taxonomic identification and species diversity assessment. Further, the ICAR- NBFGR has emerged as a lead centre for DNA barcoding of freshwater and marine fishes in South Asia. The DNA barcodes for over 600 Indian fish species have been generated.

Conservation/population genetics and genomic resources

- Documentation of genetics and genomic diversity at inter- and intra-specific levels is considered important for strategic planning for management of aquatic genetic resources. Using the molecular markers, especially microsatellite DNA, concerted efforts has provided description of genetic variation and population structure for 24 prioritized fish species from their major range of natural distributions.
- The genomic resources for understanding adaptive processes in natural populations are becoming important. These studies have pointed out genes associated with immune response and hypoxia tolerance in *Clarias magur* and their associated markers. Molecular resources were identified in *Perna viridis, Scomberomorus commerson* and other important marine species for stock characterization of the species across Indian waters.

Ex situ conservation & germplasm/genomic repository

- Cryopreserved sperm can effectively be utilized to overcome from such milt related problems in aquaculture and in on-farm conservation works. As an *ex-situ* conservation tool, species-specific sperm cryopreservation protocols have been developed for over 30 fish species. Under agro-biodiversity platform, initiative has been taken up to establish pilot scale 'Live Germplasm Resource Centre' for prioritized fish species for on-farm conservation.
- Work on surrogate broodstock technology using germ cell transplantation in fish has been taken up and protocol for effective delivery of stem cells into recipient gonads, both by surgical and non-surgical interventions, has been developed and standardized based on the size of the fish. In the efforts towards preservation of embryonic cells from Indian fishes, a pluripotent embryonic stem cell line derived from Indian catfish, *Heteropneustes fossilis,* has successfully been completed.

In situ conservation

Under this programme, captive breeding protocols have been developed for 15 ornamental and 5 endangered fish species in collaboration with College of Fisheries, Panagad, Kerala, for conservation and sustainable utilization. In addition, a number of extension activities aimed at facilitating tribal development through fisheries-based enterprises were undertaken by providing scientific inputs under the Tribal Sub Plan Scheme. To train/ create awareness, technical know-how on fish farming is being extended to the aqua farmers/ college students. Further, exposure visit of different entrepreneurs, farmers, students and other stakeholders are arranged at progressive fish farmer’s site as well as institute farm.

National Repository of Fish Cell lines

ICAR-NBFGR has been recognized as Nodal Centre for fish cell line. At Bureau, a National Repository of Fish Cell lines (NRFC) has been established where at present 50 cell lines are being maintained. It is noteworthy to mention that Bureau has developed over 15 cell lines from various tissues of different species, *viz*. *Catla catla, Naziritor chelynoides, Etroplus suratensis, Cyprinus carpio* (koi)*, Danio rario, Channa punctatus, Horabagrus barchysoma Puntius denisonii, Sahyadria fasciatus* and *Pristolepis fasciata Wallago attu,* etc.

Genomics

De novo whole genome sequencing of *Labeo rohita* and *Clarias batrachus* has been initiated at ICAR-NBFGR Lucknow. A total of ~147 Gb and 198 Gb data including mate pair has been generated for *L. rohita* and *C. Batrachus,* respectively, and the assembly of insert reads is under progress*. De novo* whole genome sequencing of Indian Shad, *Tenualosa ilisha*, under ICAR CRP-Genomics has also been initiated. Whole mitochondrial genome for nine important species has also been sequenced and annotated.

Four online genomic databases, *viz*. FBIS, FishMicrosat, FMiR and Fish Karyome, have been developed to provide biological and taxonomic information about the fish. Genomics resources including SSRs, EST-SSRs, mitochondrial gene/ genome have been developed for over 35 fish species of economical importance.

Fish health management

- The institute is coordinating the National Surveillance Programme for Aquatic Animal Diseases (NSPAAD) which is being implemented in 15 States and 2 Union Territories through 24 collaborating partners. The major emphasis of the programme has been on strengthening the passive disease surveillance in the country so that each disease outbreak is reported and investigated. For creating awareness among stakeholders regarding the disease surveillance as well as diseases prevalent in the region, awareness programmes are being organized. The institute has diagnostic capability for all the OIE-listed and delisted diseases of finfish, crustaceans and molluscs. Furthermore, diagnostic capability for the emerging pathogens is continuously being upgraded.
- Bureau has developed monoclonal antibodies against serum immunoglobulins of *Labeo rohita*, *Channa striata*, *Clarias magur* and *Catla catla*. These antibodies have numerous applications, *viz*. sero-surveillance and checking efficacy of vaccines in candidate species. In addition, continuous cell lines have been developed from *C. catla* and *L. rohita* which display functional characteristics of macrophages.

Future thrusts for ICAR-NBFGR

In future, the emphasis would be given on expeditions to explore germplasm resources for status updation; discovery of new species; cataloguing of genetic stocks and under-utilized germplasm with potential importance; cataloguing and documentation of fish genetic resources in interactive and predictive modelling formats; conservation of endangered/ threatened/ prioritized species; valuation of aquatic germplasm resources; assessment of biological diversity in response to climate change; genome explorations of cultivable species and management of genetic/ genomic variability; ecological genomics and phenomics for understanding gene and genome functions as well as adaptive divergence in natural environment; models for conservation and management of genetic resources of cultured/ cultivable species; development of biological chips for identification/ characterization of fish species and stocks/ strains; *ex-situ* conservation tools with focus on preservation of germplasm and their utilization methodologies for conservation and aquaculture; development and maintenance of germplasm and genomic repositories; risk assessment and management of invasive species; development of specific and sensitive molecular and biosensor based diagnostic tools; development of efficient immuno-prophylactic and therapeutic measures; strengthening biosecurity measures to minimize the risks of aquatic animal disease incursions and development of predictive models for early warning of disease outbreaks

IV. ICAR-National Bureau of Agriculturally Important Microorganisms, Maunath Bhanjan

ICAR- National Bureau of Agriculturally Important Microorganisms (ICAR-NBAIM) was established under the IXth Five Year Plan in the year 2001. The Bureau started functioning at Old ICAR-NBPGR Building, New Delhi. The ICAR-NBAIM shifted on June 1, 2004 to the campus earlier occupied by the National Institute of Sugarcane and Sugar Technology (NISST) at Kushmaur, Mau Nath Bhanjan, Uttar Pradesh. During the XIth plan, ICAR-NBAIM was designated as a Recognized Repository under the National Biodiversity Act (2002) for storing microbial wealth in India and in 2014, the Bureau acquired ISO 9001:2008 certification. It is among one of the premier organizations of agricultural and microbial biotechnology prioritizing its responsibilities in the area of collection, isolation, conservation, management and utilization of agriculturally important microorganisms (AIMs) in the country. The Bureau is engaged in the multifarious activities in the area of microbial diversity, biological control, microbial genomics, preservation and maintenance of microbial cultures. The Bureau is also engaged in supply of pure cultures to various research organizations and provides microbial identification services.

ICAR-NBAIM has established and strengthened National Agriculturally Important Microbial Culture Collection (NAIMCC) which is an affiliated member of World Federation of Culture Collection (WFCC). NAIMCC has state-of-the-art facilities for short term and long term conservation of microorganisms with more than 6000 preserved accessions of fungi, bacteria, actinomycetes, cyanobacteria and archaea.

During 12th Plan period the network project AMMAS is focusing on different aspects of molecular microbiology and development of microbial products and technology to harness the potential of microorganisms for benefit of Indian agriculture with the modified thematic areas under six components.

Significant Achievements: Microbial Diversity

Bestowed with remarkable inherent physiological and functional diversity, microbes have found application in agriculture, industry, medicine and environment. The analysis of diversity of microorganisms, mapping of diversity in the country, utilization of the microbial diversity, bioprospecting and molecular analysis for gene mining are the key areas addressed by the Bureau.

- To explore and conserve the microbial diversity of country, the Bureau has successfully completed several exploratory missions and extensive surveys for the collection of samples from different habitats (soils, plants, fresh water, hot-water lakes, extreme cold conditions, marine ecosystems, mangroves, agro-waste soils etc.) in order to isolate, identify and characterize useful microbes and/or their products.
- Diversity analysis of northern Indo-Gangetic plains clearly indicated that the soils do have a population of *Bacillus* isolates and fluorescent *Pseudomonas* in high numbers but the isolates/strains have lost the ability to express plant growth promoting attributes. This study on functional diversity provided microbiological reasons for the reduction in productivity under Rice- wheat cropping system in IGP.
- Long term application of pulp and paper mill effluent in agriculture has led to significant functional and structural shift in soil microbial community and consequently to deterioration of soil health and overall soil crop productivity.
- The genetic diversity of soil-borne populations of *Macrophomina phaseolina* collected from geographically distinct regions led to its classification into 9 groups.
- A broad database of pink-pigmented methylotrophs isolated from the soil and plant samples was developed.
- From the rhizosphere of *Salicornia*, methylotrophs that grows profusely at 6% NaCl were isolated and may have a role in the establishment of this plant in saline soils.
- Actinomycetes isolated from the soil samples collected from northen Indo-Gangetic plains belonged to different species of *Streptomyces* indicating their predominance. Some other species identified were *Micromonospora* and *Nocardia*.
- Diversity analysis of various extreme environments including Rajgir thermal springs, Bihar; Bhitarkanika Mangroves and Chilka lake, Odisha; Rohtang, Lahul & Spiti and Manikaran thermal springs, Himachal Pradesh; Rann of Kutch, Gujarat, Leh cold desert, Sunderbans mangroves,

West Bengal; Kovalam district of Kerala, Jaisalmer and sambhar salt lake, Rajasthan; Andaman & Nicobar island; Mangroves of Goa led to the development of huge database of microorganisms from these extreme habitats.

- *Penicilliopsis clavariiformis* AP, a rare salt tolerant fungus reported for the first time from India was identified through polyphasic taxonomy.
- Based on the sequencing some of the rare isolates identified were *Acinetobacter venetianus, Agromyces* sp.*, Bacillus altitudinis, Exiguobacterium indicum, Exiguobacterium lactigenes*, *Lysinibacillus sphaericus, Vibrio metschnikovii, Paenibacillus pabuli, Microbacterium oxydans*, *Rhodococcus qingshengii, Paenibacillus tylopili, Pseudomonas reactans, Bacillus drentensis, Bacillus pocheonensis, Bacillus aestuarii, Bacillus arbutinivorans, Bacillus niacini, Thalassobacillus devorans, Halomonas campisailis*, *Marinobacter alkaliphilus, Marinobacter hydrocarbonoelasticus, Halomonas variabilis, Alteromonadales bacterium, Nitrinicola lacisaponensis, Chromohalobacter salexigens, Marinobacter aquaeolei, Tsukamurella sp.*
- Bacterial species tolerant to high salinity (25% NaCl), high (90°C) and low temperature (4˚C) and acidic pH (4) were identified.
- Several isolates of *Bacillus thuringiensis* - potential source of novel *cry* genes were isolated and characterized.
- Three promising alkali- thermotolerant xylanase producing isolates obtained from Manikaran thermal springs were sequenced and identified as *Paenibacillus ehimensis, Bacillus cereus* and *B. subtilis*.
- Novel psychrotolerant species of fungi viz. *Thelobacter* sp., *Asordina sibutii*, *Geomyces* sp., *Penicillium* sp., *Ulocladium consortiale* and *Ulocladium* sp. were identified.
- The Diversity of *Bacillus* and predominant genera has been mapped by this Bureau and novel *cry* genes with insecticidal properties have been deciphered. More than 2000 rRNA gene sequences were submitted to NCBI GenBank and accession numbers obtained.

Nutrient Management, growth promotion and biocontrol

- The Bureau has developed bioformulations to be used as biofertilizers, biocontrol agents, abiotic stress alleviators, agricultural residue decomposers etc.
- Four psychrotolerant bacteria isolated from cold deserts of the Arunachal Pradesh and identified as *Pseudomonas arsenicoxydans* P1; *Pseudomonas koreensis* P2, *Pseudomonas koreensis* P3 and *Paenibacillus dendritiformis* P4 were developed as plant growth promoting bacteria that could remarkably enhance dry biomass in chickpea, maize and wheat.
- Fourteen heterorophic sulphur oxidizing bacteria has been identified and two isolates S 14 and Ca7 that could release 6 µg SO^{4-}/ mg of sulphur have the potential to be used as inoculants for oil seed and pulse crops.
- Coinoculation of two strains *Bacillus subtilis* and *Arthrobacter* sp. were identified for alleviation of the adverse effects of salinity on wheat growth.
- A biopriming technique was developed for the coating of rice seeds with potential cyanobacterial strains (*Plectonema boreanum, Anabaena doliolum, Nostoc commune* and an equi-proportional mix-culture of these three strains). The significant features of the technology were: enhanced viability of the coated seeds and cyanobacteria upto 18 months; 18-20% higher germination; increase of 5.3 to 7.9% increase in grain yield of rice.
- Three bioformulations of *P. fluorescens, T. harzianum* and *T. viride* namely Eco-Pesticide (Talc based bioformulation of *Pseudomonas fluorescens*); Eco-Green Fungicide (Vermi-based

bioformulation of *T. viride*) and Green Fungicide (Talc based bioformulation of *Trichoderma harzianum*) respectively, were developed successfully and found effective against a number of soil and seed borne pathogens like *Rhizoctonia, Sclerotium, Sclerotinia, Fusarium, Pythium, Ralstonia, Macrophomina, Bipolaris, Phoma*, etc.

- A fly ash based bioformulation of *Trichoderma harzianum* and *Bacillus amyloliquefaciens* named 'Bio Pulse' has been developed and evaluated for control of *Fusarium* wilt in chickpea. Treatment with formulation could suppress wilt disease by 40% and increased the grain yield by 15% in chickpea on farmers' field.
- Bio-protective microbial agents (*Pseudomonas fluorescens* PF-08 and *Trichoderma harzianum* UBSTH-501) against sheath blight disease in rice (*Oryza sativa* L.) were identified and evaluated.
- Two bacterial consortia consisting of P solubilizing bacteria, siderophore and IAA producing bacteria named 'BIOGROW-I' and 'BIOGROW-III' were developed for nutrient management in cereals and vegetable crops.

Molecular markers and Microbial Genomics

- Development of molecular markers for the diagnostics of different pathogens and beneficial microorganisms has been one of the important activities with remarkable achievements.
- DNA based diagnostic kits were developed for the identification and ecological monitoring of *Bacillus*, *Pseudomonas, Alternaria, Colletotrichum, Fusarium udum* and *Macrophomina phaseolina*.
- A simple approach was developed to distinguish *Bacillus* from other *Bacillus* derived genera and to identify *Bacillus* species.
- Two species-specific primers were designed from the specific nucleotide regions and one oligonucletide probe was designed from the conserved region for identification of *Macrophomina phaseolina*.
- An allele specific PCR assay and a hybridization assay were developed for the identification of *Fusarium udum*.
- At present the Bureau is working for development of molecular barcodes based on signature sequences for accurate detection of the microorganisms.
- The Bureau has completed the draft genome sequencing of *Mesorhizobium ciceri* strain Ca181, *Pseudomonas koreensis* P2, a cold adapted phosphate solubilizing strain isolated from Sela Lake, Brevibacillus borstelensis LCHU R05 and Staphylococcus xylosus strain LSR_02N isolated from the water (sediment) sample of confluence of river Zanskar and river Indus at Leh, Ladakh.
- The Bureau is conserving the genomic resources of microorganisms and established the Microbial Genomic Resource Repository (MGRR). Over 10000 accessions of genomic DNA, clones, plasmids, vectors and gene constructs from various sources are being maintained under MGRR.

Capacity Building

- The Bureau has a very strong component of capacity building of researchers, scientists, faculty members of universities and research students in the areas of microbial molecular biology, biotechnology, genomics, proteomics and bioinformatics.
- More than 1000 researchers have been trained in different National and International trainings conducted by the Bureau in the last decade.
- Capacity building and awareness programs for the local farmers led to the development of their skills in the bio-organic farming, applications of biological inputs in the farms, in-situ conservation of

microbial diversity in the agricultural farms, promotion of low-input farming practices, reduced use of chemical fertilizers and microbe-mediated plant growth promotion.

- To portray the activities & facilities and basic information on microbial accessions Microbial Genetic Resource Portal (www.mgrportal.org.in) has been developed.

Future thrusts for NBAIM

The future challenges in selecting microbes for agricultural application are related to the attempts at alleviating biotic and abiotic stress conditions in crops (i.e., drought, salinity, inorganic, and organic pollutants) and improving food quality. Improvements in the production process for consortia of microbial inocula, the development of new carriers based on nanoparticles, optimization of application devices and of the time of application for poly-annual crops, are all issues requiring further research to widen the implementation and efficient use of microbes in agriculture.

Though a good number of culture collections exist in India, still coverage of microbial diversity is sparse. The enormous functional microbial diversity across the country also needs to be deciphered, documented, properly conserved in repositories and utilized to interweave microbes in agriculture and other sectors. Especially, developing the strategies to tap the uncultured microbial diversity and to culture them under laboratory conditions are some of the major challenges for the ICAR-NBAIM in the area of microbial diversity.

V. National Bureau of Agricultural Insect Resources, Bengaluru

The National Bureau of Agricultural Insect Resources (ICAR-NBAIR) is the only one among the six Bureaux of the ICAR involved in the study of invertebrates particularly insects, spiders, mites and their associated organisms (including microbes). A radical shift in perspective in 2009 saw the institution transform itself from one devoted solely to the use of insects as biological control agents for the management of insect pests in agricultural situations to one which acknowledged the multifarious roles of insects in agroecosystems in particular and all of nature in general. While research in biocontrol would continue to be conducted at ICAR-NBAIR it would henceforth have the responsibility of not only documenting and studying the entire agricultural insect diversity of the country but also that of the fauna of associated organisms, *viz*., insect pathogenic bacteria, fungi, viruses and nematodes as well as endosymbionts of insect pests and their natural enemies.

Insect Systematics

Taxonomic studies of Indian insects commenced with Linnaeus himself with the description of a dozen species in the tenth edition of '*Systema Naturae'* in 1758. But the rate of discovery and description of Indian insects has not kept pace with that of the rest of the world. Many areas of the country have been poorly explored for their insect fauna. To offset this lacuna the ICAR-NBAIR has been undertaking surveys to document agricultural insect diversity from all agroecological regions of the country with special emphasis on the collection and documentation of insects in the biodiversity hotspots of the country.

Taxonomy: Many new taxa have been discovered and described from various parts of the country. These include a couple of new genera and over a hundred species of Platygastroidea, Microgastrinae, Trichogrammatidae, Mymaridae, Encyrtidae, Mymarommatidae, Tephritidae, Coccinellidae, etc. Over a hundred new records of subfamilies/ genera/species in Aphididae, Coccoidea, Tephritidae, Pentatomidae, Cerambycidae, Coccinellidae, Platygatroidea, Trichogrammatidae, Braconidae, etc. have resulted from these studies. The majority of these are parasitoids / predators that exercise natural control of insect herbivores in agricultural and natural ecosystems.

A monograph on Indian Microgastrinae along with their lepidopteran hosts, the largest of its kind in the country, has been published. The Indian fauna of the genus *Microplitis* has been revised and an illustrated key published. Keys to taxa of Platygastroidea, Pteromalidae, Braconidae, Trichogrammatidae, Mymaridae, Pentatomidae, Tephritidae, Coccoidea, Aphidiade and Coccinellidae have been developed. Checklists of many groups of pest insects like the Thysanoptera, Pentatomidae, Aphididae, etc. have been prepared.

Over 200 types in the collection of the ICAR-NBAIR have been digitized and are hosted on the ICAR-NBAIR website which is available for free access to taxonomists all over the world. Identification services for insects of agricultural importance, including both insect pests and their natural enemies are being provided free to scientists, students, farmers and entrepreneurs across the country.

Insect Museum: The insect collection in the ICAR-NBAIR museum is home to over 100,000 dry land wet specimens. The current strength of the museum is the large collection of parasitoids and predators of crop pests and weeds which is the largest in the country. This also includes voucher specimens of exotic natural enemies which were utilized in pest management during the early days of biological control in the country.

National Repository: In recognition of the expertise in insect taxonomy available at ICAR-NBAIR, the National Biodiversity Authority of the Government of India has designated this bureau as a National Repository for agriculturally important insects, spiders and mites.

Molecular Entomology

Barcodes: ICAR-NBAIR leads other organisations in the country in the generation of barcodes of Indian insects. Over 600 barcodes have been generated for insect pests, their natural enemies, mites and nematodes of agricultural importance. Studies have indicated that the ITS2 locus has higher discriminative capability than the COI locus for identifying inter and intra specific differences in species of *Trichogramma*.

Improved strains of natural enemies: Pesticide and high temperature tolerant strains of *Trichogramma chilonis* (a parasitoid of leidopteran pests) and *Chrysoperla zastrowi sillemi* (a predator) were developed and successfully used in management programmes against lepidopteran and sucking pests in different states in the country. These strains have been commercialized.

Bacillus thuringiensis: Two hundred and eighty four isolates of *Bacillus thuringiensis* collected from all over India were characterized and are being maintained. The collections include Bt strains expressing Cry genes and VIP3A.Five isolates expressing Cry4 proteins have been identified as agents for use against dipteran pests. Another isolate expressing Cry3 proteins has been developed for use against coleopteran pests. This is now ready for commercialization. The liquid formulation of a Lepidoptera specific *Bt* (ICAR-NBAIR – BTG4) has been commercialized.

Molecular studies: Whole transcriptome analyses of certain important pests like the diamond back moth of cabbage, *Plutella xylostella* and the brinjal shoot and fruit borer, *Leucinodes orbonalis*, the parasitoid *Trichogramma chilonis* and the predator *Chrysoperla zastrowi sillemi* are being undertaken to study the insecticide resistance genes and the mechanisms of resistance in these insects. Whole genome sequencing of *Leucinodes orbonalis* is in progress to unravel the molecular mechanism of insecticide stress tolerance.

Identification of insects from fragments: Fragments of an insect were received for identification from a pharmaceutical company. Morphological examination could only reveal that the insect was a dipteran– probably a sarcophagid or a calliphorid. The COX1 mitochondrial gene of 658 bp size obtained from the fragments was amplified and the barcode developed. The sequence perfectly matched GenBank accession numbers GQ409351 and JF439551.This was the sequence for *Pollenia rudis* (Fabricius) (Diptera:Calliphoridae). For the first time at ICAR-NBAIR an insect which could be identified morphologically was successfully identified through molecular means.

Insect cultures: With 110 species/ strains of live insects in continuous culture the ICAR-ICAR-NBAIR is the largest live insect repository in the country serving as the node for the supply of these agents to scientific, student and farming communities.

Perspectives

The main threats to biodiversity as perceived and submitted to the Convention on Biological Diversity (CBD) to which India is a signatory include: habitat fragmentation, degradation and loss; over-exploitation of resources; shrinking genetic diversity; invasive alien species; declining forest resource base; climate change and desertification; impact of development projects; impact of pollution. In the backdrop of the varying socio-cultural milieu and often conflicting demands of various stakeholders, there is an urgent need for augmenting and accelerating the efforts for conservation and sustainable use of biodiversity, and for the fair and equitable sharing of benefits arising from the utilisation of genetic resources.

ICAR envisaged the Agrobiodiversity Platform under the XII Plan to address management of genetic resources of plants, animals, fish, microbes and insects. The respective Bureaux coordinate these management functions involving other stakeholders in their functional areas from National Agricultural Research System (NARS) consisting of ICAR Institutes, All India Coordinated Research Project (AICRP) centres and State Agricultural Universities (SAUs). The idea is to suitably characterize, evaluate and conserve the genetic resources to ensure the availability of desirable trait specific germplasm of food and agriculture for improvement programmes. In order to ensure this objective, the CRP on Agrobiodiversity of ICAR has eight sub-projects addressing management of genetic resources of plants, animals, fish, microbes, insects, veterinary type culture collections and documentation of fungal biodiversity through fungal barcoding and on island ecosystems. The project will provide long-term strategies for management and sustainable use of agricultural biodiversity. Through this project there would be enhanced conservation, management and sustainable use of these genetic resources (and their wild progenitors/relatives) in the improvement programmes of different components of agrobiodiversity, namely, plants, animals, fish, microbes, insects and documentation of fungal biodiversity through fungal barcoding. The project would establish and strengthen the different Institutions governing genetic resources in ways that would promote the evolution and conservation of agrobiodiversity, and to ensure that they are available to be used by all regions to adapt better changing environment, as climate change is also expected to change interdependence patterns and levels.

Following the ratification of CBD and after widespread consultations, India also enacted the Biological Diversity Act in 2002 and notified the Rules in 2004, to give effect to the provisions of the CBD, including those relating to its third objective on Access and Benefit Sharing (ABS). India was one of the first few countries to enact such legislation. The Act is to be implemented through a three-tiered institutional structure: National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs), Biodiversity Management Committees (BMCs) at the local level, in line with the provisions for decentralized governance contained in the Constitution. The Biological Diversity Act is a path-breaking and progressive legislation which has the potential to positively impact biodiversity conservation in the country.

Pursuant to the CBD, a first major step was the development of the National Policy and Macro level Action Strategy (1999) that called for consolidating existing biodiversity conservation programmes and initiating new steps in conformity with the spirit of the Convention. This was followed by implementation of a UNDP/GEF-sponsored NBSAP Project (2000-2004) that yielded micro-level action plans adequately integrating crosscutting issues and livelihood security concerns. Some of the major programmes that contribute to its implementation include: Protected Areas (PA) network and its steady growth over the years, consolidation of Biosphere Reserves (BRs), establishment of more species-specific reserves, augmentation of *ex situ* efforts through the establishment of the network of Lead Gardens and initiatives in the conservation of genetic resources, etc.

Subsequent to the approval of the National Environment Policy (NEP) in 2006, preparation of the National Biodiversity Action Plan was taken up by revising the 1999 document in consonance with the NEP, using the NBSAP project report as one of the inputs. The National Biodiversity Action Plan (2008) defines targets, activities and associated agencies for achieving the goals, drawing upon the main principle in the NEP that human beings are at the centre of concerns of sustainable development and they are entitled to a healthy and productive life in harmony with nature. Work is in progress to develop national targets within the framework of the Strategic Plan for Biodiversity (2011-2020).

Bioversity International: Research for development in agricultural and tree biodiversity

Ann Tutwiler

Director General, Bioversity International, Rome, Italy

To feed nine billion people by 2050, food availability needs to expand another 60% globally and up to 100% in developing countries. Continued investments in research on staple grains are essential as these crops will continue to provide a large share of global calories, but complementary approaches are needed to meet new global challenges, which include:

- Reduce global malnutrition
- Adapt to climate change
- Increase productivity and reduce risk
- Address shrinking food diversity.

Agricultural biodiversity is the diversity of crops and their wild relatives, trees, animals, microbes and other species that contribute to agricultural production. This diversity exists at the ecosystem, species, and genetic level and is the result of interactions among people and the environment over thousands of years. Agricultural and tree biodiversity is among the earth's most important resources because it:

- Makes agriculture more resilient and sustainable
- Provides for current and future food, crops and forests
- Improves productivity and reduces pre-harvest losses
- Improves the resilience and adaptation of crop and tree species to climatic risks
- Sustains soil health, water quality, food and habitats for important pollinators and predators vital to agricultural production, and
- Delivers on multiple Sustainable Development Goals.

Farm households and rural communities have long since used agricultural and tree biodiversity to diversify their diets, and to manage pests, diseases and weather-related stress in their farms. In the past, however, policymakers and researchers considered these approaches as economically uncompetitive. More recently, scientific evidence has demonstrated that agricultural and tree biodiversity, used in combination with novel technologies and approaches, has much to offer in addressing these challenges. It is also being increasingly recognized as a tool to achieve the global Sustainable Development Goals.

Therefore, increasing the sustainable use of agricultural and tree biodiversity in production and consumption systems plays an important part in solving today's challenges.

Mission, objectives and activities of Bioversity International

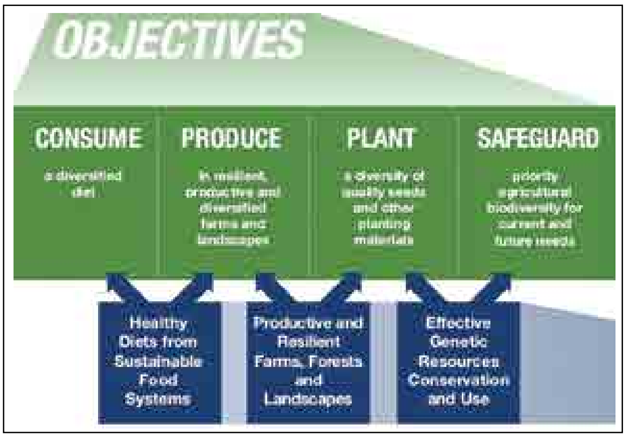
Bioversity International is a global research-for-development organization. We have a vision – that agricultural biodiversity nourishes people and sustains the planet.

We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. We work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation.

Bioversity International's staff exercise thought leadership with an agricultural biodiversity-related lens on the challenges and issues facing the world. We concentrate our research on agricultural biodiversity within and between species, at field, farm and landscape levels.

Our research is integrated across four strategic objectives, which are to:

- Consume a diversified diet
- Produce in resilient, productive and diversified farms and landscapes
- Plant a diversity of quality seeds and other planting materials
- Safeguard priority agricultural biodiversity for current and future needs.



Bioversity International's research is integrated across these four strategic objectives.

To achieve these objectives, Bioversity International integrates its research portfolio into three research initiatives:

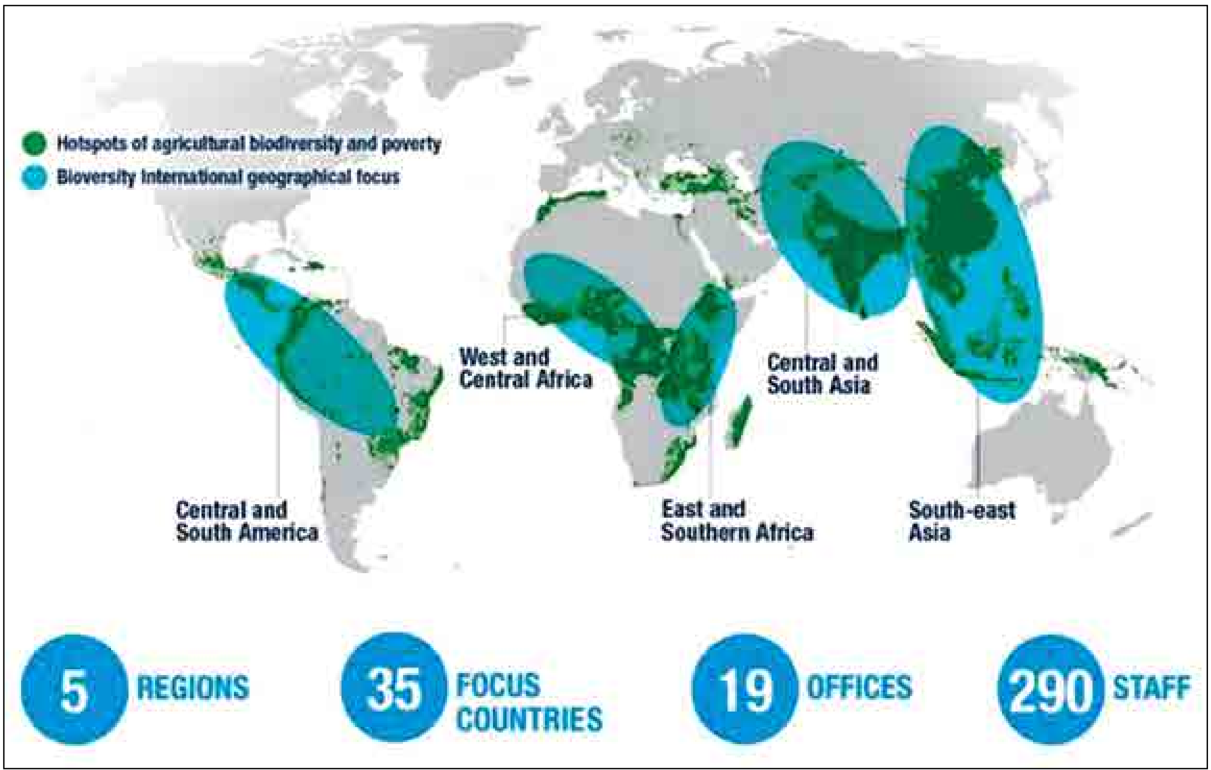
- **Healthy Diets from Sustainable Food Systems** - This initiative studies how agricultural and tree biodiversity can be better used within food production systems through rural to urban agri-food value chains and local agri-food systems.
- **Productive and Resilient Farms, Forests and Landscapes** - This initiative studies the role that agricultural and wild biodiversity plays in sustaining ecosystems and food security in rural communities.
- **Effective Genetic Resources Conservation and Use** - This initiative studies how to curb the loss of crop and tree biodiversity, how to open information and plant flows among users, and how to develop an enabling environment for the conservation and use of these genetic resources.

In order to achieve the four strategic objectives, Bioversity International integrates its research portfolio into these three research initiatives.

Who do we work with?

Bioversity International is a CGIAR Research Centre. CGIAR is a global research partnership for a food-secure future. In addition to our CGIAR partner organizations, we work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation. Our stakeholders include: national and international research systems and advanced research institutes, non-governmental organizations, foundations, private sector organizations, government ministries, UN agencies and other international bodies.

Bioversity International's work would not be possible without the financial support of our funding partners who share our vision and mission. Funding partners include CGIAR Fund members, governments and institutions, foundations and other international organizations, the private sector, universities and NGOs.



Map of Bioversity International's research areas.

Bioversity International research-for-development portfolio

Bioversity International has been producing research-for-development solutions for more than 40 years investigating and promoting the conservation and use of agricultural and forest biodiversity. We deliver a research-for-development portfolio that covers the following specialist areas:

1. Adaptation to climate change
2. Agricultural ecosystems
3. Banana genetic resources and management systems
4. Conservation of crop diversity
5. Diet diversity for nutrition and health
6. Forest and tree genetic diversity
7. Fruit tree and tree crop diversity
8. Marketing diverse species
9. Policies for plant diversity management

Adaptation to climate change: Using agricultural biodiversity in the fight against climate change is about building climate-smart agricultural systems - responding to variety with diversity. Diversity can help farmers mitigate, adapt and ensure food and nutrition security, by providing them with more options to manage climatic risks and strengthen the resilience of their farms and surrounding landscapes. To do this, we carry out research at the genetic, species and landscape level.

Genetic level: Different crop varieties can be used to deal with climate-induced stress and unpredictability.

Species level: Different crops and livestock respond differently to environmental stresses such as drought, frost and salinization. Having different species on farm prevents farmers from losing everything, and some species will cope better with unpredictable shocks than others.

Landscape level: Diverse sources of food and smarter seasonal planting help communities cope with 'hungry' seasons and a landscape with many different land uses can help communities and their ecosystems deal with environmental shocks.

Genetic Level

Assorted beans and pulses (Phaseolus vulgaris, Lens culinaris). Credit: Bioversity International/C. Zanzanaini

Species level

Chickens owned by Esikoma Ushirika Self-help Group, Kenya, for earning more income. Credit: Bioversity International/A. Grasso

Landscape Level

Agricultural landscape of rice and other mixed crops, with wild areas and homes nearby, Son La province, northwestern Vietnam. Credit: Bioversity International/L. Sebastian

Close-up of a bee pollinating a flower. Credit: Bioversity International/L. Sebastian

Agricultural ecosystem: People benefit from ecosystems in many ways, these are known as ecosystem services. In agriculture, these services include pollination, the provision of clean water, natural pest and disease control, nutrient cycling and more. Yet despite the importance of ecosystem services to farming communities, markets, policies and research often focus on specialization and economies of scale where biodiversity is seen as an impediment to crop productivity and farm income.

Banana genetic resources management systems: Millions of people around the world depend on banana as a source of food and income. However, despite increasing global banana production, yields of banana – both dessert and cooking types – are far below their potential. Production is affected by: a range of pests and diseases such as *Fusarium* wilt, bacterial wilts, nematodes, weevils, black leaf streak and bunchy top; declining soil fertility; abiotic stress such as drought and extreme weather events brought about by climate change. For over 30 years, Bioversity International has played a leading role

Transporting bananas to market, Cibitoke, Burundi. 'Cibitoke' means land of the bananas ('ibitoke' means banana). Credit: Bioversity International/P. Lepoint

in ensuring the long-term conservation of the global diversity of banana, to provide options for present and future generations. We have specialist scientific expertise in developing protocols and innovative approaches for the medium- and long-term conservation of banana, and through our research contribute to a better understanding of the crop's selection, adaptation and diversification processes.

Conserving crop diversity: Bioversity International's research seeks to enhance the relationships between people, their food and the environment to the benefit of all three. One way we do this is by focusing our research on the agricultural systems and plants that have evolved over millennia, managed by the people who rely on them. The heart of this research programme is to enable the women and men farmers who manage their crop diversity on a daily basis to benefit more directly from it by having strengthened food security, better diet quality, increased income, and more options in an uncertain world. By continuing and accelerating a millennia-old tradition of co-evolution of people and crops, we can provide options in which people benefit from their crops while crop diversity continues to provide the ecosystem and evolutionary services necessary for change. Our research will develop interventions that have a positive

Peninah Mwangangi is one of the leaders of the Kyanika Womens Group in Kitui, Eastern Kenya, and plays a key role in conserving local farmer landraces of a variety of crops. Here she shows some sorghum that the group is conserving. Credit: Bioversity International/ Y. Wachira effect both on women and men's livelihoods and on the conservation of biodiversity, and principles for identifying the best locations for these interventions. Another important research area studies the public benefits provided by the actions of individuals, for example investigating the functional relationships between amounts of crop diversity and the provision of ecosystem services in agricultural systems.

Diet diversity for nutrition and health: Bioversity International is investigating how agricultural and tree biodiversity can be better used within local food production systems to improve access to nutritionally-rich food sources and increase dietary diversity, with a particular focus on women of reproductive age and children under two. We work with partners to mainstream locally available food biodiversity for sustainable food systems and healthy diets into national programmes and policies on food and nutrition security.

Forest and tree genetic diversity: Although several organizations are tackling these problems, Bioversity International occupies a unique niche, studying at a global level, how to use and conserve valuable tree genetic resources. Bioversity International's tree genetic resources research focuses on documenting the diversity within tree species that are important for people, analyzing the threats to trees and their genetic resources and learning how these threats can be addressed to achieve their conservation and sustainable use in protected areas, managed forests and woodlands.

Fruit tree and tree crop diversity: Fruit tree and tree crop diversity is crucial for nutrition, livelihoods and ecosystem resilience around the world. For more than 30 years, Bioversity International has worked closely with fruit tree and tree crop professionals and farmers around the world to share experiences, challenges, and new methods and approaches regarding the integration of diverse knowledge sources.

Markets for diverse species: Bioversity International leverages the potential of diverse crop species and varieties in order to strengthen food security, increase access to nutritionally-adequate diets, build resilience to crop production, and help communities to diversify local food production. We work with farmers to increase their food security, both directly and indirectly, and improve their access to markets. By increasing the markets for diverse species, farmers perceive the incentives to cultivate them and expand their livelihoods. Along with this indirect strengthening of food security, communities also benefit directly from consumption of diverse and nutritious species and varieties.

Policies for plant diversity management: Using participatory research methods, Bioversity International works to strengthen the capacity of our partners to conduct policy research, and to proactively engage in policy development processes by developing science-based technical contributions for consideration by policymakers from local to global levels. Our work has a direct effect and application for: farming communities; community, national and international genebanks; local, national and international policymakers; non-governmental organizations; and researchers from national and international organizations.

Learn more about Bioversity International by visiting www.bioversityinternational.org

The Importance of Crop Diversity and *Ex Situ* Conservation: The Crop Trust's Role within the Global System

Marie Haga

Executive Director, Global Crop Diversity Trust, Platz Der Vereinten Nationen 7, 53113 Bonne, Germany

The Importance of Crop Diversity

Crop diversity provides vital options for the survival of mankind

Crop diversity is the foundation of agriculture, enabling it to evolve and adapt to meet the never-ending challenge of producing not only sufficient food, but sufficient nutritious food for an increasing population. For millennia, food plants have been domesticated, selected, exchanged, and improved by farmers in traditional ways, within traditional production systems.[1] In the 20th century, this process was hugely accelerated and focused by scientific crop improvement, leading to historic achievements such as the Green Revolution and the steady rise in yields since then. Half of the increases in food production globally can be attributed to improvements through natural breeding, whose benefits also include reduced reliance on environmentally harmful inputs, smaller fluctuations in yield from year to year and higher nutritional value.

Despite these undoubted achievements, challenges are vast. There are two billion people who are still malnourished, and of these about 749 million do not get enough calories.[2] Meanwhile, yield gains are decreasing for some major food crops and climate change has introduced additional, urgent challenges for farmers. Today, modern tools and new methods allow researchers to be more accurate and efficient in managing genetic diversity. However, for plant breeders to continue delivering benefits, they require continued access to plant genetic diversity from around the world.

Recognition of the significance of crop diversity to our future is clearly epitomized by the agreement of a global treaty addressing the issue, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), which came into force in 2004. Now ratified by more than 135 countries, it provides a legal framework for how crop diversity is conserved and made available for food and nutritional security.

More recently, the UN Sustainable Development Goals (SDGs) have challenged the global community to eradicate hunger. The SDGs recognize the important role crop diversity plays in helping us achieve this goal, and explicitly call for its protection and use in Targets 2.5 and 2.a:

- **SDG Target 2.5:** "By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed."

[1] Plucknett, D., Smith, N., Williams, J.T., Anishetty, N.M., 2014. GeneBanks and the World's Food. Princeton University Press.

[2] IFPRI, 2015. Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development. International Food Policy Research Institute.

- **SDG Target 2.a:** "Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries and landlocked developing countries, in accordance with their respective programmes of action."

Climate Change and the Future of Crop Diversity

Evidence of rising temperatures, changing seasonal patterns and increasing frequency of extreme weather events is growing. Climate change will affect agricultural productivity worldwide. The adaptation of the agricultural sector will be crucial to ensure food security for a global population of nine billion people in 2050. Although climate change is one of the drivers of loss of biodiversity in general, crop diversity in particular is expected to play a significant role both in mitigating the adverse effects of, and adapting to, climate change.

A report by FAO (2015)[3] places crop diversity at the forefront of adaptation solutions.[4] Simulation studies have demonstrated simple and feasible changes in farm practices that can have significant impacts on crop productivity, such as changing varieties and planting times to avoid drought and heat stress during dry periods. The continued availability and accessibility of both traditional and improved varieties is necessary to future improvements in crop productivity under climate change.

For example, the "scuba" rice varieties released in India, Bangladesh, the Philippines, Indonesia, Myanmar, Lao PDR and Nepal, are able to grow in flood-prone areas and withstand submergence under water for up to two weeks. Such conditions are expected to become much more common under even conservative climate change scenarios. These varieties were produced by the International Rice Research Institute (IRRI) through the introduction of a gene from an Indian landrace.[5]

Safeguarding Crop Diversity

While we now understand the treasure that crop diversity represents, much genetic diversity was lost as agriculture developed.

> **While securing the world's food supply will require much work beyond crop diversity conservation – such as further advances in crop science, building efficient markets, and reducing the waste of food – none of this can be effective if the genetic base of our food supply is lost.**

The establishment of many of the world's genebanks took place during the 1970s and 1980s in an atmosphere of crisis. Scientists rightly believed that the race against genetic erosion was a race against time. Every day, traditional crop varieties and their wild relatives were disappearing from farmers' fields and from the forests, cast aside in favour of genetically uniform, potentially high-yielding types or victim to changing cropping patterns, resource degradation, destruction of habitats and shifting ecosystems. This led to the mobilization of a worldwide effort to collect imperilled crop resources for safeguarding in genebanks.

This eleventh hour rescue effort would eventually lead to the establishment of about 1,700 genebanks around the world, holding more than 7 million accessions. These include the genebanks of the CGIAR centres, which collectively host the foremost international effort to conserve and manage crop, forage and agroforestry genetic resources. One of these, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is located here in India, in Hyderabad.

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[3]FAO, 2015. Coping with Climate Change: The Roles of Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations.

[4]Asfaw, S., Lipper, L., 2012. Economics of plant genetic resource management for adaptation to climate change: A review of selected literature (No. 12-02). ESA Working Paper. Food and Agriculture Organization of the United Nations.

[5]Almendral, A., 2014. Scientists develop "scuba rice" that can stand up to climate change. Next City, March 14.

Despite their prescience in setting up crop diversity collections, however, a large number of genebanks established during the crisis years did not make sufficient provision for on-going financial support. Many of the collections maintained in developing countries are in a precarious state. And even the best of them struggle for funding.

Long-term conservation requires long-term financial support. Without regular, stable funding, there is no certainty that operations can be maintained, much less improved or expanded. Without regular, stable funding, for viability monitoring and regeneration, materials in crop collections can be lost forever.

The declining conditions of many plant genebanks does not take place in a vacuum. Crop diversity in farmers' fields is diminishing too, and the wild relatives of our food crops are disappearing in their natural habitats – be it by clearing of forests or urban sprawl.

In short, agrobiodiversity today is threatened on three fronts: in the wild, in farmer's fields, and even in the crop genebanks that are intended to be safe houses for the future. We must secure safe havens from the threats posed in all of these places.

The Crop Trust - Supporting Crop Diversity Conservation

The reliability of genebank funding is absolutely crucial given that even a slight shortfall in financial resources can lead to the permanent loss of unique varieties. The Crop Trust's objective is to ensure stable, predictable funding for a global system of crop collections, in perpetuity.

The Endowment Fund allows the Crop Trust to fulfill its purpose: to build and fund a cost-effective, rational global system of crop diversity conservation.

Founded in 2004 in Rome, Italy by the Food and Agriculture Organization (FAO) and Bioversity International on behalf of the CGIAR, the Crop Trust is a small organization with a big mission. At the heart of our task is the permanent, self-sustaining Crop Diversity Endowment Fund. Each year, a portion of the fund's value is paid out to ensure conservation and maintenance of crop diversity held in genebanks. The support provided by the Fund comes solely from investment income earned, leaving the endowment itself untouched.

Thus, completing the Crop Diversity Endowment Fund is of the highest priority. The Crop Trust is working to reach the fund's target size which, once complete, will support an efficient global system for crop diversity conservation, the further development and maintenance of information systems and the operation of the Crop Trust secretariat.

This global system of crop diversity is based on three pillars: international crop collections (as shown in Figure 1); national and regional collections of the highest importance for food security; and the Svalbard Global Seed Vault, the final back-up of the world's crop collections.

- **International Crop Collections:** Currently, the Crop Trust has signed agreements to provide 'in perpetuity' funding to some of the world's most important collections of 17 crops (shown in Figure 2), all recognized under Article 15 of the Plant Treaty. These are among the most comprehensive and widely used collections of crop diversity. As the endowment grows, the Crop Trust will be able to secure more and more crops through fully-funded long-term grants. Until the endowment is fully funded, the Crop Trust has entered into a five-year partnership (the Genebanks CRP) with the CGIAR Consortium to manage and provide sustainable support for the crop collections held at CGIAR Centers until the end of 2016.

  The goal is to make this diversity available to breeders and researchers in a manner that meets international scientific standards, and which is cost efficient, secure, reliable, sustainable over the long-term and supportive of the Plant Treaty.

Figure 1. The Genebanks Supported by the Crop Trust through long-term grants from the Endowment Fund and the Genebanks CRP

CGIAR Centers	Crops	# of crop accessions
AfricaRice Benin	Rice	19,983
International Institute for Tropical Agriculture Nigeria	Cowpea, Yam and Cassava	30,388
Bioversity International Belgium	Banana	1,455
International Maize and Wheat Improvement Center Mexico	Maize & Wheat	175,526
International Center for Agricultural Research in the Dry Areas Syria	Barley, Chickpea, Faba Bean, Forages, Lentil and Wheat	136,350
International Center for Tropical Agriculture Colombia	Bean, Cassava and Forages	67,574
International Crops Research Institute for the Semi-Arid Tropics India	Chickpea, Groundnut, Minor Millet, Pearl Millet and Sorghum	129,081
International Livestock Research Institute Kenya	Forages	17,716
International Potato Center Peru	Andean Roots and Tubers, Potato and Sweet Potato	15,756
International Rice Research Institute Philippines	Rice	121,595
World Agroforestry Center Kenya	Agroforestry Trees	5,490
Centre for Pacific Crops and Trees Fiji	Aroids and Yams	1,467

Figure 2. Long-Term Grants provided by the Crop Trust

• Edible Aroids – Fiji (SPC)	• Grass pea – Syria (ICARDA)
• Banana and Plantain – Belgium (Bioversity International)	• Lentil – Syria (ICARDA)
• Barley – Syria (ICARDA)	• Maize – Mexico (CIMMYT)
• Bean – Colombia (CIAT)	• Pearl millet – India (ICRISAT)
• Cassava – Colombia (CIAT)	• Rice – Philippines (IRRI)
• Cassava – Nigeria (IITA)	• Sorghum – India (ICRISAT)
• Chickpea – India (ICRISAT)	• Sweet Potato – Peru (CIP)
• Faba Bean – Syria (ICARDA)	• Wheat – Mexico (CIMMYT)
• Forages – Syria (ICARDA)	• Yam – Fiji (SPC)
• Forages – Ethiopia (ILRI)	• Yam – Nigeria (IITA)

Managers of the eleven crop genebanks provide technical and financial reports to the Crop Trust through an Online Reporting Tool, and nineteen agreed Performance Indicators are being monitored for each of the crop collections involved. While the end of this partnership term is nearing, the Crop Trust and CGIAR staff are working to create a new partnership agreement for the next 6 years.

- **National Crop Collections:** Beyond the Article 15 collections, the Crop Trust is also planning to help conserve and make available other key collections of the 25 Annex 1 crops which are most important to agriculture in Least Developed Countries (LDCs), as reflected by production statistics. Global crop strategies have been developed, and will be revised, to help identify priority collections for both short- and long-term support.

- **The Svalbard Global Seed Vault:** Deep inside a mountain on a remote island in the Svalbard archipelago, halfway between the northern-most tip of mainland Norway and the North Pole, lies the Svalbard Global Seed Vault. This is a fail-safe, last-chance backup facility for the world's crop diversity. It currently holds more than 860,000 samples of crop diversity from more than 60 institutions, and nearly every country in the world. The Crop Trust maintains the Vault in partnership with the Norwegian government and the Nordic Genetic Resources Center, which is responsible for its management and operation.

Worldwide, more than 1,700 genebanks hold collections of food crops for safekeeping, yet many of these are vulnerable, exposed not only to natural catastrophes and war, but also to avoidable disasters, such as inadequate recurrent funding and outdated equipment.

It was the recognition of the vulnerability of the world's genebanks that sparked the idea of establishing a global seed vault to serve as a backup storage facility. The purpose of the Vault is to store duplicates (backups) of seed samples from the world's crop collections. It will secure, for centuries, millions of seeds representing every important crop variety available in the world today.

2015 was a big year for the Svalbard Global Seed Vault, with the first ever retrieval of seeds.

Something as mundane as a poorly functioning freezer can ruin an entire collection. And the loss of a crop variety is as irreversible as the extinction of a dinosaur. Given the vault's remote and cold location inside the permafrost, it provides a cost-effective method for long-term seed storage.

Last October, seeds were withdrawn from the Global Seed Vault for the first time when ICARDA, the international agricultural research centre formerly domiciled in Aleppo, Syria withdrew 40,000 of its crop accessions from Svalbard in order to re-establish collections of these crops in facilities in Lebanon and Morocco. This demonstrates that the Vault can help overcome the kinds of crises that may threaten genebanks in these turbulent times.

You can read more about ICARDA's retrieval on our website.

However, our work is not restricted to long-term funding to genebanks. The Crop Trust is also implementing short-term, strategic projects that underpin the global system and strengthen crop diversity conservation worldwide. For example:

- **Crop Wild Relatives Project:** The Crop Trust and its partner, the Millennium Seed Bank of the Royal Botanic Gardens, Kew, UK, have embarked on a global effort to collect, conserve and use the wild relatives of 29 crops of global importance to food security. The 10-year project Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives, a USD 50 million initiative funded by the government of Norway, is the most systematic and comprehensive ever bid to conserve the world's crop wild relatives on a global scale. The project will ensure that collected seed can be crossed with existing varieties, a process known as "prebreeding," to see if the traits of interest can then be introduced effectively into domesticated plants. Once this is done, the diversity is available to all plant breeders, everywhere.

Crop wild relatives (CWR) are the un-domesticated cousins of our crops. These wild plants, living under the pressures of their natural environments, but threatened in many places, hold great potential to help crops adapt to pests, diseases and adverse climatic conditions. They can also make crops more productive, and more nutritious.

- **Information Systems:** Ensuring the effective use of crop diversity depends on long-term, ready access not just to the diversity itself, but also to any information that exists about it. The Crop Trust has worked with Bioversity and the International Treaty to develop Genesys, an online portal bringing together information from genebanks worldwide. This user-friendly window which includes more than 7 million samples of crop diversity stored around the world allows breeders, researchers and other users to search multiple genebank databases on multiple criteria, and acquire genetic resources simply and efficiently. The Crop Trust has also supported, in close partnership with the United States Department of Agriculture, the development of the GRIN-Global genebank data management software. We are committed to supporting national genebanks around the world in upgrading their documentation systems, including through adopting GRIN-Global, and sharing their information on Genesys, thus contributing to a truly global conservation system.

Feeding our growing global population is not an option we can choose to pursue or not. We have to do it, however hard it may be, and for that we need the raw materials for genetic improvement of our crops represented by the genetic diversity in genebanks, the foundation for food security.

We all eat. We all benefit from the work that genebanks do around the world. Clearly, everybody can help in some way, and indeed everybody should get involved.

We know that securing the world's food supply is going to require support and work beyond crop diversity conservation – but nothing in agriculture can be effective if the genetic base of our food supply is lost. And that's why the Crop Trust urges you to help us secure the foundation of this entire system now, so that future innovators can use this material to create a sustainable and healthy food system for our children's children.

Protection of Plant Varieties & Farmers' Rights Authority

R.R. Hanchinal[1#]

Chairperson, Protection of Plant Varieties & Farmers' Rights Authority, New Delhi - 110012, India

Introduction

Plant Genetic Resources (PGR) are the heritage of humankind and the foundation for attaining food, nutritional and health security. Before 1993, the PGR were shared freely among countries for the betterment of human being, till concerns of conservation of biological diversity were raised by the Convention on Biological Diversity (CBD). Consequently, many issues regarding the rights of the farmers as conservers, protectors and developers of PGR in the biodiversity hot spots, the researchers and breeders who invest on development of improved varieties with superior traits, the users of PGR and intellectual property rights related matters emerged.

India is a signatory to both CBD and World Trade Organization (WTO) conventions. The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is an International Agreement administered by the WTO that sets down minimum standards and regulations for many forms of intellectual property (IP) as applicable to WTO Member Nations. Nations seeking to obtain easy access to the numerous international markets opened by the WTO must enact the strict intellectual property laws mandated by TRIPS. The WTO under the Article 27.3 (b) of the TRIPS, for the protection of plant varieties provided different options namely by patents, by an effective *sui generis* system or a combination of both.

As a corollary to this, India opted for the *sui-generis* system for the plant varieties giving importance to farmers' rights compared to the provision of the International Union for the Protection of New Varieties of Plants (UPOV). With intensive and extensive national level consultations and dialogues, the Government of India enacted the "Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act)" in 2001. The Act seeks to address the rights of plant breeders and farmers on equal footing. The PPV&FR Act, 2001 is unique to befit the national situations yet matching with the larger global commitment. The PPV&FR Act protects both the variety and the denomination assigned to the variety. Another special feature of this legislation is that the protection accrues to a person from the date of filing of application for it gives priority and provisional protection. India is the first country to provide substantial rights to farmers and registration of their varieties is one of them. The PPV&FR Act recognizes the rights of farmers with respect to their contributions made in conserving, improving and making available PGR for the development of new plant varieties and also evolvers of farmers' varieties.

The Act became functional with the establishment of the PPV&FR Authority at New Delhi in 2005, hereinafter mentioned as the Authority. Regional Offices have been established at Guwahati and Ranchi. The PPV&FR Rules were notified on 12 September, 2003 and amended three times during 2010, 2012 and 2015 looking to the needs. The Protection and Plant Varieties and Farmers' Rights Regulations were notified on 7th December, 2006 and further amended during 2009 and 2015.

[1#]Chairperson, Protection of Plant Varieties & Farmers' Rights Authority, Ministry of Agriculture, Govt. of India, NASC Complex, DPS Marg, New Delhi – 110012, India; (IAC- 2016, New Delhi, India)); email: chairperson-ppvfra@nic.in

Objectives of the Act

- To establish effective system for protection of plant varieties, rights of farmers and plant breeders and to encourage increased breeding activities and encouragement of new types of breeders such as private breeders, researchers and farmer breeders
- To accelerate agricultural development in the country, protect plant breeders rights, stimulate investment for research and development both in public and private sector for the development of new plant varieties to facilitate the growth of seed industry which will ensure the availability of high quality seeds and planting material to farmers
- To recognize and protect the rights of farmers in respect of contribution made at any time in conserving, improving and making available plant genetic resources for development of new plant varieties

Various Rights Under the Act

1. Breeder's Rights

The Act, provides an exclusive right on the breeder or his successor, or his agent or licensee, to produce, sell, market, distribute, import or export the variety registered under the Act. A breeder may authorize any person to produce, sell, market or otherwise deal with the variety registered under this Act.

2. Researcher's Rights

A Researcher can use any of the variety registered under this Act for conducting experiment or research. However, authorization of the breeder of a registered variety is required where repeated use of such variety as parental line is done for commercial production of other newly developed variety.

3. Farmers' Rights

A farmer is entitled to save, use, sow, re-sow, exchange, share or sell his farm produce including seed of a protected variety in the same manner as he was entitled before operation of the PPV&FR Act, provided that he shall not be entitled to sell in branded form of a protected variety.

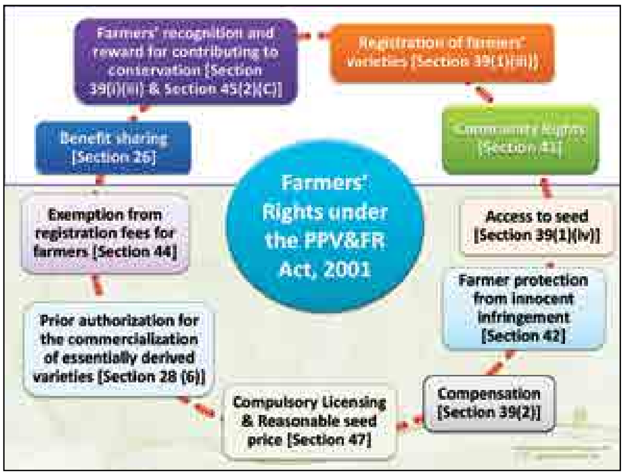


Fig. 1. Provisions related to the Farmers' Rights

The Act treats the farmer also as plant breeder so far as the farmers' variety is concerned and they can register them under the Act. Farmers are entitled for recognition and reward from the Gene Fund provided that the material so selected and preserved (land races and wild relatives) has been used as donors of genes in varieties registerable under the Act. The provisions related to the farmers' rights are presented in Fig.1.

National Gene Fund For Promoting PGR Activities On the basis of richness of agrobiodiversity i.e. number of crop species, crop varieties, wild relatives of various crop species cultivated, social relevance and ancientness of the agriculture, wild relatives of crop species occurring in the region, number of species domesticated and the uniqueness of the agro-ecosystems, the Authority has identified 22 agrobiodiversity hotspot regions in India, viz., 1. Cold Desert Region, 2. Western Himalayan Region, 3. Eastern Himalayan Region, 4. Brahmaputra Valley Region, 5. Khasia-Jaintia-Garo Hills Region, 6. North-eastern Hill Region, 7. Arid Western Region, 8. Malwa Plateau and Central Highlands Region, 9. Kathiawar Region, 10. Bundelkhand Region, 11. Upper Gangetic Plains Region, 12. Lower Gangetic Plains Region, 13. Gangetic Delta Region, 14. Chotanagpur Region, 15. Bastar Region, 16. Koraput Region, 17. Southern Eastern Ghats Region, 18. Kaveri Region, 19. Deccan Region, 20. Konkan Region, 21. Malabar Region and 22. Islands Region (Andaman & Nicobar Islands, Lakshadweep) (Fig. 2).

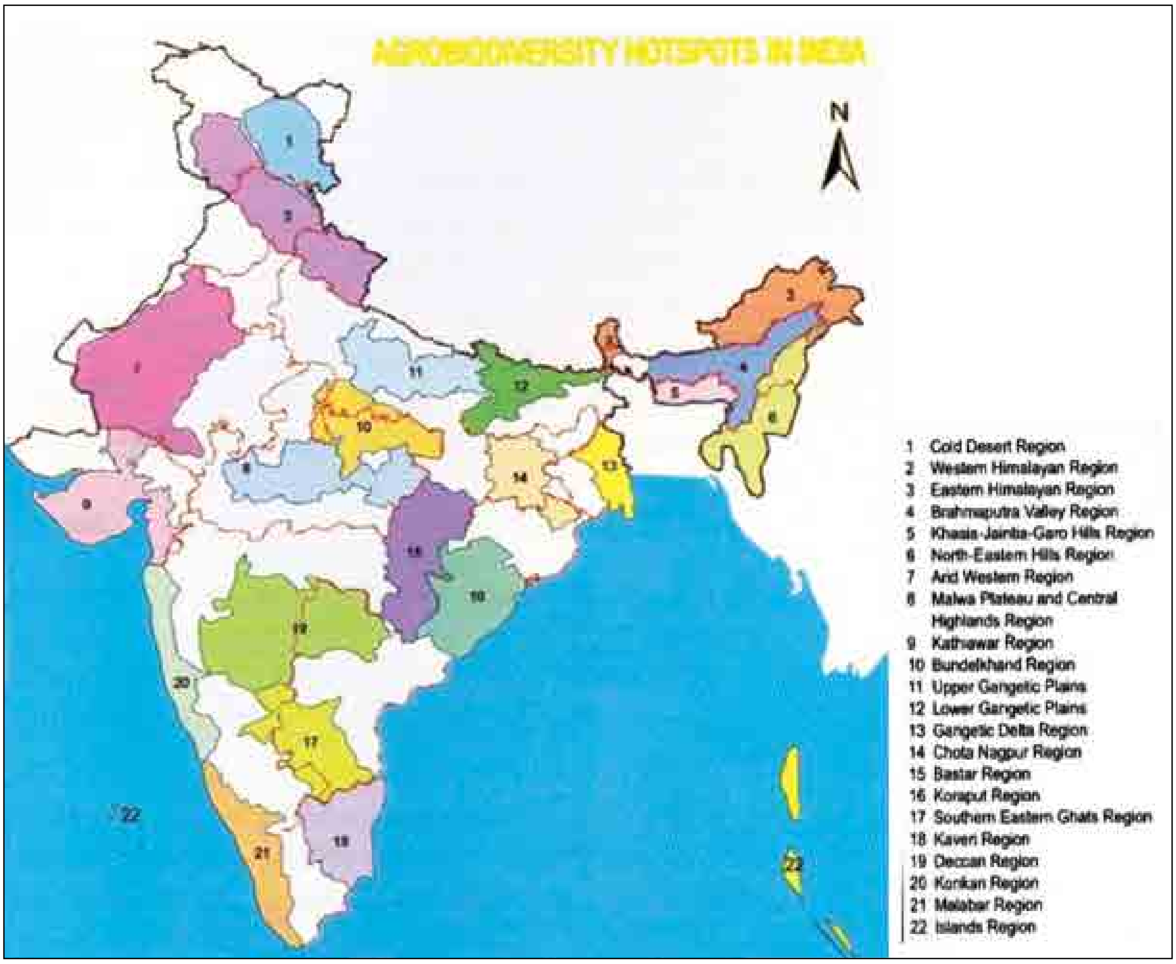


***Fig. 2.** Agrobiodiversity hot spot regions of India*

Farmers who have been engaged in conservation and preservation of plant genetic resources (PGR) of landraces and wild relatives of economic plants and their improvement through selection and preservation in these identified 22 agrobiodiversity hotspots, receive recognition and rewards from the National Gene Fund. This provision, when taken in conjunction with the provisions relating to the farmers' privilege, is similar to the concept of Farmers' Rights contained in the International Treaty on Plant Genetic Resource for Food and Agriculture (ITPGRFA).

The National Gene Fund receives contributions from central government, national and international organizations and other sources [section-45 (1-d)]. The gene fund also receives funds from benefit sharing [section-45 (a)] from the breeder of the variety or an essentially derived variety registered under the Act or propagating material, the compensations deposited [section-41 (4)] and the annual fee payable to the Authority by way of royalty [section-35 (d)]. The expenditures of the fund are earmarked to support the conservation and sustainable use of PGR including *in situ* and *ex situ* collections. Thus, in this way it can be considered to be a national equivalent to the global benefit-sharing fund operating within the ITPGRFA.

Plant Genome Saviour Awards, Rewards and Recognition

The Gene Fund is also utilized to support and reward farmers, particularly the tribal and rural communities engaged in conservation, improvement and preservation of genetic resources of economic plants and their wild relatives, particularly in areas identified as agro biodiversity hotspots (**Fig. 2**). Recognizing the important contribution of farmers and farming communities and their role in enhancement of quality in research and development in agriculture and to energise and implement Rule 70(2) (a) of PPV&FR Rules, 2003 and the provision of section 45 of PPV&FR Act, 2001, the PPV&FR Authority in consultation with the Govt. of India instituted the Plant Genome Saviour Community Awards (maximum of five awards per year consisting of a citation, a memento and cash of one million Rupees each). This is being awarded since 2009-10. Government of India has notified the Protection of Plant Varieties and Farmers' Rights (Recognition and Reward from the Gene Fund) Rules, 2012, whereby a farmer who is engaged in the conservation of genetic resources of landraces and wild relatives of economic plants and their improvement through selection and preservation and the material so selected and preserved has been used as donors of gene in varieties registerable under the PPV&FR Act, 2001 shall be entitled to Plant Genome Saviour Farmer Reward (maximum of 10 rewards per year comprising of a citation, memento and cash of Rupees one lakh fifty thousand each) and Plant Genome Saviour Farmer Recognition (maximum 20 recognitions per year consisting of a citation and memento and a cash of Rupees one lakh each.

Supporting Plant Genome Saviour Awardee Communities

PGR conservation, protection and promotion for sustainable use are being practiced by farmers and their families since ancient time. This has allowed them to cultivate a large number of different local varieties in different crop species of economic importance. This is how India has been regarded as one of the mega bio-diversity centres in the world. To support the activities of PGR, the Authority has selected the Genome Saviour Awardee Communities to support their efforts of saving local varieties and land races. As climate change has a significant impact on agricultural production, growing local varieties which have a high degree of genetic diversity is highly important because these varieties have the ability to better withstand and adapt to environmental stresses and change. Setting up community seed banks may help farmers to acquire varieties that are adapted to local conditions; these varieties may not be accessible through formal seed systems, may be costly or may suffer from erratic supplies. To make available the quality seeds of popular local varieties/planting material through informal seed chain, the Authority is promoting "Community Seed Bank Concept" for field crops and "Community Nursery Bank/Community Clonal Gene Bank" for vegetables, fruits and trees, medicinal and aromatic plants and fodder grasses at different Agro climatic bio diversity hotspots where improved varieties have not made impact on production and productivity. Authority has identified regions in agro biodiversity hotspots and mainstreaming of farmers' varieties is being taken up by following unique maintenance breeding program for the supply of seed/planting material.

Categories of Varieties Eligible for Registration Under the Act

New Varieties

A new variety shall be registered for breeder's right if it conforms to the criteria of Novelty, Distinctiveness, Uniformity and Stability. The variety should also have a denomination in accordance with the provisions of PPV&FR Act, 2001. Novelty criteria is, if, at the date of filing of the application for registration for protection, the propagating or harvested material of such variety has not been sold or otherwise disposed of by or with the consent of its breeder or his successor for the purposes of exploitation of such variety in India, earlier than one year; or outside India, in the case of trees or vines earlier than six years, or in any other case, earlier than four years.

Extant Variety

Extant Variety is defined as a variety available in India which is notified under Section 5 of the Seeds Act, 1966 (54 of 1966); or Farmers' Variety; or a Variety about which there is common knowledge; or any other variety which is in public domain;

Farmers' Variety

"Farmers' variety" is defined as a variety which has been traditionally cultivated and evolved by the farmers in their fields; or is a wild relative or land race or a variety about which the farmers possess the common knowledge.

As per the Act, "farmers" means any person who cultivates crops by cultivating the land himself; or cultivates crops by directly supervising the cultivation of land through any other person; or conserves and preserves, severally or jointly, with any other person any wild species or traditional varieties or adds value to such wild species or traditional varieties through selection and identification of their useful properties.

Variety of Common Knowledge

Variety of Common Knowledge (VCK) refers to a variety which has not been released and notified under the Seeds Act, 1966, have been sold or otherwise disposed of in India for more than a year from the date of filing the application. The variety which is under cultivation in a State/region/country, even as "truthfully labelled" variety, finds a entry in official list/register of varieties in any country granting Plant Variety Protection (PVP), including filing of an application for Plant Breeders Rights (PBR), Inclusion in a recognized publicly accessible collection, including an accession in a National/International Gene Bank and adequate description of the variety in a publication that may be considered a part of the public technical knowledge may find their eligibility under the VCKs.

Essentially Derived Variety

A variety (the initial variety), shall be said to be Essentially Derived Variety (EDV) from such initial variety when it is predominantly derived from such initial variety, or from a variety that itself is predominantly derived from such initial variety, while retaining the expression of the essential characteristics that results from the genotype or combination of genotypes of such initial variety; is clearly distinguishable from such initial variety; and conforms (except for the differences which result from the act of derivation) to such initial variety in the expression of the essential characteristics that result from the genotype or combination of genotype of such initial variety.

Registration of Plant Variety

A variety is eligible for registration under the Act if it essentially fulfills the criteria of Distinctiveness, Uniformity and Stability (DUS) which means that the candidate variety must be distinguishable by at least one essential characteristics from a variety which is a matter of common knowledge in any country at the time of filing application, sufficiently uniform in expression of its essential characteristics which should remain unchanged even after repeated propagation. The variety should also have a single and distinct denomination.

The Authority has established 78 DUS test centres for different crop species in different parts of the country having tropical, sub-tropical climate to suite the clear expression of the DUS trait. These centres are responsible to conduct DUS test of varieties applied for registration and to maintain, multiply and characterize reference/example varieties as per DUS descriptors. In case of new variety, DUS Test is carried out for two years at two locations and for Extant variety, DUS testing is for one year only. When the DUS Test result is found to be satisfactory, certificate of registration is issued to the applicant and its details are published in the Plant Variety Journal of India for opposition if any. After three months the PVP certificates are granted. The process of registration is presented in Fig. 3.

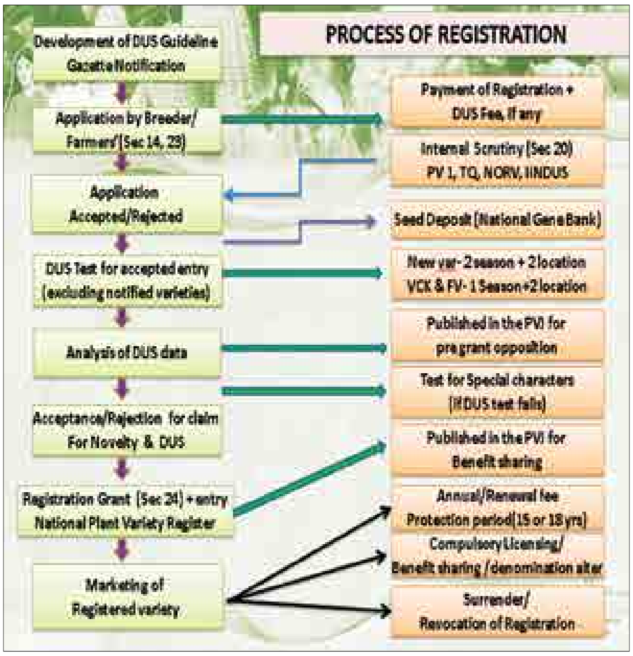


Fig. 3

The Central Government has notified **114 crop species** for the purpose of registration (Table 1). For these crop species PPV&FR Authority has developed "Guidelines for the Conduct of Species Specific Distinctiveness, Uniformity and Stability (DUS)" tests or "Specific Guidelines" for individual crop species. The purpose of these specific guidelines is to provide detailed practical guidance for the harmonized examination of DUS and in particular to identify appropriate characteristics for the examination of DUS and production of harmonized variety descriptions. Mean while in another 56 crop species development of DUS guidelines is in progress.

Table 1. Notification of 114 crop species for registration of plant varieties

Group	No.	Crop Species
Cereals	11	Bread wheat, Rice, Pearl millet, Sorghum, Maize, Durum wheat, Dicoccum wheat, Other Triticum species, Barley, finger millet, foxtail millet
Legumes	7	Chickpea, Mungbean, Urdbean, Field pea, Rajmash, Lentil, Pigeonpea
Fibre Crops	6	Diploid cotton (two species), Tetraploid cotton (two species), Jute (two species)
Oilseeds	11	Indian mustard, Karan rai, Rapeseed, Gobhi sarson, Groundnut, Soybean, Sunflower, Safflower, Castor, Sesame and Linseed
Sugar Crops	1	Sugarcane
Vegetables	17	Tomato, Brinjal, Okra, Cauliflower, Cabbage, Potato, Onion, Garlic, Ginger, Bottle gourd, Bitter gourd, Pumpkin, Cucumber, Paprika, Chili, Bell Pepper, Vegetable Amaranth, Ridge gourd, Spinach beet
Flowers & Ornamentals	17	Rose, Chrysanthemum, Bamboo Leaf Orchid, Spray Orchid, Vanda or Blue Orchid, Orchids (*Cattleya, Phalaenopsis*), Bougainvillea, Orchid (*Oncidium*), Canna, Gladiolus, Jasmine, Tuberose, China Aster, Carnation, Orchid (*Paphiopedilum), Mogra*
Spices	6	Black pepper, Small cardamom, Coriander, Fenugreek, Turmeric, Jaiphal
Fruits	23	Mango, Almond, Walnut, Cherry, Apricot, Apple, Pear, Pomegranate, Grape, Ber, Acid lime, Mandarin, Sweet orange, Banana, Muskmelon, Watermelon, Papaya, Peach, Japanese Plum, Strawberry, Beal, Jamun, Sitaphal
Medicinal and Aromatic plants	7	Isabgol, Menthol mint, Damask Rose, Periwinkle, Brahmi, Noni, Kalmegh
Plantation crops	8	Coconut, Eucalyptus (two species), Casuarinas (two species), Tea (three species)

Progress in filing applications and PVP certificates issued

Applications which have fulfilled all requirements and have been finally accepted by the Registrar for registration are granted PVP certificates. Details of applications received (Table 2) and PVP certificates granted (Table 3) are indicated hereunder.

Table 2. Institution-wise details of applications received in different categories of plant varieties for registration (IPR-entitlement)

Applications received year-wise/applicant-wise											
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Till Sept. 2016**	**Total**
Public	287	322	193	31	125	129	141	136	89	277	**1730**
Private	143	220	368	505	295	266	534	420	420	189	**3360**
Farmer	2	5	127	4	941	304	1002	1964	1957	1049	**7355**
Individual Breeder	0	0	0	0	0	0	0	0	2	0	**2**
Total	**432**	**547**	**688**	**540**	**1361**	**699**	**1677**	**2520**	**2468**	**1515**	**12447**

Table 3. Details of Registration Certificate (PVP entitlement) granted in different categories of plant varieties

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Till Sept. 2016**	**Total**
Public	-	-	149	49	95	154	154	250	64	79	**994**
Private	-	-	16	-	21	55	104	124	121	90	**531**
Farmer	-	-	3	-	-	3	46	459	200	162	**873**
Total	**0**	**0**	**168**	**49**	**116**	**212**	**304**	**833**	**385**	**331**	**2398**

The certificate of registration issued will be valid for nine years in case of trees and vines and six years in case of other crops. It may be reviewed and renewed for the remaining period on payment of renewal fees subject to the condition that total period of validity shall not exceed eighteen years in case of trees and vines from the date of registration of variety, fifteen years from the date of notification of variety under Seeds Act, 1966 and in other cases fifteen years from the date of registration of the variety.

Performance of public sector in filing applications and PVP-entitlement granted

The performance of public sector institutions in filing applications for PVP was encouraging in the beginning as a result good number of applications were received between the years 2007 to 2009. However, from the years 2010 to 2012 the filing slowed down (Table 2). Looking to the slow trend, the Authority made efforts to conduct awareness programs in the State Agricultural Universities (SAUs), ICAR research institutes and public sector seed companies viz., National Seed Corporation and State Seed Corporations. As a result again encouraging trend from the year 2013 was experienced (Table 2&4). However, in comparison to private sector (Table 5), except from filing application under extant notified variety category, the performance was not encouraging. For example in new variety category both ICAR and SAUs together filed 284 applications, whereas private seed sector submitted 1943 applications. Same trend is seen with other categories of varieties viz. VCKs and EDVs. With respect to granting PVP certificates, public institutions were granted as many as 994 certificates, in comparison to the 531 (Table 3) certificates for private sector institutions. This is mainly because public institutions under AICRP system submitted more applications in extant variety notified under

Table 4. Performance of public sector institutions in filing applications and obtaining PVP-entitlement (Applications filed/PVP Granted)

Varieties	Application received		Registration certificates granted	
	Public		Public	
	Institute/ICAR	SAU	Institute/ICAR	SAU
New	209	75	105	11
Extant Notified	918	366	637	211
Extant (VCK)	78	81	27	3
EDV	3	0	0	0
Total	**1208**	**522**	**769**	**225**

Seed Act 1966 category which does not require DUS testing, whereas other categories of varieties viz., new variety and VCK have to undergo DUS testing and EDV testing to be decided on case to case basis.

It is felt that public institutions are not commercially exploiting their varieties after getting PVP certificates, though in the Act there is a provision for licensing and cross licensing for the purpose of promoting Research and Development (R&D) on well adapted crop varieties. This may be due to lack of confidence or little knowledge on IPR issues and poor negotiation capacity. Hence, some system should be worked in the public seed industry / institutions to provide incentives for the variety developers and a portion of the royalty / benefit sharing be distributed so that the inventor takes interest to develop new varieties and apply for granting PVP certificates. To update the scientific community about the Plant IPR laws an innovative awareness campaign “Take it to the Plant Breeder the Breeders’ Rights through Awareness” was taken up this year. As a result of this capacity building to NARS scientist, a record number of applications in extant notified category were filed by the public institutions till date.

Performance of the Private sector

From the beginning of registration process, the performance of the private sector in filing applications for granting PVP was encouraging as indicated in Table 2. When the registration process commenced, the Authority received 143 applications during 2007. The trend continued in the subsequent years, filing 220 applications in the year 2008, 368 in 2009, 505 in 2010, 295 in 2011, 266 in 2012, 534 in 2013, 420 in the year 2014, 2015 and 189 till September 2016 (Table 2). Maximum number of applications (1943) were in the new variety category followed by 1162 applications in Extant VCK. There were 179 applications in the category of EDV indicating their preference to cosmetic breeding also.

Table 5. Performance of private sector seed industry in filing applications and obtaining PVP-entitlement

Varieties	Application received	Registration Certificates granted
New	1943	275
Extant Notified	76	56
Extant (VCK)	1162	199
EDV	179	1
Total	**3360**	**531**

With respect to granting PVP certificates to private seed industry, a total of 531 varieties have been registered till September 2016. Of these 275 new, 199 Extant (VCK), 56 Extant (Notified) and 1 EDV have been registered by the Authority (Table 5). The new variety or VCK category which require DUS testing either for two season or one season respectively with two locations and therefore take 1-2 years for registration while the Extant notified variety is being approved by Extant Variety Recommendation Committee (EVRC) for registration. In case of EDVs the testing will be recommended on case to case basis. The trends in filing of application by the private companies indicated that the private seed industry concentrates much of their research efforts in such crops where there is more business which are indigenous to our country and where there is consumer preference. It is expected that in the forthcoming years, we may expect more applications for registration of their varieties. The trend again indicates that the PPV&FR Act, 2001 is not only a balanced Act but also favourable to the commercial seed industry dealing with hybrids in field crops and varieties and hybrids in vegetables and ornamental crops.

Training and Awareness Programs

The Authority, since inception, took initiatives to popularize provisions of the Farmers' Rights provided in the Act to the civil societies and grass-root workers. There exists a close linkage with the farmers, researchers, plant breeders, intellectuals, scientists, students, NGOs, and public and private organizations active in this area. The Authority has been releasing funds for training, awareness and capacity building on the provisions of the PPV&FR Act, 2001 including Farmers' Rights, Breeders' Rights, and Researchers' Rights involving different stakeholders viz. ICAR Institutes, SAUs, KVKs, NGOs and other Govt. Departments for the farmers, researchers, plant breeders, intellectuals, scientists and students etc. and also for creating awareness through participation in agricultural fairs, kisan melas, kisan utsav, farmers' forum etc. In different regional languages bulletins have been prepared and distributed. Frequently Asked Questions have been prepared with answers and distributed to clear the doubts. Street Drama CDs have also been prepared and distributed. The details of training programmes organized by the Authority are presented in Fig. 3.

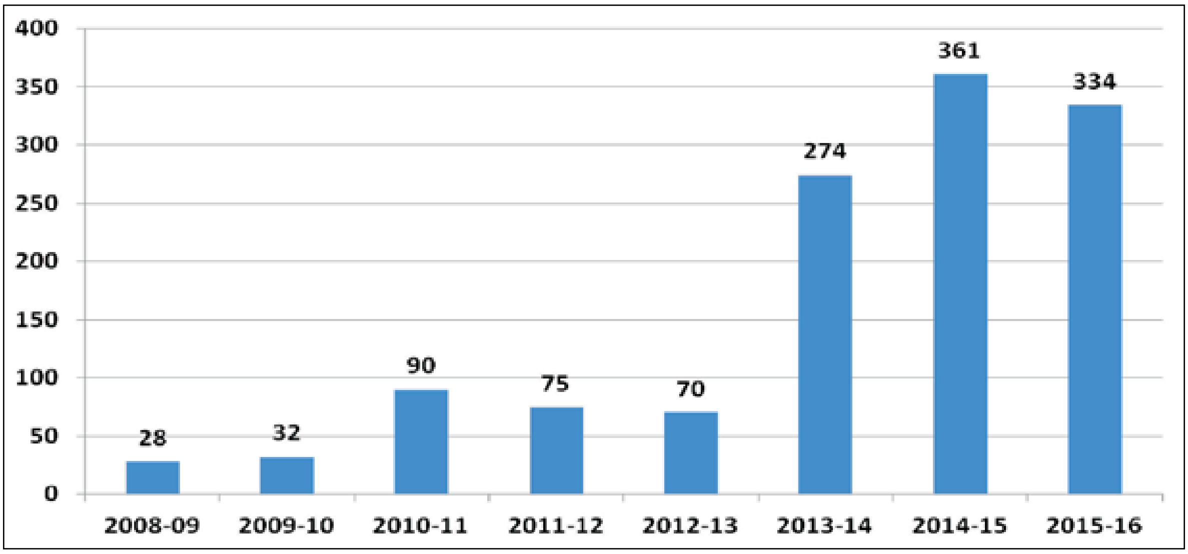


***Fig. 3.** Details of training programmes organized by the Authority*

Impact of training and awareness programs in registration of varieties and response from Plant Genome Saviour Awards

The filing of applications for registration of farmers' varieties (Fig. 4) which commenced from 2007 indicated inconsistent trend. For the first three years, it was in ascending trend with sudden increase in filing 127 applications during 2009. However, the trend in 2010 was far from optimal with only four applications being filed. On the contrary, during 2011, there was a sudden rise in the

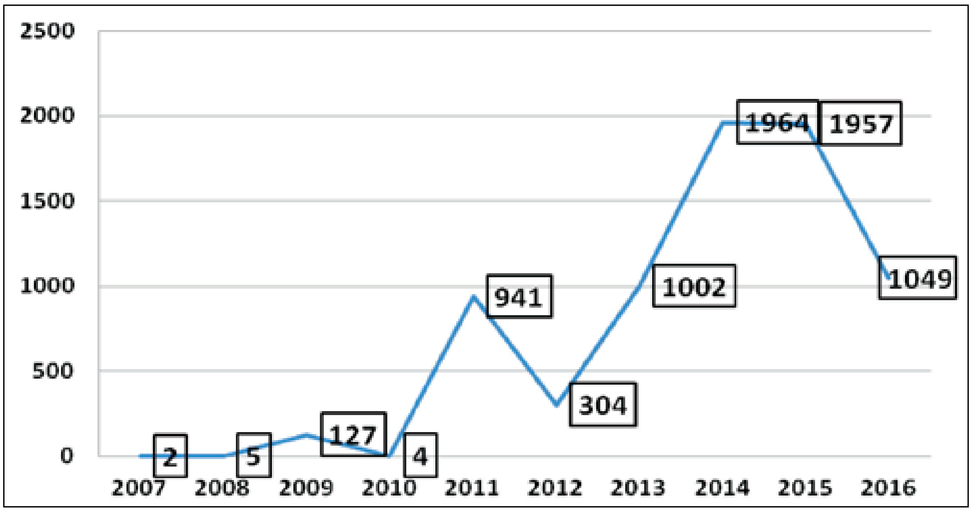


Fig. 4. *Year-wise trend of filling application of farmers' varieties for IPR*

filing of applications by 939 while in 2012, there was a sudden drop by filing only 302 applications. Further during 2013-14 the Authority launched a program **"Take it to the Farmer, The Farmers' Rights through awareness"** involving National Agricultural Research System (NARS). As a result during 2013, there was a record number of 1001 applications received and the same trend is being continued in 2014, 2015 and till September 2016 with receipt of record number of applications of 1964, 1957, and 1049 respectively. The Authority has also taken initiative in Documentation, indexing and cataloging of Farmers' varieties. The compendium of registered farmers' varieties have been published.

The awareness programmes also made good impact on the receipt of applications for genome savoiur awards also. The details of the applications received and states participated is presented in Table 6. In the beginning the response from the farmers was very poor. But as a result of awareness programmes as many as 108 farmers from 21 biodiversity rich states participated and filed applications for awards.

Notification of NARS as centres for compensation under section-41 of the Act

With the support from NARS, arrangements are being made to notify the centres under section-41 of the Act, so that any village or local community in India can file in any centre notified in the Gazette of India, the claim for compensation against registered breeder if the contribution of the community is significant in the evolution of such registered variety.

Thus, India has taken many unique initiatives to implement the provisions provided as Farmers' Rights in the Act and to conserve the PGR for sustainable use in the days to come.

Conclusion

The Protection of Plant Varieties and Farmers' Rights Act was passed by the Indian Government in 2001. After India became signatory to TRIPS agreement in 1994, a legislation was required to be formulated. Article 27.3 (b) of this agreement requires the member countries to provide the protection of plant varieties either by a patent or by an effective *sui generis* system or by a combination thereof. Thus, the member countries had the choice to frame legislations that suit their own system and India exercised this option. The *sui generis* system for Protection of Plant Varieties was developed integrating the rights of the breeders, farmers and village communities and taking care of the concerns for equitable sharing of benefits. This is the only intellectual property law in India that gives dual proprietorship of

Table 6. Details of applications received for the "Plant Genome Saviour Awards"

S. No.	Name of the award	2007-08			2008-09			2009-10			2010-11			2011-12			2012-13			2013-14			2014-15		
		Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given	Total Applications Received	States Participated	Total Awards Given
1.	Plant Genome Saviour Community Recognition Certificate	-	5	**5**	15	-	**4**				19	11	**7**												
2.	Plant Genome Saviour Community Award							20	11	**2**	19	11	**4**	27	11	**4**	28	15	**5**	26	14	**5 for Community Award Approved by the Selection committee**	14	10	**Under process**
3.	Plant Genome Saviour Farmers' Reward													30	13	**10**	80	20	**10**	78	16	**3 Applications for Reward approved by the Selection Committee**	46	10	
4.	Plant Genome Saviour Farmers' Recognition													30	13	**15**			**4**			**11 Application for Recognition approved by the Selection Committee**	46	10	

Intellectual Property on variety and its denomination. Ten years after the implementation of the Act, it is observed that the Act facilitated the enhanced private investment in selected crops and seed supply system, while strengthening the public research and conserving the plant genetic resources for sustainable use and registering the farmers' varieties to achieve balanced agricultural growth and access of technology to farmers at a competitive cost.

Australian Centre for International Agricultural Research

Andrew Campbell

Chief Executive Officer, Australian Centre for International Agricultural Research, Caneberra Act 2601, Australia

ACIAR is the Australian Government's specialist agricultural research-for-development agency. Funded through the Australian Aid Program, ACIAR does not undertake research itself, but identifies opportunities and brokers partnerships to undertake international agricultural research and capacity building, the results of which contribute significantly to the aid program and achievement of its goals.

ACIAR's research portfolio covers crops, livestock and fisheries, natural resources and forestry, and socioeconomics and policy. Under these areas, the Centre funds and manages research partnerships through projects and programs designed to generate new technologies, new approaches and new knowledge, leading to innovation at the farm level and along the value chain, greater capabilities in research and production, and better informed agricultural policy in partner countries. Projects are designed so that new knowledge and innovation also feeds into Australian agricultural systems where appropriate.

Genetic Resources

Agrobiodiversity supports the sustainable intensification and diversification of farming systems. Breeding improved varieties also critically depends on agrobiodiversity and the use of diversified genetic resources. As a result, ACIAR projects have explicit or implicit research activities concerning the study, use, conservation and exchange of genetic resources.

Continuous genetic gain delivered as improved varieties depends on the free exchange of genetic resources. Although each country owns the genetic resources on its territory, no country is autonomous for genetic resources. For most food crops, there is no gain for any country in restricting the flow of genetic resources, and no loss in allowing their flow.

Countries can facilitate the circulation of their genetic resources, under the provisions of the International Treaty on Plant Genetic Resources for Food and Agriculture, and thus avoid restrictive practices and unjustified delays.

The conservation of Plant Genetic Resources (PGR) is supported by ACIAR through the following global activities:

- Annual support to the 15 CGIAR centres
- Annual support to the World Vegetable Center for the gene bank (conservation) and the dissemination (use) of genetic resources
- Annual support to CABI (Centre for Agriculture and Biosciences International)
- Core funding to the Global Crop Diversity Trust through the CGIAR Fund for PGR conservation, informatics, and global policy work. The Australian Department of Foreign Affairs and Trade (DFAT)

and the Australian grain growers-owned Grains Research and Development Corporation (GRDC) have also been contributing direct to the Endowment Fund of the Global Crop Diversity Trust

ACIAR also supports specific projects supporting, or drawing on, agrobiodiversity in various areas of agricultural research

Nutrition and Health

An increasing focus during recent years has been on the interface between agriculture (including animal source foods) and human health and nutrition.

One of our largest investments in eastern and southern Africa aims at improving income and nutrition by enhancing vegetable-based farming and food systems in peri-urban corridors (VINESA).

In Kenya ACIAR supported research on indigenous leafy greens has been incorporated into school feeding programs. This work belongs to a large set of projects primarily funded by the Global Environment Facility (World Bank).

Other research is exploring the use of insect biodiversity for fish and poultry feed thus freeing-up soybean and fish meal for human consumption. We are also supporting the testing of common varieties of beans for their suitability for pre-cooked processing, thereby trebling the consumption of nutritious beans in the diets of low income families. These projects are co-funded by the Canadian International Development Research Centre (IDRC) under our joint CultiAf initiative.

Climate Change

Around 70% of ACIAR's portfolio is directly relevant to the global imperative to reduce greenhouse gas emissions and develop better climate change adaptation strategies and practices. To date, our projects have focused largely on adaptation in four categories:

- Research that helps strengthen the climate-vulnerable parts of rural livelihood systems (such as new salinity-tolerant rice varieties and better crop water management);
- Research that makes the climate-resilient components of rural livelihood systems more profitable (for example developing market opportunities for cassava);
- Research on more climate-resilient agricultural systems
- Research that focuses on climate change issues and increasing variability in weather patterns.

Climate change research funded by ACIAR assesses farmer responses to climate change – adjustment policy options and the policy options necessary to manage the on-farm impacts of increased variability. Improving the management of trade-offs between commodities, inputs, income and risk, and between food supply and reliability,can lead to better profitability, improved livelihoods, and reduced market and climate risk. Our research is also evaluating the benefits of climate related insurance or improved market access.

The ACIAR forestry program has played a strong role in developing forestry in agrobiodiversity, while leveraging gains for the environment, livelihoods and gender and youth equality. It aims to reduce deforestation and forest degradation, improve the management of fires, increase carbon sequestration, change forage species to adapt to climate variability and change, and increase the resilience of trees and forest systems.

Forestry projects have worked to increase the biosecurity, profitability (matching products to markets) and productivity of plantations. Projects funded by ACIAR support enhanced availability of improved tree germplasm to develop timber and non-timber forest products. For example in Laos, an innovative teak agroforestry system being developed is much better suited to farmer needs than current practices and more likely to yield high returns than the current approach.

In Vanuatu, ACIAR is assisting in the development of a sandalwood industry. Selected plantings have been used to establish clonal seed orchards, where plantings successfully distributed via community nurseries are having a significant impact on the capacity of island communities to break into this potentially lucrative rural industry.

Farming systems and their intensification:

Intensifying farming systems can benefit from increasing the system's diversity. Agrobiodiversity plays a key role in this context by offering a choice of diverse crops, and for any crops, offering options of diverse varieties. In the context of climate variability, possibly increasing due to climate change, agrobiodiversity reduces farmers' risk and provides possible climate smart solutions. Adaptation to climate variability can involve the use of broadly adapted varieties, a strategy successfully applied by wheat breeders for the past five decades.

Alternatively, targeted traits can be deployed in specific crops, or for a given crop in specific varieties, to try to cope with the changing climate. Potential traits include: tolerance to short period of flooding (for example submergence tolerant rice), ability to survive periods of elevated temperature (for example tolerance to high temperature at germination, allowing early sowing of wheat in South Asian rice – wheat systems), stay green (reducing transpiration in high vapour pressure deficit periods, to preserve soil water for grain filling), suitability for no-till conservation farming methods (for example longer coleoptiles), and tolerance to salinity.

Genetic variation for productivity in elevated CO_2 is an emerging area of investigation, which could result in the identification of new genetic resources for breeding crops adapted to high CO_2 in the future. Attempting to develop sustainable and adoptable innovations, most ....

In the Eastern Gangetic Plain of Bangladesh, India and Nepal, ACIAR projects integrate research activities on genetic (G), environment (E) and crop management (M) including designing, testing and disseminating farming systems innovations, relying on conservation agriculture, efficient use of irrigation water and diversification of crops.

In Bangladesh, India and Pakistan, various ACIAR projects try to reduce constraints to legume production. One project showed that green pea variety BARI Motorshuti3 was suitable for rabi season vegetable production in Bangladesh, between transplanted aman and irrigated boro rice crops, effectively using a fallow in rice – rice systems. In the coastal zone of Bangladesh, new opportunities for legume and wheat production in both salty and non-salty areas are being explored.

The International Mungbean Improvement Network is characterising the mungbean core collection from the World Vegetable Center in multilocation trials over Bangladesh, India, Myanmar and Australia, providing new genetic resources for breeding improved varieties for these environments. New work just starting in Pakistan will identify adoptable genetic and agronomic innovations allowing farmers to grow more chickpea, lentil and groundnut.

Increasing the diversity of farming systems, and the range of species used by farming families can improve their food security and their nutritional status and reduce their risks. However, once the expansion of markets and the widespread availability of basic food reduces the food security risk, the separate goal of raising smallholder farmers' income to lift them out of poverty can justify specialisation into a small number of high value crops rather than diversification. In this context, it is not necessarily at the farm scale but at the landscape, regional or global scale that agrobiodiversity becomes important.

Striking the right balance between the scales at which agrobiodiversity must be protected remains an important research topic.

Biosecurity factors are the main barriers for smallholders seeking to grow produce for markets. Product quality, postharvest handling and storage, and commercial imperatives have direct implications for market entry, and are the main barriers to smallholders supplying markets. Similar factors play a role in the development of export value chains, particularly disease issues.

ACIAR has long been interested in *Rhizobium* science and inoculation as a means of facilitating nodulation and nitrogen-fixation of legumes. Using legumes rather than mineral fertiliser to supply nitrogen to agricultural production systems is low-cost, environmentally benign and can provide high returns to farmers and the community.

We have funded numerous research and development projects on the *Rhizobium* species as inoculants, mineral nutrition of rhizobia and the legume host, and legume nitrogen-fixation in farming systems. Working with rhizobia has been an area of very rapid technological development.

Increased research on food legume production, especially in rice based multicropping systems for rain-fed areas, multistorey cropping in coconut plantations and crop diversification on sugar plantations is also in train.

The majority of the fast-growing tree legumes considered most useful for reforestation establish a symbiotic association with *Rhizobium* spp. to form root nodules, which fix atmospheric nitrogen (N) and thus contribute to the legumes' ability to grow well in low-fertility soils. Most are exotic species; some require specific *Rhizobium* strains if they are to nodulate well, but very little is known of the distribution of these bacteria in tropical soils.

In the Philippines, priority targets include reforestation of some 5 million hectares of unproductive grassland to improve the supply of fuelwood and timber, and to control erosion, particularly around large dams.

The challenges for research are two-fold: increasing productivity on-farm through a focus on quality through integrated crop management, disease and pest control and postharvest storage and management; and beyond the farm focusing on biosecurity, export development and commercialisation of new products.

Our animal health projects focus on diseases of regional significance including major transboundary diseases, zoonotic diseases and food safety. They aim to limit disease, and diseases affecting trade and market access. The outcomes include reduced costs of disease control, improved animal productivity, improved product quality, and improved market access.

The Australian Centre for International Agricultural Research will continue to develop and promote the adoption of technologies to improve the resilience of food production in the face of climate change, invasive species and diseases. We value our partnerships in this region, and we wish you well with this important conference.s

Plant Genetic Resources: Unlocking diversity to realize the UN Sustainable Development Goals

David Bergvinson

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana - 502324, India

Global agri-food systems are the foundation of human nutrition and health. Feeding a global population of over 9.3 billion by 2050 against a backdrop of climate change, reduced natural resource base and changing diets represents a tremendous challenge. Countries have responded to the challenge and have committed to achieving the UN Sustainable Development Goals. Crop adaptation to climate change needs to be addressed with urgency as it is likely there will be substantial reduction in yields of several staple crops with serious implications for food security. These losses are due to both abiotic (drought, flooding, heat, soil degradation) and biotic (pests, diseases, weeds) stresses. Plant diseases and pests are highly influenced by climate. Many pathogens and disease vectors are limited by climatic factors such as low temperatures. Higher temperatures will not only make some of the pathogens and vectors affect regions where they were ineffective, but higher temperature will also shorten the life cycle in many pathogens, enabling them evolve more rapidly. Further higher temperatures will enhance risk of toxin contamination such as aflatoxin in several food crops. Plant genetic resources will be vital in adapting crop production to the effects of climate change. Conservation and utilization of biodiversity will be key towards achieving the UN Sustainable Development Goals, especially zero hunger, no poverty and good health and well-being.

Plant genetic resources conservation

Plant Genetic Resources (PGR) created through natural and human selection over millennia are the raw material for breeding new plant varieties. PGR, once considered unlimited, is now seen as finite, vulnerable and fast eroding as modern varieties are replacing traditional cultivars and natural habitats are being destroyed due to industrialization, urbanization, floods, forest fires and over grazing. Therefore, PGR must be conserved, both to combat new pests and diseases that emerge from time to time and to produce high yielding cultivars having a broad genetic base and better-adapted to changing climatic and environmental conditions to meet the food and nutrition needs of the rapidly growing global population.

PGR conservation at ICRISAT

Genebank at Patancheru, India

Globally, about 7.4 million accessions are conserved in about 1800 genebanks across the world. The long-term objective of the ICRISAT genebank at Patancheru, India, is to serve as a world repository for the germplasm of its six mandate crops: sorghum, pearl millet, chickpea, pigeonpea, groundnut, finger millet; and five small millets: foxtail millet, little millet, kodo millet, proso millet and barnyard millet. With over 124,000 germplasm accessions, including wild relatives, assembled from 144 countries through donations and collection missions, it is one of the largest international genebanks. The genebank has introduced 90,928 samples from 317 organizations located in 78 countries and launched 216 germplasm collecting missions in 62 countries to collect more than 33,300 samples of six mandate crops and five small millets. The collection has been placed in-trust with the FAO of the United Nations and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) for use by the global community as international public goods. Majority of the collection is seed producing and essentially orthodox in nature. The active collection stored at 4°C and 30% RH is the basic source for distribution and utilization. The base collection is maintained at -20°C in vacuum packed aluminum foil pouches at 3-7% seed moisture content. This ensures long-term viability of the material (more than 50 years) and serves as a backup for the active collection.

Regional genebanks of ICRISAT

ICRISAT established three regional genebanks at Nairobi, Kenya; Bulawayo, Zimbabwe and Niamey, Niger to conserve germplasm of regional importance, working collections and core and mini core collections to meet the demand for mandate crop germplasm from African countries. Together the three regional genebanks conserve 34,021 accessions of mandate crops. These genebanks are responsible for assembling/collecting, characterizing/evaluating and distributing germplasm to national partners in those regions.

Safety of collections

ICRISAT genebank has deposited FAO-designated germplasm (over 110,000 accessions) at Svalbard Global Seed Vault, Norway, as a backup. The Seed Vault provides an insurance against the loss of seeds in genebanks, in the case of large-scale regional or global crisis.

Gaps in collections

Though the collections at ICRISAT genebank are large, they are not complete. My colleague Dr Hari Upadhyaya made a critical assessment of collections at ICRISAT genebank and several potential gaps in collections of different crops were revealed. For example, in the sorghum collection the geographic gaps were identified from: south Asia - 110 districts in India, 13 districts in Pakistan, three districts in Bangladesh and five districts in Sri Lanka. *Sorghum bicolor* subsp. *verticilliflorum*, *S. halepense* and *S. propinquum* were identified as taxonomic gaps in the collection (Upadhyaya et al 2016a; PGR doi:10.1017/S147926211600023X).

Similarly, in the pearl millet collection the major geographical gaps were identified from: Bihar, Chhattisgarh, Rajasthan, Madhya Pradesh, Maharashtra, and Rajasthan in India and Central Punjab in Pakistan (Upadhyaya et al 2010, PGR 8(3):267-276); 34 districts in four East African countries and 76 districts in seven southern African countries; (Upadhyaya et al 2012, PGR 10:202-213) and 62 districts Nigeria, 50 districts in Burkina Faso, 9 districts each in Mali and Mauritania, 8 districts in Chad and 7 districts in Ghana. (Upadhyaya et al 2009, PGR 8:45-51). In the collection of pearl millet progenitor (*Pennisetum monodii),* 354 districts belonging to eight countries in the primary center of diversity for pearl millet were identified as geographical gaps (Upadhyaya et al 2014, PGR 12:226-235).

In pigeonpea, 84 districts located in four east African countries and 54 districts located in three southern African countries were identified as geographical gaps. A total of 25 districts in four countries; six provinces in Tanzania and Zambezia province in Mozambique were identified as trait-diversity gaps (Upadhyaya et al 2015, Indian J. PGR 28:180-188). A total of 118 provinces covering 790 districts in Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Papua New Guinea, Philippines, Thailand and Vietnam were identified as gaps in the *Cajanus scarabaeoides* collection at ICRISAT genebank (Upadhyaya et al 2011d, PGR 11(1):3-14).

Currently ICRISAT is filling the identified gaps through targeted collecting of germplasm in collaboration with national agricultural research system partners.

Maintaining the collections

ICRISAT genebank ensures continued availability of good quality seeds for use in research and development programs globally. Maintaining seed viability and quantity of germplasm in genebank as per international standards is a critical activity. Viability of seeds conserved as active collection are tested every eight years and those conserved as base collection are tested every 10 years. Accessions are regenerated when seed viability and/or seed quantity become critical (<85% viability and <1/4 of total quantity). Genetic integrity of accessions, particularly in cross pollinating crops is maintained during regeneration by using the most efficient and economical pollination control methods. Wild relatives, which produce a few or no seeds are maintained as live plants in botanical gardens or in glass houses.

Characterization and evaluation

To assess diversity in the collections, identify useful/new genotypes, and to add value to the collections, assembled germplasm was characterized and evaluated. Nearly 95 per cent of the collections at ICRISAT genebank have been characterized for a range of selected morpho-agronomic descriptors depending upon the crop, including abiotic and biotic stress tolerance/resistance and nutritional traits. About 11,500 accessions of mandate crops and foxtail millet have been genotyped using SSR markers.

Diversity in collections

Wide variation was observed in the collections for different morpho-agronomic and nutritional traits and stress resistance. Regional, elevation and latitudinal patterns of diversity was assessed to identify trait-specific germplasm for adaptation. Phenotypic diversity was assessed by estimating different statistical parameters while genotypic diversity was assessed using molecular markers.

Wealth from the wild

The ICRISAT genebank conserves 2876 accessions of wild relatives of mandate crops and small millets represented by 78 species originating from 82 countries. Wild and weedy relatives of crop species are reservoirs of useful genes. Wild species harbor genes for higher level of resistance to stresses, superiority for agronomic and seed quality traits. Few examples include: *Sorghum nitidum*, *S. purpureosericeum*, *S. australiense, S. intrans* are resistant to downy mildew, shoot fly and stem borer. *Pennisetum glaucum* subsp. *monodii* is a source for new cytoplasmic-nuclear male sterility and *P. pedicellatum and P. polystachion* are resistant to downy mildew, rust and leafspot and produce more tillers. In chickpea, wild relatives of *Cicer* were used to improve agronomic traits and drought tolerance. In pigeonpea, *Cajanus acutifolius* a secondary genepool used for early flowering and pod borer resistance and *C. platycarpus* a tertiary genepool for early flowering, phytophthora blight, Fusarium wilt, sterility mosaic, pod borer, bruchid and podfly resistance. In groundnut, *Arachis duranensis, A. pusilla* and *A. villosa* were identified with desirable traits and 20 accessions identified with superior multiple traits. Fig 2 depicts use of wild relatives in pre-breeding.

To broaden crop cultigen genepool, synthetics combining resistance to late leaf spot (LLS) developed and recycled to capture agronomically beneficial traits in groundnut. My colleague Dr Hari Upadhyaya has identified cryptic variation for exceptional large seed size (139 g per 100 seeds) and high pod yields in introgressed breeding lines involving a synthetic (TxAG 6). Similarly, large number of interspecific derivatives were developed using *A. cardnasii*, *A. batizocoi* and *A. diogoi* in groundnut for resistance to rust, late leaf spot, foliar diseases, root-knot nematode, corn earthworm, potato leaf hopper and southern corn rootworm.

Access to collections

To ensure unrestricted access for the world community, ICRISAT has placed its germplasm collections under the auspices of the Food and Agricultural Organization of the United Nations (FAO) in 1994. As per its agreement with the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), ICRISAT supplies germplasm freely to the global research community using the Standard Material Transfer Agreement (SMTA).

Information and Knowledge sharing

Documentation of genetic resources is essential for proper conservation, management and utilization of genetic resources. Information is being maintained under four categories: (i) passport, (ii) characterization and evaluation, (iii) conservation and (iv) distribution. Passport and characterization data can be accessed through: www.icrisat.org

ICRISAT genebank has been an active participant in regional and global networks for conservation and utilization of collections. During the past 30 years, scientists at the ICRISAT genebank have published numerous germplasm-related research papers in international journals, book chapters, catalogues, information bulletins, posters etc. to facilitate selection of germplasm and sharing of information to popularize the conservation and utilization of agricultural biodiversity.

Capacity building

Many developing countries lack trained staff for proper management of genetic resources. Therefore, ICRISAT genebank aims at capacity building of national agriculture research system staff for cost-effective and efficient conservation of PGR. ICRISAT genebank has imparted training to more than 40 scientists, including interns (12), research scholars (12), research fellows (12), visiting fellows (2), in-service short-term candidates (2) from national and international genebanks, partners and universities in 11 countries.

Partnerships for PGR conservation and utilization

ICRISAT works with many national and international agricultural institutes, universities and NGOs in different countries for introduction, collection, evaluation, documentation and utilization of germplasm. Data from different sources were compiled in the form of catalogues, information bulletins and journal articles. In partnership with Generation Challenge Program (GCP), developed composite collections (452-3,365 accessions) and reference sets of 200-400 genetically diverse accessions have been established to discern the genetic structure of accessions.

Utilization of germplasm

Limitations of germplasm utilization

Large gap exists between availability and actual use of the genetic resources. Very few germplasm lines (less than 1%) have been used by plant breeders in different breeding programs. For example, the chickpea breeders in ICRISAT used only 83 germplasm lines (about 0.5% of entire collection) during the period from 1978 to 2004 for the development of 3430 advanced varieties (Upadhyaya et al 2006, PGR 4(1):13-19). A similar situation was noted at ICARDA in chickpea and groundnut at ICRISAT.

Enhancing germplasm utilization

One of the main reasons for the low use of germplasm includes large size of collections and lack of reliable data on traits of economic importance which show large genotype x environment interactions and require replicated multilocational evaluation to identify useful parents. ICRISAT genebank scientists have been active in developing strategies to enhance use of germplasm in crop improvement globally.

Mini core collections

To overcome size related issues in enhancing use of germplasm Frankel (1984) suggested developing representative core collection (10% of entire collection). The ICRISAT genebank scientists developed core collection of our mandate crops and five small millets. However, they soon realized that in crops where entire collection consists of several thousands of accessions (over 20,000 in chickpea, over 39,000 in sorghum), a core collection would still be too large for multilocation replicated evaluations. To overcome this, Upadhyaya and Ortiz (2001, TAG 102: 1292-1298) postulated the mini core collection concept where 10% of the core or 1% of entire collection is selected to represent species diversity (Fig. 1). ICRISAT developed mini core collection of six mandate crops consisting of 35 to 242 accessions (Table 1).

Table 1. Mini core collections of ICRISAT six mandate crops and foxtail millet

Crop	Entire collection	Mini core number	Reference
Chickpea	16,991	211	Upadhyaya and Ortiz 2001, TAG 102: 1292-1298
Groundnut	14,310	184	Upadhyaya et al. 2002, Crop Sci. 42: 2150-2156
Pigeonpea	12,153	146	Upadhyaya et al. 2006, Crop Sci. 46: 2127-2132
Sorghum	22,473	242	Upadhyaya et al. 2009, Crop Sci. 49: 1769-1780
Pearl millet	20,844	238	Upadhyaya et al. 2011, Crop Sci. 51: 217-223
Finger millet	5,940	80	Upadhyaya et al. 2010, Crop Sci. 50: 1924-1931
Foxtail millet	1,474	35	Upadhyaya et al. 2011, Field Crops Res. 124: 459-467

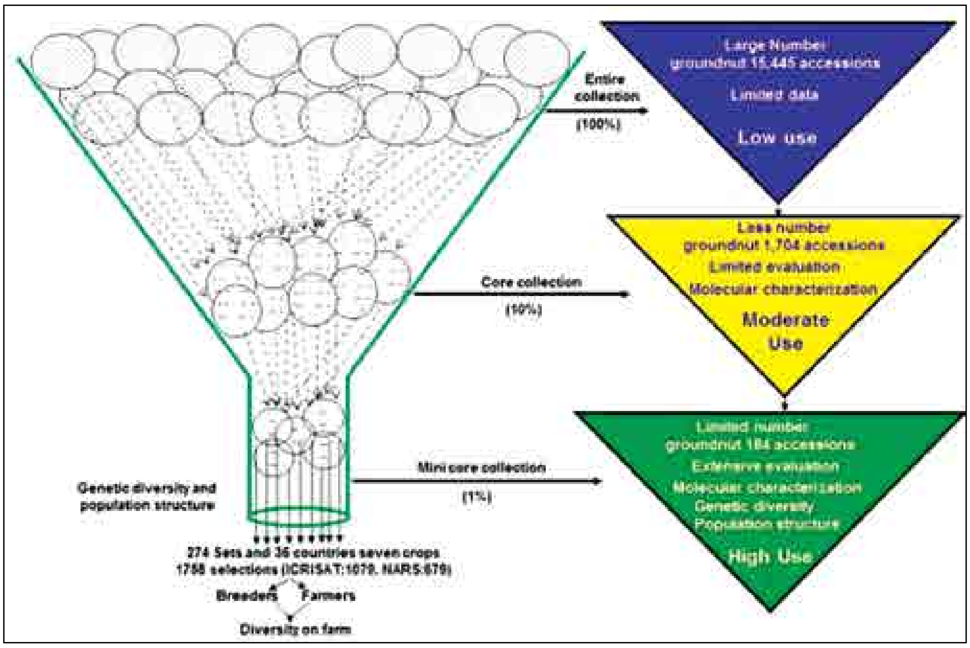


Fig. 1. *Developing mini core collections*

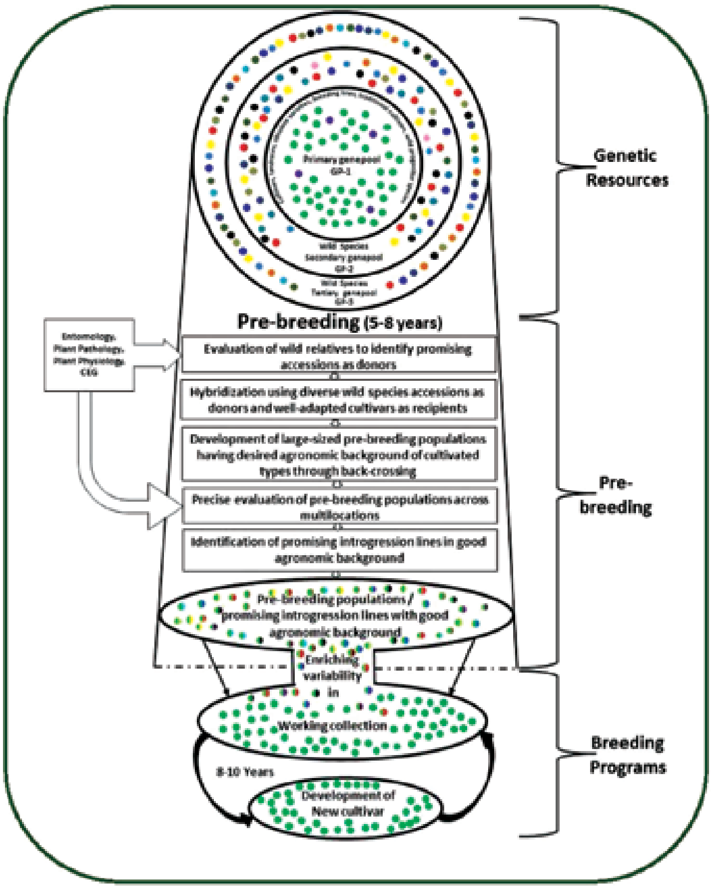


Fig. 2. *Pre-breeding flowchart*

Mini core as a source of variation and an entry point to global collection

Mini core collections provide an easy access to the wider spectrum of germplasm collections for discovering useful variation for use in crop improvement. ICRISAT and national partners have extensively evaluated the mini core collections for agronomic and nutritional traits and resistance/ tolerance to abiotic and biotic stresses and reported a number of germplasm accessions with beneficial traits. The genetically diverse germplasm with multiple resistant traits offer breeders the opportunity to combine multiple resistances into an agronomically improved genetic background for cultivar development and genetic mapping populations for trait mapping. Since mini core collections have been genotyped using SSR and SNP markers, the needs of breeders are met by the mini core collection in ICRISAT mandate crops.

Genetically diverse multiple trait specific germplasm with agronomically desirable traits have been identified in ICRISAT mandate crops, which can be used by the breeders to develop high yielding climate change resilient cultivars with a broad genetic base. To illustrate a few examples identification of sources resistant to important biotic and abiotic stresses and nutritional traits of different crops are given below.

Chickpea: Chickpea mini core c was evaluated for agronomic traits during the period 2000 and 2001 to 2003 and 2004 in post-rainy seasons under irrigated and non-irrigated conditions. The promising sources identified include traits for: abiotic stress tolerance (transpiration efficiency, terminal drought, partitioning coefficient, carbon isotopes discrimination, herbicide tolerance, and heat tolerance); biotic stress tolerance (fusarium wilt, ascochyta blight, botrytis gray mold, dry root rot, legume pod borer) (Upadhyaya et al 2013, Crop Sci. 53: 2506-2517) besides micronutrient dense traits (protein, Fe and Zn).

Groundnut: Mini core consisting of 184 accessions was evaluated for agronomic traits in multi-environment trials at Patancheru, India. The promising sources identified include traits for: abiotic stress tolerance (drought, heat, salinity, herbicides, low temperature and phosphorus deficiency (28 accessions); biotic stress tolerance (leaf spots, rust, *Aspergillus flavus,* bud necrosis disease and bacterial wilt covering 30 accessions); nutritional quality traits (oil (%), protein (%), Oleic/Linoleic ratio and Fe and Zn covering 16 accessions); agronomic traits (18 accessions) and multiple traits that cover biotic, abiotic, agronomic and nutritional traits (9 accessions) (Upadhyaya et al 2014, Crop Sci. 54: 679-693).

Pigeonpea: The pigeonpea mini core collection consists of 146 accessions selected from 1290 core collection accessions. The promising sources identified includes: trait-specific germplasm (19 accessions), multi-trait-specific germplasm for water-logging tolerance; biotic stresses - Fusarium wilt, Sterility mosaic disease; agronomic traits; nutritional traits - protein, Fe and Zn (53 accessions); multiple resistances in superior agronomic background (6 accessions) and vegetable type (51 accessions).

Sorghum: The sorghum mini core collection (242 accessions) (Upadhyaya et al 2009, Crop Sci. 49: 1769-1780) has been evaluated and promising germplasm identified include traits for: resistance to salinity, stay green and transpiration efficiency; anthracnose, leaf blight, rust, grain mold and downy mildew; bioenergy efficient and superior agronomic traits (15 accessions) and nutritional and agronomic traits (61 accessions) (Sharma et al. 2010, Plant Dis. 94: 439-444; 2012, Plant Dis 96:1629-1633; Upadhyaya et al. 2014b, Crop Sci. 54: 2120-2130; Upadhyaya et al. 2016b, Crop Sci. 56: 374-384).

Pearl millet: The pearl millet mini core collection consists of 238 accessions selected from 2,094 core collection accessions representing 46 countries. Promising germplasm identified for traist such as: resistance to salinity, high temperature and transpiration efficiency; blast and downy mildew resistant and nutritional quality traits - Fe and Zn (10 accessions)

Finger millet: The mini core (80 accessions) was selected from 622 core collection accessions. This mini-core collection is an ideal pool of diverse germplasm for identifying new sources of variation and enhancing the genetic potential of finger millet. Promising germplasm identified include traits for: resistance to salinity and drought; leaf blast, neck blast and finger blast; nutritional quality traits - Fe, Zn, Ca and protein (24 accessions) (Babu et al. 2013, Eur. J. Plant Pathol. 135: 299-311; Krishnamurthy et al. 2014a, Plant Sci. 227: 51-59; Krishnamurthy et al. 2016, Crop Sci. 56: 1-13; Upadhyaya et al. 2011a, Field Crop Res. 121: 42-52)

Foxtail millet: The evaluation of foxtail millet core (155 accessions)/ mini core resulted in identification of promising germplasm identified for: resistance to neck blast, leaf blast, head blast and sheath blast; multiple nutritional quality traits - protein, Fe, Zn and Ca (26 accessions) (Sharma et al. 2014, Plant Dis. 98: 519-524; Krishnamurthy et al. 2014b, Crop Pasture Sci. 65: 353-361; Upadhyaya et al. 2011b, Field Crop Res. 124: 459-467)

Exploiting novel allelic variation in breeding programs

Sources identified from mini core have provided novel alleles of variation to develop breeding lines with exceptionally high trait values. For example using high oil containing sources identified in groundnut mini core collection (Upadhyaya et al 2012. Crop Science 52: 168-178), my colleague Dr Hari Upadhyaya developed breeding lines with exceptionally high oil (up to 63%) breeding lines.

Mini core as an entry point to global diversity

Mini core collections serve as an entry point to the entire collection through evaluation of genotypes from the selected clusters from which desirable sources for specific trait(s) have been identified (Fig. 1).

Mini core collection as an association mapping panel

Due to its reduced size and representativeness of species diversity, mini core collections can be evaluated extensively for various traits and used in association mapping. Sorghum mini core (Upadhyaya et al 2009, Crop Sci. 49: 1769-1780) have been used in association mapping to identify marker-trait associations for various traits; plant height and maturity (Wang et al. 2012, Mol. Bree. 30: 281-292; Upadhyaya et al. 2012, Genome 55: 471-479; Upadhyaya et al. 2013, TAG 126: 2003-2015), kernel weight and tiller number (Upadhyaya et al. 2012, Euphytica 187: 401-410), anthracnose resistance (Upadhyaya et al. 2013,TAG 126: 1649-1657), leaf rust and grain mold resistance (Upadhyaya et al. 2013, Mol. Breed. 32: 451-462), germinability and seedling vigor under low temperature (Upadhyaya et al. 2016, Genome 59: 137-145).

Impacts of utilizing mini core collections

- Mini core collections developed at ICRISAT genebank are now international public goods and serve as a gateway to access the genetic diversity by the global research community.
- Due to its reduced size and representativeness of species diversity, the mini core collections are ideal genetic resources for an in-depth characterization and evaluation to identify useful germplasm in crop improvement. So far, the genebank has provided 274 sets of mini core collections of different crops to scientists in 36 countries and 114 sets to scientists at ICRISAT.
- Evaluation of mini core collections have resulted in identification of desirable parents for resistance to biotic and abiotic stresses and for agronomic and nutritional traits for use by the breeders.
- There has been greater use of germplasm in breeding programs at ICRISAT in chickpea and groundnut due to mini core collection.
- Mini core collection has been used as association mapping panel in sorghum, chickpea and groundnut to determine marker-trait association.
- Multi-location evaluation of core/mini core collections of finger millet and foxtail millet as part of a GIZ-funded project resulted in identification of several stress resistant sources in India, Kenya and Uganda. Subsequently, the genebank has distributed four sets of finger millet and six sets of foxtail millet core and mini core collections for research use in ICRISAT and 42 sets of finger millet and 29 sets of foxtail millet to researchers in 14 countries for evaluation/screening.

Impacts and benefits of germplasm conservation at ICRISAT

- The ICRISAT genebank is an important source of diversity of its mandate crops and small millet benefiting researchers in both public and private sectors throughout the world. It has distributed more than 1.44 million samples of germplasm representing nearly 101,700 accessions to partners in 148 countries and over 92,800 accessions within ICRISAT.
- The ICRISAT collection provides an insurance against genetic erosion globally.
- ICRISAT genebank has restored over 55,000 accessions to nine national programs in Asia and Africa including 44,723 to the National Gene Bank, India, when national genebanks have lost their native collections due to natural calamities and civil unrest.
- The ICRISAT genebank has promoted testing and release of its germplasm directly as superior varieties. So far, 109 accessions have been released as 146 cultivars contributing to food security in 51 countries.
- Thousands of germplasm samples supplied from ICRISAT genebank were used as raw materials in crop improvement programs and academic studies globally.

- National partners have released more than 835 varieties in 79 countries utilizing germplasm and breeding lines from ICRISAT contributing to global food security.

The way forward

With the application of precision phenotyping, geospatial analysis of characterized accessions and resequencing of mini core and eventually core accessions, we are now well positioned to accelerate the targeted utilization of the rich genetic diversity which genebanks around the globe hold in trust to increase food and nutritional security now and for future generations. It is incumbent on all stakeholders to create awareness, appreciation and utilization of genetic resources. Key to success will be the free exchange and sharing of knowledge related to these precious resources so that as a global village we can provide safe and nutritious food to all while living within the ecological boundaries of the planet.

The examples of utilizing genetic resources at ICRISAT is replicated across all CGIAR research centers and national gene banks. The First International Congress on Agrobiodiversity is an important step towards building a global coalition to ensure we preserve, utilize and value the rich biodiversity we have inherited from farmers of the past. The agenda ahead is urgent if we are to realize the Sustainable Development Goals but together we can realize these ambitious targets by providing the support and enabling environment for germplasm and knowledge exchange to unlock agrobiodiversity to serve society and preserve our environment for future generations.

Major Activities of ICARDA on Promoting the Conservation and Sustainable Use of Dryland Agrobiodiversity

Mahmoud Solh

Director General, International Centre for Agricultural Research in Dry Areas, Beirut, Lebanon 1108-2010

Importance of dryland agrobiodiversity

Plant genetic resources are key to sustaining agricultural development and food security. They are the building blocks to ensure continuous genetic gains in breeding programs and can be used directly to restore or rehabilitate degraded farming systems. In addition, agrobiodiversity continues to sustain the livelihoods of farming and herding communities living under harsh conditions. Dryland agrobiodiversity in particular is important to adapt to the adverse effects of climate change and its conservation will require applying complementary *ex situ* and *in situ*/on-farm conservation approaches.

The International Center for Agricultural Research in the Dry Areas (ICARDA) plays a crucial role in promoting the conservation and sustainable use of dryland agrobiodiversity. Its mandate region cover four Vavilovian centers of diversity (Mediterranean, Abyssinian, West Asia and Central Asia) where crops and forages of global importance have originated including wheat, barley, chickpea, lentil, faba bean, grass pea, and several forage species (*Medicago*, *Trifolium*, *Vicia*).

Genebank activities at ICARDA

ICARDA genetic resources unit was established in 1985 with major activities including: 1) enriching the collections with novel diversity based on gap analysis and targeting adaptive traits, 2) efficient *ex situ* conservation applying best practices and international genebank standards for regeneration, characterization, storage, safety duplication and documentation of plant and rhizobium genetic resources, 3) distribution upon request of genetic resources, 4) promoting *in situ*/on-farm conservation and sustainable use of dryland agrobiodiversity, 5) contribution to the evaluation of genetic resources for sought traits and their use in pre-breeding, 6) training and technical backstopping to national genebanks, and 7) enhancing networking and contribution to building a global system for conservation and sustainable use of agrobiodiversity.

Major Achievements

- More than 245 collecting missions were organized by ICARDA in collaboration with partners, most of which are targeting the major centers of diversity. In recent years, collecting is mainly based on filling the gaps in existing collections and targeting adaptive traits.
- ICARDA genebank holds in-trust a total of 154,253 accessions with unique important collections of landraces and wild relatives of wheat, barley, lentil, faba bean, chickpea and *Lathyrus* and forage species (*Medicago*, *Trifolium* and *Vicia*). More than 98% are safety duplicated and around 116,000 were already sent to Svalbard Seed Vault for long-term conservation.

- More than 85% of the accessions are georeferenced and more than 78% characterized for major descriptors and most of passport, characterization and evaluation information are available in genebank database and are also shared in the global portal GENYSIS.
- ICARDA holds a rich rhizobium collection of its mandated food and forage legumes composed of 1,400 strains.
- ICARDA distributes on average 20,000 samples annually to its partners inside and outside ICARDA and since 2010 ICARDA has developed and is using the Focused Identification of Germplasm Strategy (FIGS approach) to provide best-bet subsets for sought traits constructed using environment-traits relationships.
- A user-friendly database is developed and accessible through internet and has applications to report transfers automatically to the International Treaty on Plant Genetic Resources for Food and Agriculture. This database can be adopted by most genebanks in CWANA region.
- ICARDA has provided 38 training courses which benefited more than 680 persons on various genetic resources conservation related aspects.
- ICARDA has provided expertise to 18 national programs in CWANA region for the establishment of their genebanks and documentation systems (8 in Central Asia and Caucasus, 10 in West Asia and North Africa).
- ICARDA, through the GEF-funded project on “conservation and sustainable use of dryland agrobiodiversity in the Fertile Crescent” has developed a community-based approach for promoting *in situ*/on-farm conservation of landraces and wild relatives which included technological, institutional, add-value, alternative sources of income options and policy recommendations along with public awareness increase activities.
- ICARDA is very active in strengthening regional and global collaboration and networking for effective conservation and use of genetic resources through, supporting the WANA-PGR network, development of PGRFA strategy for WANA region, participation to the governing body meetings and expert working groups of the FAO-Commission on PGRFA, International Treaty on PGRFA, and the Convention on Biological Diversity. ICARDA contributed to the 1st and 2nd reports on the State of the World PGRFA and Global Action Plans, and to the regional and crops genetic resources conservation strategies developed in collaboration with the Global Crop Diversity Trust.

Arrangements for decentralization of genetic resources activities

Due to the prevailing situation in Syria, ICARDA was constrained to relocate its genetic resources conservation activities following the decentralization of its research activities. While the active and base collections are still maintained at Tel-Hadia, Syria, ICARDA has relocated its genebank core activities to Lebanon and Morocco where field, laboratory and storage facilities are being established with the financial support from the CGIAR and GCDT. Efforts are initiated in 2016 season to reconstruct active and base collections in these two locations using accessions retrieved from Svalbard. Lebanon site will focus on multiplying and conservation of faba bean and *Lathyrus*, forage and range species and cereals and food legumes wild relatives. Morocco site will be involved mainly in the multiplication and conservation of genetic resources of cultivated barley, wheat, chickpea and lentil. The GIZ funding over last two years have allowed to establish seed health and rhizobium laboratories in Morocco.

The process of decentralizing genetic resources core activities will require a minimum of seven years to be able to resume the full capacity of conserving and distribution of all accessions.

World Agroforestry Centre

Anthony Simons

World Agroforestry Centre, United Nations Avenue, Gigiri, P.O. Box 30677-00100, Nairobi, Kenya

The **World Agroforestry Centre's** (ICRAF) mission is to generate science based knowledge about the diverse roles that trees play in agricultural landscapes and to use its research to advance policies and practices that benefit the poor and the environment. With nearly four decades of experience working with smallholder farmers in Africa, Asia and Latin America, ICRAF is uniquely positioned to address a range of social and environmental challenges through agroforestry.

The Research for Development is organized around six research programs, which in complementarity, respond well to the complexity and interactions of the key development challenges related to agroforestry. These are:

- **Agroforestry Systems** on maximizing on farm productivity of trees and agroforestry systems
- **Tree Products and Market** on organization of value chains for agroforestry products
- **Tree Diversity, Domestication and Delivery** on identifying, delivering and conserving quality tree germplasm
- **Land Health** on understanding land degradation and how it can be prevented and reversed
- **Environmental Services** on understanding the multi-functionality trees on landscapes
- **Climate Change** on the effects of trees on reducing farmers' vulnerability to climate variability and change and their contribution to greenhouse gas mitigation.

ICRAF part of **CGIAR**, a global research partnership dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services.

The research that addresses conservation and management of tree genetic resources is undertaken in the program on **tree diversity, domestication and delivery.**

Tree diversity, domestication and delivery

The World Agroforestry Centre's vision is for smallholders throughout the developing world to plant the highest quality trees to improve food security, nutrition, income, health, shelter, social cohesion, energy, resources and environmental sustainability. We identify, deliver and conserve quality tree germplasm and support the optimal use of the right tree in the right place for the right purpose. We do this by:

- Developing science-based knowledge needed to identify, deliver and promote wide-scale planting of the best quality tree germplasm in appropriate portfolios.
- Promoting the planting of superior tree germplasm closely linked with market developments and local needs in agricultural landscapes.

The primary objective is promoting use of tree genetic resources for productivity and resilience. Priority in our research is given to high-value tree species such food and nutrition, sawn wood, medicine, fodder and other commercial tree commodities. In addition, our research covers trees for fertilizer, energy, restoration and other uses. Our research seeks to promote superior germplasm of indigenous and exotic tree species while avoiding problems associated with invasive species.

We do this in collaboration with developmental partners, especially national governments, action NGOs and the private sector.

The effective use of tree genetic resources to bridge production gaps, ensure profitability and for the essential global diversification of agricultural production options is a priority for ICRAF, as this provides important opportunities to improve livelihoods and sustain ecosystems.

It is also crucial to reversing current cycles of land degradation and deprivation. However, the role of tree genetic resources in the provision of tree products and services has often been undervalued. This has resulted in the cultivation of trees not matched to context, with poor yields and low-quality traits. Opportunities to prevent deforestation and landscape degradation, and to stop narrow agricultural intensification and dietary homogenization, have therefore been lost.

ICRAF with its partners addresses this through research on safeguarding tree genetic **diversity**, on tree **domestication** and on tree planting material **delivery** options. By together drawing on recent methodological advances in each of these three areas, effective coordinated approaches are mainstreamed to provide a route to greater impact.

Below we outline some of the units and major activities undertaken by the tree diversity, domestication and delivery program.

Safeguarding diversity

Safeguarding research ensures the proper characterization and continued availability of the fundamental resources – the trees – that support agroforestry and restoration planting, while protecting the utility of existing tree populations through their proper genetic management. ICRAF's work with partners on safeguarding tree genetic resources includes support for global and regional conservation strategies including *circa situ* (on farm) safeguarding. Research develops and disseminate appropriate and efficient conservation and sustainable use approaches for tree genetic resources that benefit women, men, and their households, in different ecosystems, and in various national and regional settings. Research seeks to resolve questions regarding mainstream theory on tree genetic resource conservation practice, such as the assumption that the cultivation of timber and tree commodities is sufficient to safeguard their genetic resources. Research determines the conditions when such wisdom holds, based on production systems, landscapes and tree biologies, and through synthesis integrates this information with the wider concerns of production system and landscape conservation.

Genetic Resources Unit

The Genetic Resources Unit collects, conserves, documents, characterizes and distributes a diverse collection of mainly indigenous agroforestry trees species. The ex situ seed collection is maintained at headquarters in Nairobi, Kenya, and there are 38 field gene banks in 15 countries in Africa, Asia and Latin America.

The **seed** and **field** genebanks ensure the supply of superior tree germplasm for research. A few samples of available agroforestry tree seeds are availed for research. For bulk request, the genebank assists sourcing for quality germplasm from national partners where the species may be available. The genebank supplies agroforestry tree germplasm for ICRAF domestication programs and to research partners.

Genetic resources databases provide information on agroforestry tree taxonomy, uses, suitability and sources of seed as well as details of the ICRAF agroforestry genetic resources collection. The **Genetic Resources Strategy** ensures that collections are conserved to international standards, encouraging quality research to fill information gaps and promote use, and sharing knowledge and germplasm to improve livelihoods.

The **Genetic Resources Policy** guides the acquisition and distribution of tree genetic resources, access and benefit sharing, including of technologies and information related to tree germplasm. The policy facilitates awareness of and compliance to the international agreements that guide access to germplasm and information.

The Standard Material Transfer Protocol guides the conservation and sustainable use of plant genetic resources for food and agriculture, and the fair and equitable sharing of the benefits arising out of their use. Being a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture, ICRAF genebank distributes the agroforestry seeds via the **Standard Material Transfer Agreement (SMTA)**.

Vegetationmap4africa

The **vegetationmap4africa** is an interactive web-based map designed as a decision support tool for the selection of suitable indigenous tree species for restoration, forestry, agroforestry and landscape diversification projects. The map is also available offline as a mobile phone app. The map currently covers eight African countries including Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia. Understanding the distribution of natural vegetation provides a good approximation of where wider planting of indigenous tree species will contribute to ecosystem services, and food and nutrition security. The map also shows where planting materials for a particular species could be obtained. Via the **Agroforestry Species Switchboard,** each tree species is linked to information in 26 web-based databases, supporting the selection of the right tree species.

The Agroforestry Species Switchboard

The **Agroforestry Species Switchboard** is a "one-stop-shop" to retrieve data about a particular plant species across a wide range of information sources. Its objective is to provide information that supports research on trees and tree-based development activities such as agroforestry planting and wider restoration initiatives. The latest version of the Switchboard documents the presence of 26,301 plant species (34,066 species including synonyms) across 23 web-based information sources. When available, hyperlinks to selected species in particular information sources are provided. The Switchboard also provides links to check on the correct spelling of particular species, and on synonyms and current names. The Switchboard cross-links various databases of the World Agroforestry Centre by establishing a centralized naming system.

Domestication to enhance tree products and services

Domestication research is concerned with the use of large gene pools to support significant genetic gains in tree traits that are important for product and service provision, matched to the production systems and landscapes of growers. Focus is on the domestication of tree species identified by producers and consumers as priorities to enhance production, profitability and farm-level resilience.

In particular, we research on tree domestication approaches and innovations in input supply chains, leading to the sustainable production and distribution of quality seeds, seedlings and other tree planting material. Domestication research includes guidelines and decision-support tools for appropriate approaches that can be implemented with national and private sector breeders through the **African Orphan Crop Consortium**.

Large gene pools support the domestication of new tree species, of continued domestication of incipient domesticates, and of already domesticated tree commodities. However, the value of these gene pools has often been ignored except for a few high value trees. Greatly accelerated and better targeted genetic gains are achievable by combining traditional methods for selection such as multi-locational field trials with novel genomic, phenomic and modeling approaches. These techniques can now be applied to previously little-researched trees because of the lower costs of approaches, providing opportunities to revisit the use of these species in farming systems. Since wild trees tested in genomic studies evolved *in situ*, environmental datasets based on their sample locations are of particular value in genome-environment association studies to identify markers linked to adaptive traits.

The *ex-situ* conservation of diversity is addressed within the **genetic resources unit.**

African Orphan Crops Consortium

The African Orphan Crops Consortium's (AOCC) goal is to sequence, assemble and annotate the genomes of 101 traditional African food crops to improve their nutritional content. This will provide long lasting solutions for Africa's nutritional security. The resulting information will be put in the public domain with the endorsement of the African Union.

Role of AOCC is upstream in helping the national agriculture research systems to develop locally available crops and supply nutritious and high yielding varieties by transferring the genomics technologies to breeding schemes.

AOCC includes primarily comprises African Union's New Partnership for Africa's Development **(AU-NEPAD Agency); Mars, Incorporated;** World Agroforestry Centre **(ICRAF); BGI; Thermo Fisher Scientific** (formerly Life Technologies); **World Wildlife Fund; University of California, Davis; CyVerse** (previously iPlant Collaborative); **LGC; Illumina; Google; UNICEF;** and Biosciences eastern and central Africa – International Livestock Research Institute **(BecA/ILRI)** Hub.

Based at the World Agroforestry Centre, AOCC will train 120 plant breeders in genomics and marker-assisted selection for crop improvement over a five-year period. The work will drive the development of improved planting materials that will then be available to smallholder farmers throughout Africa.

Under the auspices of the **African Plant Breeding Academy**, the **Seed Biotechnology Center** at the University of California, Davis in collaboration with NEPAD and AOCC, trains practicing African plant breeders in the most advanced theory and technologies for plant breeding.

Fruit Tree Portfolio

The **fruit tree portfolio** approach involves cultivating a set of fruit trees on farms, which is carefully designed to supply nutritious fruits throughout the year, for diverse diets and improved health. The *fruit tree portfolio* for a particular locality gives the optimum number and combination of ecologically suitable agroforestry tree species to provide for year-round fresh fruits for households' requirements of vitamin C and pro-vitamin A, both essential nutrients. Because the trees in the portfolio have different harvest seasons spanning the entire calendar year, they provide a year-round supply of at least one fruit species per month for the household.

Delivery systems for restoration and livelihood

Smallholder farmers require access to high quality planting material to boost their productivity. To improve yields, breeding should be made available as common good. Investing in quality seed development and supporting a decentralized system of tree nurseries producing and distributing seedlings through public-private partnerships may offer the solution.

Research into tree planting material delivery systems ensures that high quality, needs-matched, germplasm reaches growers efficiently to support wide-scale adoption of product and service options.

It is essential to breed tree species that can adapt to future climate. However, this requires multinational effort to mobilize and build the tree genetic resources. Any breeding program for more than 50 priority species includes the identification of distribution and deployment zones under current and future climatic conditions. Work on planting material delivery systems includes large restoration projects where genetic quality (site matching to environment and purpose) is crucial for success.

Creating sustainable networks for production and distribution of quality seeds and seedlings requires substantial institutional changes to the implementation of restoration projects. Production of tree seedlings should be planned for at a landscape scale, which is much larger than most restoration projects do. A system of economically viable nurseries is required to supply tree seedlings. They must have access to knowledge of seed procurement, treatment and handling, and storage.

The short-term nature of many restoration projects lacks the capacity to support such networks of tree nurseries. In dry land restoration projects, for example, seedlings require long periods to develop sufficiently to survive planting.

To ensure access to high quality planting material, a combination of options, depending on species and target groups, is preferred.

Blogs on tree diversity, domestication, and delivery

- Avoiding hunger gaps with fruit tree portfolios in Kenya
- Unlocking the potential of sustainable agroforestry practices: Farmers meet ICRAF staff at agricultural fair
- The little-understood indigenous African fruit trees
- The fruits of success: a programme to domesticate West and Central Africa s wild fruit trees is raising incomes, improving health and stimulating the rural economy [PDF]
- Trees and food security in Africa; what’s the link?
- The right tree for the right place: vegetationmap4africa v2 includes smartphone app
- Characterizing baobab, the nutritious African ‘Tree of Life’
- From obscure forest species towards globally traded commodity: lessons from Allanblackia

Asia-Pacific Association of Agricultural Research Institutions (APAARI) Activities and Achievements

Raghunath Ghodake

Executive Secretary, Asia-Pacific Association of Agricultural Research Institutions, Bangkok 10100, Thailand

Genesis

Aware of the problems and challenges and realizing the opportunities available, the heterogeneity among National Agricultural Research Systems (NARS) and the regional needs to coordinate agricultural research and development for the benefit of all stakeholders, the Food and Agriculture Organization of the United Nations (FAO) had organized two regional conferences/consultations in mid 1980s (Islamabad, 1984 and Bangkok, 1985) which recommended the creation of a Regional Association to strengthen NARS. This led to the establishment of the Asia-Pacific Association of Agricultural Research Institutions (APAARI) in 1990, mainly to strengthen the national agricultural research capabilities and to enable the sharing of experiences among national partners in order to help alleviate poverty, increase productivity, protect/conserve the environment and attain agricultural sustainability in the Asia-Pacific region.

Organizational Structure and Management

APAARI is a unique voluntary, neutral, membership-based, apolitical non-profit and multi-stakeholder partnership organization in the Asia-Pacific region. The activities of APAARI are carried out by its Executive Committee which is elected from among members once every two years. It is composed of a Chairman, a Vice-Chairman, and Executive Secretary and other members. The General Assembly develops policies and programs. The Executive Committee is responsible for strategic planning in accordance with policies and directives adopted by the General Assembly. The Secretariat of APAARI is headed by the Executive Secretary who is responsible for carrying out the overall program, allocation of resources, convening of Executive Committee and General Assembly meetings. Currently, the Secretariat is located at FAO Regional Office, Bangkok. An Editorial Committee is designated to prepare and review APAARI publications including the regular APAARI Newsletter, which currently has about 300 subscribers. Short-term consultants are commissioned for special assignments under the direct supervision of the Executive Secretary.

APAARI Vision, Mission and Goal

Vision

Strengthened research and innovations for sustainable agricultural development in Asia and the Pacific.

Mission

Promoting, coordinating and strengthening agriculture and agri-food research and innovation systems through partnerships and collaboration, capacity development and advocacy for sustainable agricultural development in Asia and the Pacific.

Goal

The Asia-Pacific region benefits from and values APAARI's leadership and contribution to developing agriculture and agri-food research and innovation systems.

Objectives

The overall objective of the Association is to foster agricultural research and innovations for development of agri-food systems in the Asia-Pacific region so as to help address the concerns of hunger, poverty, environmental degradation and sustainability of agricultural production and to help contribute to the realization of sustainable development goals in Asia and the Pacific.

More specifically, the objectives are as follows:

- To promote the exchange of scientific and technical know-how and information in agriculture
- To encourage the establishment of appropriate collaborative research and training programs in accordance with identified regional, bilateral or national needs and priorities
- To assist in prioritizing agri-food research and innovation needs, strengthening of agri-food research and innovation systems (AFRIS) and management and governance capabilities of such systems.
- To strengthen cross-linkages among national, regional and international research and innovation organizations including universities, CSOs, CG centers, the private sector.

Membership

APAARI is a self-sustaining organization mainly based on its membership subscriptions since its establishment. Membership is open to national agricultural research institutions/councils/organizations/universities, CG centers, AIRCA members working for the Region. Presently, it has 68 members.

Key Challenges and Opportunities

The Asia-Pacific region faces new emerging challenges of ensuring efficient use of natural resources, improved rural livelihoods and social well-being, enhanced resilience of people, communities and ecosystems to climate change and market volatility, as well as good governance, policy and financing framework. Some of the key challenges defining APAARI's role to contribute to meeting the needs of the region are: i) increasing the productivity of agricultural and farming systems and producing affordable, safe, healthy, nutritious and high quality food, ii) reducing the losses of agricultural produce in the supply chain, iii) enabling agricultural systems to produce new bio-materials and integrate with more advanced agro-industries, agri-business and agri-services, iv) emphasizing sustainable use of natural resources and forests / agroforestry, v) coping with risks of climate change, extreme weather aberrations, price risks and economic shocks, vi) expanding opportunities for communication and capacity development to promote adoption of agricultural technologies, innovations and best practices, vii) sustainable generation and use of energy, viii) linking multi-disciplinary agricultural research to development outcomes with innovation pathways, desired milestones and targets, and ix) weak and underfunded AFRIS. .

There are tremendous opportunities in the region which could be harnessed for addressing the problems of poverty, malnutrition and environmental protection. These include: i) technological and institutional innovations, ii) renewed political recognition of AFRIS, and iii) increasing role of sub-regional organizations. These opportunities are important for establishing capable AFRIS. APAARI plays an important role to catalyse and facilitate all these processes to act collectively and coherently for strengthening of agri-food research and innovation systems in Asia and the Pacific.

Core Values

APAARI's key core values are as follows;

Visionary approach : Foreseeing the future and working in the frontier areas through collaboration and partnership to realize the full potential of scientific research for sustainable development, advancing ideas and innovations, and encouraging creativity and initiatives.

Devoted to merit and excellence : Functioning as a capable and motivated organization providing an enabling environment for attaining excellence by investing available resources optimally to leverage the full potential of research and innovation for development.

Learning and growing : Continually enhancing knowledge and skills to identify opportunities and capitalize on them for the growth and development of community, system, the nation and the weaker and smaller NARIs and NAROs.

APAARI Theory of Change (TOC)

APAARI's change strategy is to make a contribution toward the strengthening of AFRIS through enhanced collaboration, facilitation, promotion and advocacy in the region. It envisaged in the APAARI Vision 2030, a set of strategies and results respond to current and emerging priority constraints and opportunities in agri-food systems (AFS) development. Achievement of these results would make a major contribution towards the transformation of AFS and sustainable agricultural development, which is a pre-condition for achieving relevant Sustainable Development Goals (SDGs). The basic assumption for this TOC is that platform members, partners and primary stakeholders effectively work in partnership and all actors align their strategies and participate in collective actions at the levels of strengthening AFRIS and developing AFS.

APAARI Thematic Areas

In view of the emerging needs, key challenges and opportunities for development of agri-food systems, APAARI has been focusing on following thematic areas:

- Mobilization, management and use of natural resources for sustainability of agri-food systems
- Management of risks and uncertainties in the agri-food systems
- Inclusive development and integration of value chains targeted at benefiting smallholders
- Analysis, strengthening and formulation of public policy to support the transformation and development of agri-food systems

APAARI Programs

The above thematic areas are addressed through the following APAARI four programs:

- Knowledge Management
- Partnership and Networking
- Capacity Development
- Advocacy

Also, cross-cutting areas on inclusion of women and youth in agri-food systems and application of foresight and visioning are followed as an integral part of implementation of APAARI Programs.

Significant Achievements

In the past over 25 years, APAARI has been serving its members, partners and other stakeholders through a number of key activities. APAARI has significantly contributed towards addressing regional agricultural research needs and enhancing food and nutritional security in Asia and the Pacific The close links, networks, partnerships and collaboration with stakeholders that APAARI has developed over the years, as well as its goodwill, authority and focus on results, make the Association as an important actor in the region that continues to make a difference in developing agri-food systems through strengthening agri-food research and innovation systems in the region. The ultimate aim of APAARI is to help realizing the SDGs.

Knowledge Management

Knowledge management has always been central to APAARI's operations as the Association has supported its members, partners and key stakeholders to collect, collate and disseminate agricultural research information In order to give a thrust to this important area, a major initiative was undertaken by APAARI by establishing the Asia-Pacific Agricultural Research Information System (APARIS) in 2000 which had contributed significantly in accelerating the pace of ICT/ICM activities. Several workshops and training programs were organized under APARIS. Since the 1990's APAARI has brought out and disseminated over 150 important publications including success stories, status reports and proceedings of conferences, workshops, expert consultations, and policy dialogues. These publications along with six monthly newsletters had been extremely useful in sharing knowledge and information with APAARI members, partners and other stakeholders in the region.

Application of Agricultural Biotechnology

Another important initiative was the Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB) established in 2003 which contributed significantly in promoting the application of agricultural biotechnology. The strategic areas and priorities for APCoAB included policy advocacy, capacity building and knowledge resources and dissemination. A large number of workshops, conferences, expert consultations and brainstorming sessions relating to agricultural biotechnology were organized and several publications were brought out and widely disseminated

Promoting ARI4D

APAARI effectively promoted agricultural research and innovation for development (ARI4D) in the region through well planned global and regional conferences, workshops , expert consultations and policy dialogues in specific areas such as linking farmers to markets, use of biofuels, farmer-led innovations, outscaling farm innovation, climate change, conservation agriculture, women in agriculture, retaining youth in agriculture, use and management of agrobiodiversity and improving crop production and productivity (wheat, maize, medicinal and aromatic plants),and high level policy dialogue on investment in agricultural research, etc.

Collaboration and Partnership

APAARI made concerted efforts for strengthening agricultural research partnership and collaboration in the region and played a significant role through close links with several crop and regional networks such as the Council for Partnerships on Rice Research in Asia (CORRA),Cereals and Legumes Asia Network (CLAN), Rice-Wheat Consortium (RWC),Tropical Asia Maize Network (TAMNET),Inter-regional

Network on Cotton in Asia and North Africa (INCANA), Underutilized Tropical Fruits Asia Network (UTFANET), International Tropical Fruits Network (TFNET); Group on Fisheries and Aquaculture Research (GoFAR), and Biosaline Networks. APAARI also promoted and strengthened plant genetic resource networks such as RECSEA-PGR for Southeast Asia, SANPGR for South Asia, EA-PGR for East Asia, PAPGREN for the Pacific and crop networks such as Coconut Genetic Resources Network (COGENT), Banana and Plantain Network (BAPNET), International Network for the Improvement of Banana and Plantain (INIBAP), Asian Fruits Genetic Resources Network (AFGRN), Asia-Pacific Forest Genetic Resources Program (APFORGEN).

APAARI also established a close collaboration with Food and Agriculture Organization of the United Nations (FAO), Global Forum on Agricultural Research (GFAR), CGIAR Centers (ICRISAT, CIMMYT, IRRI, ICARDA, IWMI, CIP, IFPRI, ICRAF, ILRI, CIFOR), Bioversity International, World Fish Center); other international ceners/fora (AVRDC, CABI, ICBA, ICIMOD, CFF, GFRAS, TAP, GCHERA, PROLINNOVA); regional organizations/networks (SAARC, ASEAN, SPC, SAC, CAPSA, APIRAS, AIT, EFARD, APEON, FARA, ARINNENA,CACAARI, FORAGRO, APSA, NACA, APAFRI) and also with the private sector. Several activities were undertaken in collaboration with these organizations.

Representation in Key Committees/Meetings

APAARI also represented the Asia-Pacific region and contributed effectively at a large number of key global/regional events. APAARI also represented as Chairman, Program Committee, GFAR (2009); Chairman, Organizing Committee, GCARD2 (2012), Member, CG Fund Council (2013); Member, Evaluation and Impact Assessment Committee of CG Fund Council (2013); Chair, Independent Advisory Committee (IAC) on CRP-Grain Legumes (2013); and Member Steering Committee of Tropical Agriculture Platform (TAP) (2016); ICRISAT CRP Grain Legumes Consultation Meeting (as Chair of Independent Advisory Committee), 2015.

Declarations/Frameworks

APAARI had been instrumental in bringing out the following important declarations/frameworks for providing strategic directions for agricultural research and innovation in the Asia-Pacific region:

- Tsukuba Declaration on Adapting Agriculture to Climate Change (2008)
- Bangkok Declaration on AR4D adopted (2009)
- Suwon Agrobiodiversity Framework adopted (2010)

Trust for Advancement of Agricultural Sciences (TAAS)

Raj S. Paroda

Trust for Advancement of Agricultural Sciences (TAAS), Avenue II, IARI, New Delhi - 110012, India

Preamble

The Trust for Advancement of Agricultural Sciences (TAAS) is a non-profit organization dedicated to serve the cause of agrobiodiversity, agricultural sciences, farmers, enterprises/industry, researchers, students, and women and youth in agriculture. It was established in response to a joint vision statement issued by all Science Academies of India at the 88th Session of Indian Science Congress (88th ISC) in New Delhi in January 2001 and inaugurated by the then Prime Minister of India Shri Atal Bihari Bajpai. The theme of the science congress was "Food, Nutrition and Environmental Security". The United Nations Millennium Development Goals (MDGs) were proclaimed in the preceding year and it was being realized that science and technology will perhaps be the most important instruments to help shape evolution of humankind in the new millennium.

It was realised during the 88th ISC that having achieved food self-sufficiency in majority of the developing world, we need to achieve sustainable food and nutrition security. Similarly, percentage of the population living below the poverty line having come down, and having overcome starvation broadly, we need to lay onwards focus on overcoming malnutrition. To ensure a new world order towards food and agriculture in the 21st century, we need to take science to people and create strong scientific temper through much needed policy advocacy and public awareness. Thus, a continuous efforts for reorientation of public policies and their effective application for the benefit of stakeholders would be a critical requiring continuous 'foresight and "think-tank' process.

Considering above and in view of successful conduct of the 88th Science Congress, the scientific community got deeply impressed about the importance of food, nutrition and environmental security, and the need for making continuous efforts to ensure these objectives. Also, Dr. R.S. Paroda the General President of the Congress and the then Secretary to Government of India (GOI) Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research (ICAR) suggested two critical follow up points. These were: (i) the agricultural sciences need further systematic nurturing and promotion through research and extension to contribute to sustainable economic development, and (ii) the 88th ISC should not be seen as an event in itself. On the contrary, it should be a beginning of a new initiative towards harnessing agricultural science for the welfare of people and the national economy. These, thus, laid the foundation of a new chapter for continuous scientific pursuits for agricultural research and innovation for development (ARI4D) through the establishment of a Trust called "Trust for Advancement of Agricultural Sciences" (TAAS) under Dr. R.S. Paroda, as its founder chairman. Hence, TAAS was registered on 17 October 2002 with its Headquarters located at the Indian Agricultural Research Institute (IARI) campus, New Delhi.

Goal, Mission and Objectives

Goal

- To ensure an accelerated movement for harnessing agricultural science for the welfare of people.

Mission

- To promote growth and advancement of agriculture through scientific interactions and partnerships.

Objectives

- To act as a Think Tank to deliberate on key issues relating to agricultural research for development (AR4D) and influence policy decisions.
- Organizing workshops, conferences, brainstorming sessions, seminars and special lectures on emerging issues and new developments in agricultural sciences.
- To disseminate knowledge among stakeholders through publication of proceedings and policy papers.
- Instituting national awards for the outstanding contributions to Indian agriculture by the scientists of Indian and foreign origin
- Facilitating the scientific initiatives of and building partnerships with Non-Resident Indian agricultural scientists on short visits to India.

Governance Mechanism

The activities of TAAS are managed by a Board of Trustees comprising: Chairman, Vice-Chairman, Secretary, Treasurer and eight member Trustees. New members get periodically inducted in place of outgoing Trustees. The Board meets once in every quarter, reviews activities and decides its future programs. The Board also identifies other organizations with whom to collaborate for implementing its programs/activities. The achievements and the financial status of TAAS is reviewed and audited on annual basis.

Activities of TAAS

TAAS continuously organizes a number of activities to achieve its objectives. Important among these are:

i. Brainstorming Sessions/Symposia/Seminars/Workshops on topics of contemporary importance in collaboration with national, regional and international organizations.

ii. Foundation Day/ Special Lectures by the leading scientists / policy makers, with established record of scientific excellence and leadership.

iii. Bringing out publications like policy/strategy papers on thematic areas of national importance.

iv. Conferring an annual Award, known as Dr. M.S. Swaminathan Award, in recognition of immense service rendered by great visionary and father of Green Revolution in India, for lifetime scientific achievements and leadership in agriculture, as evident by obvious impact on the society.

v. Recognition of innovations developed by the farmers that have impacted sustainable farming practices/higher yields and increased farmers' income and their scientific validation for scaling out for larger impact.

Seminars/Conferences/Dialogues Organised

Overall, TAAS as a 'Think Tank' has been debating on issues of national importance and coming out with well articulated recommendations for consideration of policy makers, the Government and all other stakeholders. So far, a total of 30 such events have been organized. Following are some important issues on which TAAS had convened, in collaboration with other concerned organizations/institutions, the national dialogues/debates involving key stakeholders

i. Genetic resource conservation through use
ii. Regulatory mechanisms for genetically modified crops
iii. Increasing farm productivity
iv. Out scaling conservation agriculture
v. Promoting farmer-led innovations
vi. Linking farmers to markets
vii. Promoting public-private partnerships
viii. Soybean and QPM maize for nutritional security
ix. Linking research with development
x. Role of women in agriculture
xi. Promoting agricultural innovations and value chains
xii. Retaining youth in agriculture
xiii. Building leadership in agriculture
xiv. Agricultural knowledge management and sharing
xv. Managing climate change and soil health
xvi. Policy advocacy for creating enabling environment for good agronomic practices and resilience in agriculture
xvii. Regional and sub-regional partnerships for ARI4D
xviii. Innovative extension systems for empowering farmers
xix. Agroforestry: The way forward
xx. Conservation of farm animal genetic resources

Dr. Swaminathan Award for Leadership in Agriculture

The Trust for Advancement of Agricultural Sciences (TAAS) has been conferring an award in honour of the renowned agricultural scientist Dr. M.S. Swaminathan, whose pioneering contributions to Indian agriculture had led to the Green Revolution in the late 1960s resulting in food self-sufficiency in India and neighboring countries. The award is given annually to an eminent scientist (either from India or abroad) forhis/her outstanding leadership qualities in agriculture as demonstrated by significant contributions made towards overall agricultural growth in the developing world, especially in India. TAAS has conferred eight such awards and the details of distinguished recipients are given below.

i. The first award was given to Nobel Laureate for Peace Dr. Norman E. Borlaug, the only agricultural scientist to have received this honor for his work on wheat improvement at the International Maize and Wheat Improvement Center (CIMMYT), Mexico. His high yielding dwarf wheat varieties resulted in Green Revolution in India and other developing countries in mid-sixties when there was acute food scarcity. This award was presented to Dr. Borlaug by the then Hon'ble President of India, Dr. A.P.J. Abdul Kalam on March 15, 2005 at Vigyan Bhawan, New Delhi.

ii. The second award was given to renowned rice breeder, Dr. G.S. Khush, the recipient of world Food Prize, by the Hon'ble Prime Minister of India, Dr. Manmohan Singh at Vigyan Bhavan, on October 9, 2006. Dr. Khush, while working at the International Rice Research Institute (IRRI), Manila was responsible for the development of more than 300 high yielding rice varieties which gave tremendous boost to productivity of rice in many countries, resulting in increased rice production globally.

iii. The third award was presented to Dr. S.K. Vasal, an accomplished maize breeder, by Prof. M.G.K. Menon, Former Minister of State (Planning), Govt. of India on May 3, 2008 at Shinde Auditorium, NASC Complex, New Delhi. Dr. Vasal's work at CIMMYT, on maize, led to the development of protein rich maize, known as Quality Protein Maize (QPM), which has resulted in nutritional improvement of several million people in the developing world. His work also enabled India to release few QPM hybrids in India.

iv. The fourth award in the series was given to Prof. Rattan Lal, an eminent soil scientist from Ohio State University (OSU), for his outstanding contributions in the field of sustainable management of natural resources. His contributions have made great impact on food production through better soil management by the resource poor farmers of developing courtiers. This award was presented to Prof. Rattan Lal by Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission on August 11, 2009 at Dr. BP Pal Auditorium, New Delhi.

v. The fifth award was presented to Dr. Sanjay Rajaram, a distinguished wheat breeder. His work at CIMMYT led to the development of improved wheat varieties which have been released in more than 50 countries, including around 25 in India. These varieties have helped in increasing wheat production in many developing countries. This award was presented by Dr. A.P.J. Abdul Kalam, former President of India on December 10, 2010 at Shinde Auditorium, NASC Complex, New Delhi.

vi. The sixth award was presented to Dr. M.C. Saxena, an eminent agronomist and crop physiologist whose work on food legumes at International Center for Agricultural Research in Dryland Areas (ICARDA) has enormously benefited the resource poor farmers in West Asia, North Africa, Central Asia (CWANA) and South Asia, particularly Bangladesh, India, Nepal and Pakistan. His seminal work has helped in increasing the pulse productivity in these countries. This award was presented by Dr. Balram Jakhar, former Union Minister of Agriculture and the Governor of Madhya Pradesh on January 25, 2012 at Dr. BP Pal Auditorium, IARI, New Delhi.

vii. The seventh award was presented to Dr. William D. Dar by Dr. K. Kasturirangan, Member, Planning Commission on June 24, 2013 at Dr. BP Pal Auditorium, IARI, New Delhi for his outstanding contributions towards food security and agricultural sustainability in Asia and Sub-Saharan Africa. The work done by him in the capacity of Director General, ICRISAT, has created considerable impact on resource poor farmers. Dr. Dar is well known for his efforts to promote public-private partnership and for his efforts towards inclusive market oriented development (IMOD).

viii. The eighth award was given to Dr. Thomas Lumpkin, former Director General of CIMMYT on 28th September, 2015 by father of Green Revolution in India Dr. M.S. Swaminathan himself as a Chief Guest. Support provided by Dr Lumpkin for wheat and maize research in India and for the establishment of Borlaug Institute for South Asia (BISA) have been appreciated widely.

Overall Achievements and Impact of TAAS

As already stated, TAAS has been forwarding from time to time the recommendations emerging out of the discussions held in various symposia/ workshops/ seminars/brainstorming sessions organized by TAAS to the concerned Government Departments/ Ministries and other relevant organizations/ agencies. Most of the recommendations have been received well and appropriate actions have been taken for their implementation. In the process, during the last one decade, TAAS as a 'Think Tank', has been able to catalyze the process of either creating an enabling policy environment or generating much required public awareness on issues of national importance. A description highlighting the impact on policies and organizational restructuring is listed here:

1. The Parliament of India had passed the Protection of Plant Varieties and Farmers Rights PPV&FR) Act in 2001 and Rules were framed in 2003, However, the process for creation of office and proper functioning of PPV&FR Authority was accelerated by the Department of Agriculture and Cooperation (DAC) when urgency for the same was highlighted through a TAAS debate; especially when same was getting delayed for more than 5 years. The details concerning implementation of the Act are available at: <www.plantauthority.gov.in>.

2. Based on a recommendation to accelerate seed replacement rate and promotion of hybrid seeds, involving effectively the Private Seed Sector, a separate Seed Mission has been launched during the 12th Five Year Plan by the Central Government to improve crop productivity in different crops. Also the Department of Agriculture and Cooperation (DAC) had stepped up the introduction of Revised Seed Bill 2004 in the Parliament on December 9, 2004. Subsequently, this Bill was amended on November 9, 2010 but the same is awaiting its approval by the Parliament.

3. The Department of Biotechnology (DBT) took necessary action towards the establishment of a Biotechnology Regulatory Authority of India (BRAI) as a single window clearance system for GM crops. The Bill was introduced in the Parliament on April 22, 2013, which is awaiting its approval.

4. The Indian Council of Agricultural Research (ICAR) created in 2011 a National Advisory Board on Genetic Resource Management (NABGRM) to provide an oversight and necessary guidance for managing our genetic resource, under the Chairmanship of Dr. R.S. Paroda. The Board has accelerated the process of establishing guidelines for managing GR of plants, animals, fish, agriculturally important insects and microbes. Also for the Access and Benefit Sharing (ABS), a Standard Material Transfer Agreement (SMTA) has been finalized for sharing the germplasm with both public and private sector organisations.

5. The Department of Agriculture and Cooperation (DAC) finally included maize in the Food Security Mission based on strong recommendation made by TAAS. As a result, maize production is now showing highest annual growth rate among all cereals. It got doubled in just last one decade based on higher adoption of single cross hybrid technology through active role of private seed sector.

6. The ICAR and the State Agricultural Universities (SAU) have accelerated their efforts to promote Public-Private Partnership (PPP) through non-exclusive licensing system adopted lately as a new initiative.

7. Both DAC and ICAR have given high priority to open access for knowledge sharing to the farmers through ICT and other mass communication means. In this context, a long standing demand of TAAS to have a dedicated channel on agriculture has been met recently by the Government.

8. Some States have taken progressive steps to establish their Farmers' Commission to address the concerns and to provide needed incentives for out-scaling innovations for improving livelihood of small holder farmers.

9. Necessary steps have been taken by the Government to promote soybean and quality protein maize (QPM) as food crops to address the current concern of protein malnutrition (especially of children below 5 years of age).

10. Ministry of Agriculture has launched a Livestock Mission under the 12th Five Year Plan to accelerate growth of animal sector and to ensure genetic resource conservation of indigenous livestock breeds. ICAR has also prepared a national action plan on improvement of genetic resources in accordance with Ranchi Declaration brought out earlier by TAAS.

11. On the basis of recommendations emerging out of a national dialogue on improving soil health, needed public awareness concerning conservation and sustainable use of natural resources, such as land, water and agrobiodiversity has been created for increased production, profitability, environmental sustainability and improved livelihood of smallholder farmers. Also awareness about

soil test based use of fertilizers to overcome existing imbalance of nutrients/micro-nutrients in the soil has helped in ensuring rational use of need based nutrients/fertilizers.

12. The scientists, policy makers, farmers and other stakeholders have been sensitized through a national debate towards sustainable diversification of agriculture by reorienting research agenda towards “farming systems’ mode” through integration of crops, livestock and fisheries to improve both farm productivity and profitability.

13. Urgent need has been stressed for out-scaling innovations that can save inputs and enhance income of the farmers such as: conservation agriculture, plastic mulching, direct seeding of rice, alternate furrow irrigation, micro-irrigation, fertigation, IPM etc. Also, attention of policy makers has been drawn towards faster adoption of small farm mechanization for achieving much needed resilience in agriculture.

14. Proper knowledge has been disseminated regarding the judicious use of water, its pricing policy as well as crop diversification, as per scientific land use planning, around horticulture, agro-forestry and silvi-pastoral system. Also much needed promotion of micro-irrigation systems in place of existing practice of flood irrigation for improved water use efficiency has been advocated.

15. TAAS was instrumental in organizing the first ever Global Conference on Women in Agriculture with participation of 760 delegates from more than 37 countries. Through this, the specific problems of women engaged in agriculture were emphasized and suitable strategies suggested to overcome their drudgery in farm operations through appropriate technological interventions, engendering (through capacity building) and empowering them with in-depth knowledge, legal rights, needed policies and proper incentives. It also became evident that empowering farm women will not only help in increasing farm production by almost 20 per cent but would also ensure household nutrition security, which is a major national concern.

16. Considering a major challenge of retaining youth in agriculture, TAAS could catalyze the National Agricultural Research System (NARS), especially the ICAR, to engage youth in agriculture and evolve progressive strategies to attract them towards secondary/specialty agriculture by ensuring much needed vocational training and bank credits. The proposal to make them technology agents/service providers and/or input/implement providers, entrepreneurs for value addition and primary processing and also for linking farmers to market is currently receiving much needed attention of the policy/decision makers.

17. The researchers, policy makers, and development officials have been sensitized to up-scale and out-scale farmer led innovations, which are cost-effective, sustainable and useful for increasing both production and profitability. In this context, an Agriculture Innovation Fund has been created by the ICAR and some states in order to scientifically validate and promote their large scale adoption through training enterprising farmers, especially the women and youth.

18. In order to address the concerns of farmers, some of the states like Haryana, Punjab and Rajasthan have already been catalyzed to establish Farmers’ Commission and taken initiatives to adopt state agricultural policies.

19. For open access to knowledge, which farmers need badly, a National Agriculture Information System (NAIS) is being created and efforts are on to provide need based knowledge to the farming community through use of ICT, smart phones and media. In this context, long standing recommendation of TAAS for a dedicated TV channel on agriculture has recently been made effective by the Government so that farmer gets timely access to knowledge on all aspects concerning ‘plough to plate’.

20. In order to address effectively the adverse effects of climate change and also the weather related calamities, the recommendations to promote climate smart agriculture, crop as well as

livestock insurance, establishment of seed banks, credit at low interest rate to farmers, immediate compensation for crop damage using GIS based weather data and rapid on spot assessment are being suggested as possible optionsl to redress the grievances of small holder farmers.

21. Importance of increasing wheat production to a level of 100 mt by 2015 was emphasized through a dialogue held in 2010 and a Roadmap was proposed to catalyze the system. Accordingly, pushing aside the setback to crop due to weather aberrations in several states, this goal is likely to be achieved next year.

22. Awareness about importance and relevance of GM crops for Indian agriculture has been created through national dialogue and relevant publications. Efforts have also been made to change the public perception based on scientific reasoning and informed knowledge about benefits of technology to both farmers and consumers. Also the need for efficient regulatory system and specific role of ICAR in the conduct of confined field trials and ultimate release of GM crops for general cultivation in the national interest has been emphasized. Accordingly, concrete steps have been taken both by DBT and ICAR.

23. In order to scale out innovations, especially biotechnology, IPM, hybrid technology etc., the importance of public-private-partnership has been emphasized to ensure quick delivery to the end users. Accordingly, some institutions and number of state agricultural universities have initiated actions to build public-private partnerships. For this, different models of PPP have now been put in place.

24. Awareness concerning use of soybean as a food crop to overcome existing serious problem of protein malnutrition, being an important challenge, has been created. Also its use through various food products (flour, tofu, milk, oil, puffs, biscuits, ice cream etc.) through promotion of small scale industry and producer companies has been advocated, for which role of research institutions/ universities/KVKs has also been highlighted. For use of Soya as healthy food, the need for creation of a Soybean Board has been emphasized to the Government.

Activities on Agrobiodiversity

Some specific activities of TAAS relating to agrobiodiversity and the germplasm use have been illustrated in the commemorative document entitled: 'Building Trust: A journey by TAAS (2001-2015). Also some details are given in the above section on achievements under serial numbers 1-5, 10, 22 and 23.

Strategy Papers/Special Lectures

TAAS has brought out a number of strategy papers on important issues and subjects related to emerging concerns before indian agriculture and also published a number of special lectures delivered by eminent personalities invited to deliver TAAS Foundation Day lectures. So far, a total of 10 strategy papers and 12 special lectures have been published and circulated widely for attention of all stakeholders concerned with agricultural growth and development in India.

TAAS Publications

TAAS has been regularly publishing strategy papers/lectures of eminent scientists and the proceedings of national seminars organized from time to time. These have been circulated widely to a number of stakeholders and special efforts have been made to catalyze the policy makers and create much needed public awareness on issues of national relevance. All these documents have been posted regularly on TAAS website (www.taas.in) for the benefit of scientists, farmers and other key stakeholders.

Indian Society of Plant Genetic Resources: Journey of Three Decades

R.K. Tyagi[1] and Anuradha Agrawal[2]

[1]General Secretary, [2]Treasurer, Indian Society of Plant Genetic Resources (ISPGR), C/o ICAR-National Bureau of Plant Genetic Resources (NBPGR), Pusa Campus, New Delhi - 110012, India

Genesis

A 'National Symposium on Plant Genetic Resources' was organized by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, 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, the then Director of NBPGR proposed the creation of ISPGR, which was also welcomed by all the delegates of the symposium. The primary objective of the Society was 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 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 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 since then EC tenure has been changed to three years.

Governance

There shall be two bodies representing the Society, *viz*., the General Body (GB) and the Executive Council (EC).

(i) **The General Body (GB):** The GB shall comprise of all the enrolled members of the Society. The GB shall be supreme authority of the Society. It shall determine the general policies and programmes of the Society in conformity with the constitution and bye-laws and elect the members of the EC. It shall be the only body that can make amendments to or altogether change the rules of the Society according to the procedure laid down in this constitution.

(ii) **The Executive Council (EC):** The administration, direction and management of the activities/functions of the Society shall be entrusted to an Executive Council (EC) consisting of President, two Vice-Presidents, one General Secretary, one Joint Secretary, one Treasurer and eight members from the GB. The zones will be demarcated by the EC. The office bearers should be the life members of the Society.

(iii) The term of the above office bearers will be for a period of three years. The immediate past President will be *Ex-officio* member of the EC of the Society. The General Secretary, the Editor-in-Chief and the Treasurer shall be from the Headquarters of the Society and in the event of any office bearer leaving the headquarters for more than six months, the EC shall be empowered to fill such vacancies by nomination for the interim period only. None of the office bearers should serve in the same post for more than two terms, except President and General Secretary.

(iv) Director, NBPGR is the *Ex-officio* member of the EC of the Society, without having any voting right.

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.

Presently, ISPGR is headed again by Dr R.S. Paroda as President who is Chairman of Trust of Advancement in Agricultural Science 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.

Objectives

The Society provides an opportunity to the scientists from different disciplines of plant genetic resources (PGR), to address themselves to the problems confronting various aspects of PGR, *viz.* collecting, exchange, characterization and evaluation, conservation and utilization in a concerted and integrated manner and to express their scientific views on existing national and international PGR programmes and policies. The main objectives of the Society are:

(i) 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.

(ii) 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.

(iii) To collect, collate and disseminate information on PGR.

(iv) To encourage and promote close association/collaboration among members belonging to various disciplines.

(v) To work in association and collaboration with other national and international societies/organizations having similar objectives.

(vi) To publish a journal at regular interval, as decided by the Executive Council (EC), as an official publication of the Society.

Scientific Activities Undertaken

The ISPGR is an old and experienced society of PGR scientists, actively engaged for the cause of genetic resources since 1987. It has organized several dialogues, conferences, symposia, meetings in the past that have led to *inter alia* formulation and publication of 'National Policy' and 'Action Plan' on agricultural biodiversity, including the PGR. A few important events are mentioned as below: The present efforts being made by the Society in organizing the symposium are timely and well placed.

National Dialogues

1. **The first Dialogue- "Plant Genetic Resources in India- Developing National Policy Option",** December 1-2, 1993, New Delhi.
2. **The second Dialogue – "Issues in Management of Plant Genetic Resources",** December 1-2, 1998, New Delhi.

Conferences, Symposia, Workshops

1. The ISPGR actively contributed to the deliberations of the Second Crop Science Congress and also organized a Satellite Symposium in November 1996, New Delhi.
2. The 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. In the first Indian Science Congress of the New Millennium (88th session), held in January, 2001, New Delhi. The Society made significant impact on the deliberations on household Food, Nutrition and Environmental Security.
3. Symposium on **"Plant Genetic Resources Management:Advances and Challenges"** organized by the Society during 1-4 August, 2001, New Delhi.
4. National Conference on **"Transgenics in Indian Agriculture"** was organized by Society in collaboration with ICAR and NBPGR during 9-10 March, 2004, New Delhi.
5. International Symposium on **"Introduction Achievements and Opportunities in South Asia"** was organized by ISPGR in collaboration with NBPGR during 15-17 February, 2005, New Delhi.
6. National Symposium on '**Recent Global Developments in the Management of Plant Genetic Resources',** organized by ISPGR and NBPGR, New Delhi, 17-18 December 2009.
7. 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.

Ist International Agrobiodiversity Congress 2016 – The Current Event

Science, Technology, Policy and Partnership

Agrobiodiversity includes all components of biological diversity relevant to food and agriculture: the varieties, breeds and populations of useful plant, animal, and fish species and the diversity of insects, microbes and other species that are part of production systems. Human-mediated co-existence in diverse agro-ecosystems around the world has shaped, and sustained the unique structures, processes, functions and their economic value. Currently about 800 million people suffer from insecure food supplies and malnutrition globally. Recently, the United Nations has renewed commitment to push the sustainable development agenda, in which food, nutrition and environmental security figures as the key sustainable development goals (SDGs). Capacity building, trained human resource and partnerships, to research and adopt new technological options is imminently required for meeting the future demand of new varieties and breeds in agriculture through fast track germplasm use. Efficient and sustainable agrobiodiversity management also requires functional convergence of global policy and regulatory frameworks [United Nations Convention on Biological Diversity (CBD), International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), Food and Agriculture Organization of the United Nations (FAO), Commission on Genetic Resources for Food and Agriculture (CGRFA), Nagoya Protocol on Access and Benefit Sharing (NP-ABS), Aichi Targets 2011-2020; Framework Convention on Climate Change (UNFCCC), World Trade Organization (WTO), etc.] shaping biodiversity, food and agriculture, climate change and trade related mechanisms.

To address the above agrobiodiversity-centric issues, the IAC2016 has been jointly conceived and being organized by the Indian Society of Plant Genetic Resources (ISPGR) and Bioversity International, in collaboration with the Indian Council of Agricultural Research (ICAR), Protection of Plant Varieties and Farmers' Right Authority (PPV&FRA), National Biodiversity Authority (NBA), Trust for Advancement of Agricultural Sciences (TAAS), National Academy of Agricultural Sciences (NAAS), M.S. Swaminathan Research Foundation (MSSRF) and Indian Society of Genetics and Plant Breeding (ISGPB). Co-sponsors of the Congress include many partners such as International Maize and Wheat Improvement Centre (CIMMYT), International Centre for Research in Semi-arid Tropics (ICRISAT), International Centre for Research in Dryland Areas (ICARDA), Global Crop Diversity Trust (GCDT), Japan International Research Centre for Agricultural Sciences (JIRCAS), Centre for Agriculture and Biosciences International (CABI), German Corporation for International Cooperation (GIZ) and Asia Pacific Association of Agricultural Research Institutes (APAARI) to:

(i) provide a common platform to share experience and knowledge on the sustainable conservation and use of agrobiodiversity,

(ii) critically evaluate the current research and systems of management and use of agrobiodiversity and to assess the preparedness for meeting short- and long-term requirements of humanity,

(iii) identify and prioritize research areas that require greater inputs and thrusts for better management of agrobiodiversity, and

(iv) strengthen capacity and build new partnerships to help manage agrobiodiversity worldwide.

The major expected outputs from IAC2016 can be envisaged as mentioned below:

- New thinking on the sustainable management and use of agrobiodiversity through interdisciplinary exchange of ideas and opinions among various stakeholders.
- A roadmap to enhance food, nutrition and health security by optimal utilization of agrobiodiversity while protecting agro-ecosystems and landscapes.
- Mainstreaming agrobiodiversity related issues into global discussions to ensure fair access, benefit sharing and sustainable use.
- Developing a network of partnerships to strengthen agrobiodiversity management systems at the national, regional and global level.
- Develop a 'Delhi Declaration on Agrobiodiversity Management' as a vision document to execute the above-mentioned action plan.

Based on the Nagoya Protocol (NP), the guidelines on the Access and Benefit Sharing (ABS) came into effect in recent past. For effective implementation of NP, there are many issues exist due to several complexities of the guidelines and lack of awareness among all the stakeholders. Several legislations and obligations to national and international laws/treaties are required to be harmonized for utilization of genetic resources and associated knowledge within country and across the trans-boundary areas. ISPGR, in collaboration with Anand and Anand, a leading law firm dealing with IPR and patent etc., organizing a brainstorming session on "Access and Benefit Sharing (ABS) - Striking the Right Balance" on October 22, 2016 – a pre-IAC2016 event.

Awards and Recognitions

To recognize the contribution of in area of PGR and to motivate the researchers, ISPGR has instituted following awrards:

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 50,000 in cash, a gold medal, 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 eminent scientists who have made outstanding contribution in the field of PGR with special reference to India.

2. **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. To recognize the outstanding contributions of young scientists in area of PGR, this prestigious award is given by ISPGR annually.

3. **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 5,000 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.

4. **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 10,000 cash prize and a plaque of honor.

5. **'Fellows' of ISPGR**. The process was initiated in 2007 and six Honorary Fellows included Prof MS Swaminathan, Late Dr AB Joshi, Prof GS Khush,, Prof. S Rajaram, Prof. RB Singh and Prof. Emile Frison. In addition, the Society has recognized valuable contributions of …Fellows in the areas of PGR researchhave been52 Founder fellows were selected in the year 2007. Five to six fellows are selected for each year.

Publications

Indian Journal of Plant Genetic Resources – A Journal dedicated to PGR Research

In accordance with objective (vi) of the Society, the Society publishes a triennial journal, Indian Journal of Plant Genetic Resources (IJPGR, ISSN 0971-8184), to disseminate/update knowledge on plant genetic resources activities. It publishes full-length papers or short communications of original scientific research in the field of plant genetic resources. Review articles summarizing the existing state of knowledge in topics related to plant genetic resources are also published. In addition, it also notify the trait-specific germplasm/genetic stock 'registered' by the ICAR. In 2012, IJPGR has completed 25 years of serving the PGR community by disseminating the research results and knowledge to all stakeholders.

Books

The Society has also facilitated to compile and collate the information on PGR and published in form of books as mentioned below:

1. Plant Genetic Resources in India - Developing National Policy Options edited by RS Rana, RK Arora, BP Singh and S Kochhar. Proceeding of the ISPGR Dialogue, 1993 held at New Delhi, December, 2003, 219p.

2. Prospects of Medicinal Plants edited by PL Gautam, R Raina, U Srivastava, SP Roychaudhuri and BB Singh. This is based upon the proceedings of UHF-IUFRO international Workshop on “Prospects of Medicinal Plant” jointly organized by the International Union of Forestry Research organization and Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan from November 4-9, 1996, 290p.

3. Plant Genetic Resources Oilseed and Cash Crops edited by BS Dhillon, RK Tyagi, S Saxena and A Agrawal, Narosa Publishing House, New Delhi, Indian Society of Plant Genetic Resources, NBPGR, Pusa Campus, New Delhi 110012, 215p.

4. Plant Genetic Resource Management edited by BS Dhillon, RK Tyagi, Arjun Lal and S Saxena, Narosa Publishing House Pvt. Ltd., Indian Society of Plant Genetic Resources, NBPGR, Pusa Campus, New Delhi 110012, 434p.

5. Plant genetic Resources (Horticultural Crops) edited by BS Dhillon, RK Tyagi, S Saxena and GJ Randhawa, Narosa Publishing House Pvt. Ltd., Indian Society of Plant Genetic Resources, NBPGR, Pusa Campus, New Delhi 110012, 332p.

6. Plant Genetic Resources Foodgrain Crops edited by BS Dhillon, S Saxena, A Agrawal and RK Tyagi, Narosa Publishing House Pvt. Ltd., Indian Society of Plant Genetic Resources, NBPGR, Pusa Campus, New Delhi 110012, 345p.

Epilogue

ISPGR has been serving the PGR research community for about past 30 years in various ways. Being an academic society, 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. It aims to popularize and highlight the importance of management of PGR to achieve sustainable agriculture. Under the able guidance of past 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. In future, contemporary issues need to be deliberated at various fora to create awareness among the researchers, policy makers, farmers, students and other stakeholders and also for effective utilization of PGR, which play a significant role in increasing the production, productivity of crops and farmers’ income.

ICAR-National Bureau of Plant Genetic Resources

(In Service of Plant Scientists and Indian Farmers)

Managing Plant Genetic Diversity for Sustenance

Kuldeep Singh and Shashi Bhalla

ICAR-National Bureau of Plant Genetic Resources, New Delhi - 110012, India

The Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR), an ISO 9001:2008 certified organization was established under the Crop Science Division of the ICAR in 1976 as a nodal institute at national level for acquisition and management of indigenous and exotic plant genetic resources (PGR) for food and agriculture and to carry out related research. The overall management of PGR includes activities such as PGR collection through exploration and exchange, quarantine, conservation, characterization, evaluation, and documentation.

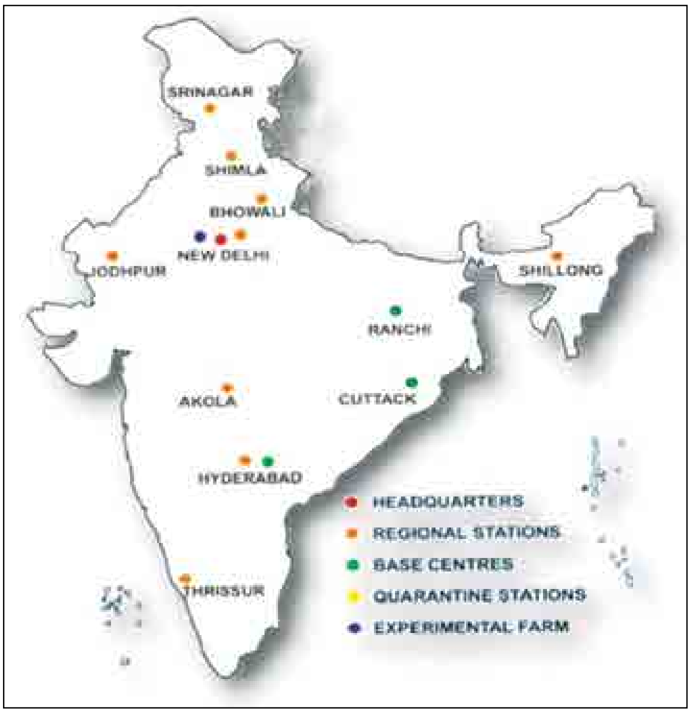
Since its inception, ICAR-NBPGR has played a pivotal role in crop improvement and diversification and management of PGR and related activities at national and international level. The ICAR-NBPGR has 10 Regional Stations covering all the agro-ecological zones of the country and a network of 59 National Active Germplasm Sites (NAGS). The component activities include, collection, characterization, evaluation, safe conservation using both conventional storage and biotechnological approaches for *in vitro* conservation and cryopreservation; DNA fingerprinting of agri-horticultural crops, generation and conservation and use of genomic resources and GM detection. Over the years, ICAR-NBPGR has made unprecedented progress in the management of PGR. ICAR-NBPGR has so far undertaken >2, 600 explorations and assembled over 2.66 lakh indigenous germplasm accessions. Most of these accessions have been duly characterized and safely conserved in the National Genebank (NGB). The NGB at ICAR-NBPGR presently holds over 4.25 lakh accessions representing about 1,800 crop/ plant species. Besides, it is a nodal institute authorized by Government of India to facilitate international exchange of germplasm for research purposes and to undertake the quarantine. The PGR information has been duly documented in user friendly databases. In addition, NBPGR is deeply involved in human resource development (HRD) in PGR through regular trainings and education. NBPGR in collaboration with IARI teaches courses in PGR for awarding M.Sc and Ph.D degrees.

Mandate

- Management and promote sustainable use of plant genetic and genomic resources of agri-hotricultural crop and carry out related research
- Coordination and capacity building in PGR management and policy issues governing access and benefit sharing of their use
- Molecular profile of varieties of agri-horticultural crop and GM detection technology research

Objectives

1. To plan, organize, conduct and coordinate exploration and collection of desired indigenous and exotic PGR.
2. To undertake introduction, exchange and quarantine for augmenting PGR.
3. To characterize, evaluate, document and conserve crop genetic resources and promote their use in collaboration with other national organizations.
4. To develop genomic resources and tools, to discover and validate the function of genes of importance to agriculture and to develop bioinformatics tools for enhanced utilization of genomic resources.
5. To develop information network for effective utilization of PGR.
6. To conduct research, undertake teaching and training, develop policy guidelines and create public awareness on PGR.
7. To promote use of PGR for sustainable agriculture at international level.



To achieve the mandated objectives, presently NBPGR has staff strength of 313 (Director, 122 Scientists, 75 Technicals, 49 Administrative and 67 skilled supportive staff)

Activities and Achievements

PGR Exploration and Collection

- To develop new varieties in various agri-horticultural crops for farmers settled in different agro-climatic zones, new germplasm/ parent material with desired traits or genes is a continuous requirement of the plant breeders. Therefore, periodically such germplasm is collected by ICAR-NBPGR Scientists in collaboration with crop-based institutes of ICAR and SAUs. PGR collected is in the form of healthy seeds, vegetative propagules, and cutting from natural habitats, farmer's field, institutes, from areas of high diversity and national importance.

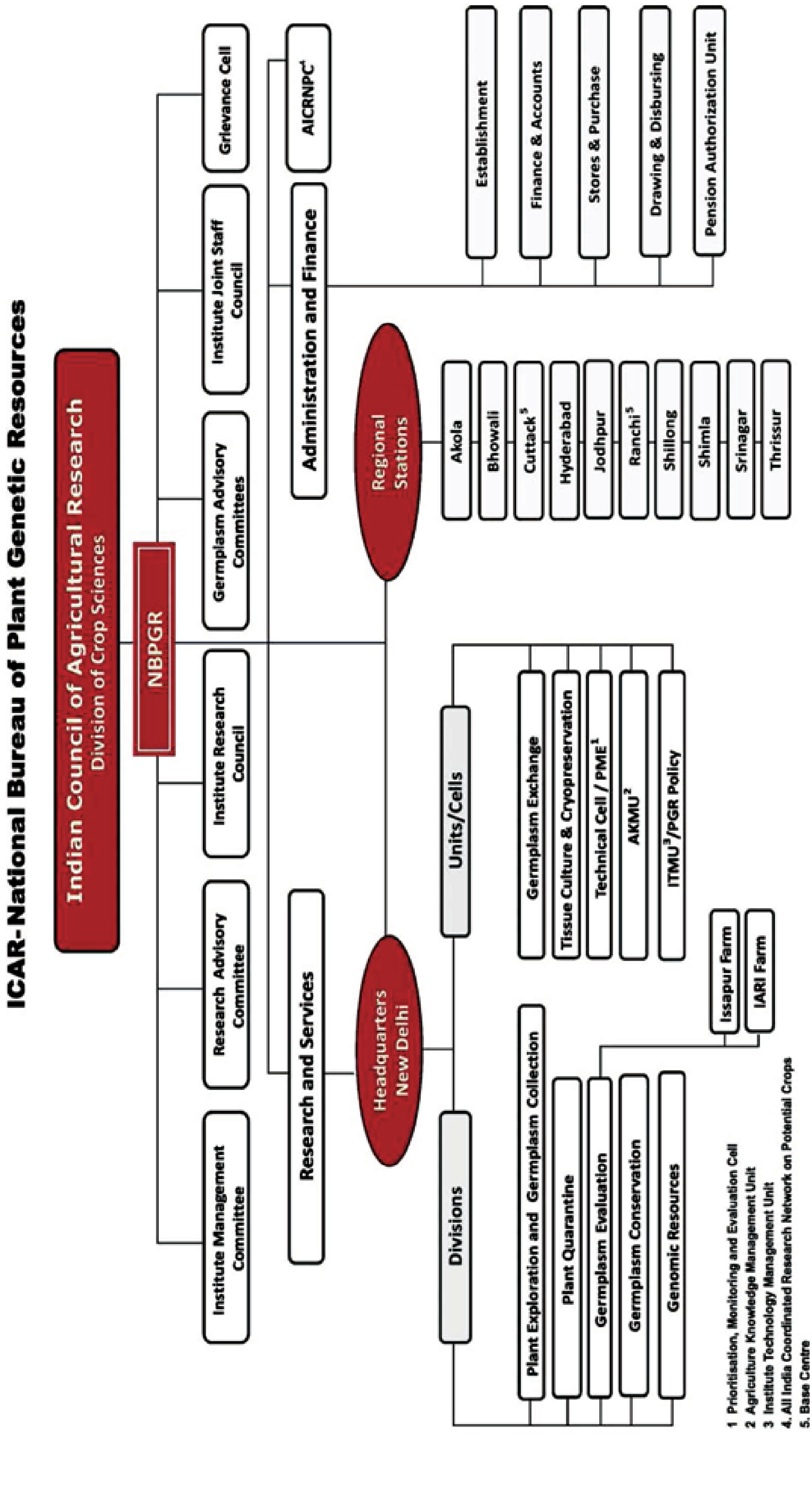


Fig 1.Organogram of ICAR-NBPGR

- Explorations undertaken on regular basis are area-specific, crop-specific or trait-specific. Germplasm of various crops has been collected from diversity-rich spots (including the difficult unreached areas in different parts of the country). Special missions are undertaken in areas affected by natural or man-made disasters.
- **The institute has so far undertaken 2644 explorations within the country and collected about 2.67 lakhs accessions of crop species and their wild relatives.**

PGR Exchange

- ICAR-NBPGR is the nodal agency for import and export of all PGR for research purpose in compliance with national and international regulatory mechanism.
- Exchange carried out with >100 countries and CGIAR institutes under bi-or multi-lateral agreements. Annually, ~25,000 accessions of PGR and ~75,000 samples of international nurseries/ trials introduced in India for use in crop improvement programmes. **Till date about 6.5 lakh germplasm accessions of various crops including the transgenic planting material have been introduced/ imported into the country**.
- NBPGR is instrumental in introduction of several crops in India such as soybean, sunflower, kiwi, tree tomato, oil palm, jojoba, guayule, hops etc. and aromatic plants like rose and geranium which are getting popular in Himalayan states of Uttarakhand and Himachal Pradesh.
- To import PGR, online application for import permit can be submitted at URL http://www.nbpgr.ernet.in/gep/

Plant Quarantine

- Introduction of planting material, including transgenics from other countries carries risk of entry of the associated pests (insects, diseases and weeds). Hence, all genetic resources acquired from foreign countries are tested using plant quarantine measures (legislative measures) to prevent the entry of exotic pests (fungi, bacteria, viruses, insects, nematodes, weeds etc.) 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, including transgenics, meant for research purposes.
- ICAR-NBPGR also undertakes quarantine processing of germplasm meant for export and issues the Phytosanitary Certificate.
- ICAR-NBPGR is engaged in development of protocols for diagnostics for detection of various pests and quarantine treatments for salvaging of infested/infected germplasm.
- The quarantine has resulted in the interception of several pests of high economic significance including (>50) those not yet reported from the country. Such interception signify the success of quarantine as otherwise these pests could have entered the country and played havoc with the plant biodiversity and Agriculture.

PGR Conservation

- The Indian National Genebank (NGB) was established at ICAR-NBPGR to conserve the national heritage of PGR in the form of seeds, vegetative propagules, *in vitro* cultures, budwoods, embryos/ embryonic axes, genomic resources and pollen.

Seed Genebank

Cryo Bank

In vitro Bank

- The NGB consist of four kinds of facilities, namely, Seed Genebank (4°C and -18°C), Cryogenebank (-170°C to -196°C), *in vitro* Genebank (25°C), and Field Genebank, to cater to long-term as well as medium-term conservation.

- Indian Genebank with a capacity to conserve about one million germplasm in the form of seeds is currently conserving about 0.426 million accession belonging to nearly 1,800 species. Over 11, 000 accessions of seed, dormant buds, pollen and genomic resources are cryopreserved in liquid nitrogen in cryogenebank and about 1900 accessions in the *in vitro* genebank. Also, horticultural crops are conserved in the form of *in vitro* cultures (~40,000 cultures of 130 plant species).

- The NGB is supported by the active partnership of other intuitions designated as the NAGS. NAGS are responsible for maintaining, evaluating and distributing germplasm from their active collections to NGB and user scientists.

- It is mandatory for both public and private sector research institutes to deposit the seeds with ICAR-NBPGR and get IC (Indigenous Collection) number for any variety to be notified by Central Variety Release Committee (CVRC) under Seed Act.

PGR Characterization and Evaluation

- The utilization of PGR in crop improvement programs rests on identification of promising accessions. The collected or introduced germplasm is characterized and evaluated to assess its potential, by recording morphological and biochemical traits for yield, quality, agronomy, and biotic stress tolerance.

- Approximately 10,000 accessions are characterized/evaluated every year at NBPGR and its regional stations. Till date, more than **2.35 lakhs accessions of different agri-horticultural crops have been characterized and evaluated using morphological traits and molecular marker profile.**

Field view of wheat germplasm at CCS, HAU, Hisar

Field view of chickpea germplasm characterization

- Core sets have been developed in crops viz., brinjal, chickpea, mungbean, okra, sesame and wheat to facilitate the enhanced utilization of germplasm. Pre breeding, to widen the genetic base was undertaken in chickpea and lentil including their wild species.
- Mega programme on characterization and evaluation under the National Initiative for climate Resilient Agriculture (NICRA) executed in collaboration with SAUs. Under this initiative as many as 21,822 accessions of wheat and 18,775 of chickpea were evaluated earning its place in Limca Book of Records.

DNA Fingerprinting and Conservation of Genomic Resources

- About **5606 varieties, registered germplasm and landraces of more than 44 crops have been fingerprinted using DNA markers.** Also the new varieties are being DNA fingerprinted to avoid any biopiracy by any unauthorized person or country.
- The National Genomic Resources Repository is involved in collection, generation, conservation and distribution of genomic resources for biotechnological research in the country. The aim is to promote conservation, sharing and utilization of enormous amount of genomic resources generated in the country and elsewhere. All forms of genomic resources including clones, gene constructs, large DNA fragment libraries as well as genomic sequence information can be deposited in this repository (http://www.nbpgr.ernet.in:8080/repository/home.htm). It has conserved 45 validated gene constructs, 10 full gene sequences and 4,608 genomic DNA of over 23 crops and wild species.
- All depositions or requests are to be made along with material transfer agreements in order to protect the interest of the depositor and the sovereignty of the Nation over the genetic resources. The IP rights (if any) shall remain with the depositor.
- **GM Detection Technologies Developed and transferred:** Rapid/cost-effective assays based on visual and real-time Loop-mediated isothermal amplification (LAMP) targeting commonly employed eight transgenic elements, which can also be used on-site. Multi-target real-time PCR system, simultaneously targeting 47 targets, including 21 GM events of five crops. GMO matrix for 141 GM events of 21 crops with 106 genetic element targets as decision support system. Hexaplex PCR targeting commonly employed marker genes to check the GM status irrespective of trait and crop. Singleplex and multiplex PCR-based diagnostics developed for 12 GM crops.

Germplasm Utilization

- The Bureau is supplying ~10,000 germplasm accessions every year collected indigenously or from exotic sources to the breeders and other researchers in the country. The germplasm supplied by ICAR-NBPGR to various breeders have been used in varietal development.
- The NBPGR was also involved in the release of about 100 varieties in the past in different agri-horticultural crops either through direct introduction or by selection from the introduced germplasm and popularized several such introductions for commercial cultivation.
- Several indigenously supplied germplasm accessions have helped to develop improved varieties in various national programmes. These include rice variety (Maruteru sannalu), sorghum variety (Parbhani Moti), red okra (Aruna), Chinese potato (Nidhi), coriander variety (Sudha), and yam variety (Indu).

PGR Documentation

- 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 (www.nbpgr.ernet.in/pgrportal).

Germplasm Registration

- 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. NBPGR plays a vital role in germplasm registration.
- About 1250 potentially valuable germplasm of over 204 species of various crops are registered so far.

All India Coordinated Network Project on Potential Crops

This network programme is located at NBPGR, New Delhi and has 13 main centers in different parts of the country. The major functions are introduction, evaluation, conservation, breeding and popularization of new potential and useful plant species for acclimatization to local condition. Grain amaranth, buckwheat, ricebean, Jatropha and Simarouba have been developed and popularized under this project.

Human Resources Development

- NBPGR faculty teaches M.Sc. and Ph.D. courses in PGR under the Post-graduate School of Indian Agriculture Research Institute (IARI), New Delhi.
- National and international training programmes conducted routinely on various aspects of PGR management.
- NBPGR is designated as the Centre of Excellence since 2006 by ICAR and Bioversity International to impart training on in vitro conservation and cryopreservation of PGR and more than seven trainings conducted.

National and International Linkages

- Close collaborations with Bioversity International, ICARDA, IRRI, CIMMYT and other countries on genetic resources management and utilization are in place.
- Collaborations with all ICAR institute, State Agricultural Universities, CSIR institute, DBT, DST, DRDO etc. for trait-specific evaluation and utilization of germplasm.
- Memorandum of Understanding (MoU) was signed between the Indian Council of Agricultural Research (ICAR) and the Royal Botanic Gardens (RBG), Kew, UK on 13th February, 2014 to enhance capacities of both the institutions in research on conservation biology.
- The National Permafrost Facility (prototype) created as a result of joint initiative of ICAR and DRDO with the involvement of the Bureau at Leh, Ladakh (Chang-La) would be useful for conservation of safety duplicates at a very low-cost.

New Initiatives

Gap Analysis and Biodiversity Mapping using GIS tools: Mapping of collected diversity followed by gap analysis was undertaken in some crops. In rice, more than 35, 000 accessions; in maize > 8, 000 accessions and in sesame over 2, 500 accessions collected from different states of the country were georeferenced.

Mission-mode mega programme on characterization and evaluation of Wheat and Chickpea germplasm: Wheat germplasm (21, 822 accessions) and chickpea (18, 800 accessions) conserved in National Genebank were characterized and evaluated for various biotic and abiotic stress tolerance traits. Core sets of wheat (2, 226 accessions) and chickpea (1, 103) were developed. ***The Wheat characterization and evaluation experiment conducted by ICAR-NBPGR (2011-12) entered the Limca Book of Records 2013***

Identification of useful gene sources in secondary and tertiary gene pool of Chickpea and Lentil: Pre-breeding and genetic enhancement efforts in lentil and chickpea identified sources with specific traits. One representative set of global wild *Lens* accessions was developed by extracting 96 accessions using PowerCore approach.

Identification of climate analogues in crops for enhancing adaptive capacity to climate change: Changing climatic regimes demand identification of specific prospective genotypes to be fed to the varietal development chain. ICAR-NBPGR linked attributes of the *ex situ* germplasm collections, i.e. agronomic descriptors and geographic origins with current and future environmental data. 84 accessions (pre-adapted to predicted changes) belonging to pearl millet, chickpea, pigeon pea and sorghum crops were identified.

CRP on Agro-biodiversity to undertake characterization of entire genebank collections and evaluation in select crops. The Platform has specific sub-projects addressing genetic resources management issues related to plants, animals, fish, microbes and insects. The respective Bureaus coordinate these management functions involving other stakeholders in their area domain.

CRP on Genomics was initiated with a focus on generating genomic resources for value addition to PGR for genetic improvement of crops. The establishment of a genomics platform would provide a state of the art infrastructure and expertise for carrying out genomics work at all NARS/ICAR institutes including five Bureaus.

Technologies transferred

- Application of DNA-based markers to differentiate citrus root stocks.
- PCR based detection assays and protocols for ten genetically modified (GM) crops.
- Five technologies related to PCR based GMO detection were transferred to (i) M/s DSS Imagetech Private Limited, Delhi, in 2015 (ii) Punjab Biotechnology Incubator, Mohali, in 2014 , (iii) Basmati Export Development Foundation, Meerut, in 2013, (iv) Amar Immunodiagnostics Pvt. Ltd. Hyderabad in May, 2010

Human resource development

- ♦ ICAR-NBPGR faculty teaches M.Sc. and Ph.D. courses in PGR under the Post Graduate School of Indian Agricultural Research Institute (IARI), New Delhi
- ♦ ICAR-NBPGR conducted ~ 50 national/ international training programme on various aspects of PGR management. It is designated as the Centre of Excellence since 2006 by ICAR and Bioversity International to impart training on *in vitro* conservation and cryopreservation of PGR and 8 trainings have been conducted so far.
- ♦ About 120 deputations/ visits abroad were undertaken by the scientists

ICAR-NBPGR received the following Awards

- ***Krishi Sansthan Award*** (Public Sector Organization of the year) as part of Mahindra Samriddhi India Agri Awards 2011.
- ***5th Research Leadership Award 2012*** by Agriculture Today, the national agriculture magazine.

ICAR-National Bureau of Animal Genetic Resources

Arjava Sharma

Director, ICAR-National Bureau of Animal Genetic Resources, Karnal - 132001, Haryana, India

ICAR-National Bureau of Animal Genetic Resources (ICAR-NBAGR), an ISO 9001:2008 certified organization is a premier institute dedicated to the work for characterization and conservation of indigenous animal genetic Resources (AnGR) as per the assigned mandate. The need for the establishment of National Institute of Animal Genetics was accepted in principle during 4th Five Year Plan. During 5th and 6th Five Year Plans, various government agencies coordinated the efforts for the establishment of this institute. Therefore, National Bureau of Animal Genetic Resources (NBAGR) and National Institute of Animal Genetics (NIAG) were set up on 21st September 1984. These institutes started working at Bangalore and then shifted to Karnal in 1985. Both Institute and the Bureau were merged to function as a single unit as National Bureau of Animal Genetic Resources in 1995. National Bureau of Animal Genetic Resources has been the nodal organization in India for undertaking research for overall management of livestock and poultry diversity of the country. It has following vision, mandate and objectives:

Vision

Striving for excellence in innovative research to identify genetic potential of indigenous livestock for improvement and conservation

Mandate

- Identification, characterization, conservation and sustainable utilization of livestock and poultry genetic resources of the country.
- Coordination and capacity building in the management of animal genetic resources.

Objectives

- To conduct systematic surveys to characterize, evaluate and catalogue farm livestock and poultry genetic resources and to establish their National Data Base.
- To design methodologies for *ex situ* conservation and *in situ* management and optimal utilization of farm animal genetic resources.
- To undertake studies on genetic characterization using modern techniques of molecular biology.
- To conduct training programmes as related to evaluation, characterization and utilization of animal genetic resources.

Major Programmes at NBAGR:

- Identification and Characterization of Livestock Genetic Resources
- Registration and Documentation of Livestock Genetic Resources
- Conservation of Livestock Genetic Resources
- Sustainable Utilization of Livestock Genetic Resources
- Livestock Genomic Studies
- Informatics and Data Repository

To achieve the mandated objectives, cader strength of 85 man power (Director, 35 Scientists, 19 Technical, 21 Administrative and 9 Auxiliary) was sanctioned against which Director, 28 scientists, 16 technicals, 18 administrative and 5 auxiliary staff is in position. The infrastructure in terms of divisions/ sections/units kept on changing from time to time. Of late, As per ICAR letter. No. AS 5/21/2012.IA.I dated 22.07.2013 following divisions have been created to carry out the research activities under envisaged programmes.

- Animal Genetic Resource Division
- Animal Genetics Division
- Animal Biotechnology Division

In addition to these, two sections namely Livestock Information Management section and Network Project section are also functioning to support the divisional activities. Besides these divisions and sections, the bureau also has dedicated cells to look after project monitoring, technology management, consultancy services, administration and finance etc.,

Animal Genetic Resource Division

Animal Genetic Resource (AGR) Division has been engaged in developing formats for breed characteristics, survey strategies and breed description methodologies. At present this Division along with its 'National Gene Bank' is working for phenotypic characterization, stainable utilization and conservation of indigenous livestock and poultry breeds. The surveyed breeds/populations are documented in the form of breed monographs, breed descriptors and charts in addition to research publications. Based on the information, new strategies have been formulated for improvement and conservation of the breeds under field conditions. The in situ conservation has been implemented for breeds of various livestock species. In addition, the division is also working in the frontier areas of long term ex-situ conservation of germplasm.

Animal Genetics Division

This division, in fact, is a mini form of National Institute of Animal Genetics (NIAG) whose major thrust was on the characterization of indigenous genetic resources using cytogenetic and biochemical polymorphism studies. The initial research projects focused on studies of chromosomal profile of cattle, buffalo, sheep, goat, pigs and camel. Later, emphasis was given to species, like pigs, equines and poultry. immunogenetics, and molecular genetics became the part of Animal Genetics Division which was established in the year 1996 and formally approved in 2014. In the year 1997, divisional research activities were modified to include research projects on molecular characterization and biodiversity analysis of native breeds of cattle, buffalo, sheep, goat, other livestock species (camel, horse, yak, mithun, pig, donkey) and poultry using molecular markers especially microsatellites. Efforts were also made to use mitochondrial D-loop markers to understand the nature of mitochondrial DNA diversity, maternal lineages and evolutionary relationships amongst native breeds. Significant work was also done in the field of immunology especially on the genetic aspects of MHC and bovine interleukins in Indian cattle.

Animal Biotechnology Division

The division is a transformation of DNA Fingerprinting Unit existing earlier at bureau. Besides STR markers based genetic characterization of different livestock species, major emphasis is on use of genomic tools for the identification and evaluation of genes, and transcripts involved in adaptation, disease resistance and various production related traits of livestock species. In addition to institutional projects, the divisional activities also concentrate on search of specific biomolecules which are unique for indigenous livestock/poultry.

Biotechnology Lab

Livestock Information Management Unit

This Unit is engaged in digitization of information on animal resources and to provide it to the users in an easily retrievable format. This section also provides LAN, Internet and computing facilities to the institute. The section has also been looking after registration of livestock and poultry genetic resources.

Network Project Unit

The Network Project was initiated in 1996 with the following objectives to characterize the breeds in terms of both qualitative and quantitative traits, molecular genetic characterization and candidate gene studies in indigenous breeds, to develop the breed descriptors and to conserve the germplasm.

The updated achievements included phenotypic and genetic characterization and development of breed descriptors of 11 breeds of cattle (Deoni, Ongole, Gir, Umblachery, Bachaur, Dangi, Amritmahal, Khillar, Gaolao, Tho Tho, Gangatiri), 3 breeds of buffalo (Jaffarabadi, Nagpuri, Surti), 8 breeds of sheep (Changthangi, Deccani, Mecheri, Mandya, Rampur Bushair, Banpala, Coimbatore, Chhota-Nagpuri), 5 breeds of goat (Osmanabadi, Barbari, Attapady,Ganjam, Mehsana), 2 breeds of chicken (Aseel, Ankleshwar), Kutchi Camel, Spiti horse and Arunachali mithun. Conservation of AnGR includes 5 cattle breeds (Krishna Valley, Ponwar, Kherigarh,Kangayam, Nagori), 3 buffalo breeds (Pandharpuri, Jaffarabadi, Toda), 3 sheep breeds (Magra, Nilgiri, Kilakarsel), 2 goat breeds (Beetal, Surti) and Spiti horse.

In-situ conservation model successfully implemented in the field involving livestock keepers and other stakeholders for enhancing the population size of declining Beetal Goat, Krishna valley Cattle, Kilakarsal Sheep in their respective native tract.

Salient Achievements

Technology / Methodology developed

- Survey methodology for AnGR characterization- Widely used for breed documentation
- *In situ* conservation model-Used by SAUs, SAH departments and development agecies
- Digitized database on AnGR-Widely used in decision support
- Test for fecundity gene in sheep used for identification of prolific animals
- Standard karyotypes of livestock species- Used widely to screen chromosomal abnormalities as diagnostic tools for detecting genetic disorders in breeding bulls
- Molecular diversity analysis-Standardized protocol for establishment of genetic relationship among different breeds of a species.
- Breed assignment based on microsatellite genotyping-Assignment of individuals to breeds/ populations
- New single universal sex determination methodology in 6 bovid species by single universal duplex PCR
- Parentage verification kits for cattle, buffalo, goat and camel while one kit can resolve parentage and related issues in all ruminant livestock species-cattle, buffalo, goat, sheep yak and mithun
- Non-invasive tool to study molecular aspects of lactation biology in buffalo and native cattle
- PCR based differentiation of cattle and buffalo meat and milk
- PCR-RFLP and tetra-ARMS PCR based genotyping of novel SNPs identified in TLRs and other functional genes for association studies in buffalo and goats

Characterization of AnGR

Species	Registered breeds	Characterization		Documentation
		Phenotypic	Genetic	
Cattle	40	37	35	30
Buffalo	13	12	12	13
Goat	26	23	23	23
Sheep	42	35	37	27
Camel	09	04	04	03
Horse	06	06	06	04
Chicken	17	14	15	14
Pig	06	02	02	01
Donkey	01	01	01	01

Majority of the indigenous breeds of various species have been characterized phenotypically as well as genetically. The current status of breeds characterized and documented is given below:

Characterization of Major Genes

Candidate gene characterization for growth, production, immune response and heat regulation revealed polymorphisms at nucleotide level. A number of SNPs have been identified at different gene loci in different farm species. Gene/gene fragment characterized in cattle, buffalo, sheep, goat, yak and mithun are mentioned below:

Cattle : Myostatin, osteopontin, growth hormone receptor, growth hormone releasing hormone receptor, interleukins, insulin like growth factors, butyrophilin1, 3, beta lactoglobulin, prolactin, pituitary-specific transcription factor 1, kappa-casein, beta-casein, alpha S1 casein, alpha S2 casein, bovine growth hormone, alpha lactalbumin, monocyte chemotactic protein, inducible nitric oxide synthase gene, heat shock protein 70, pitutary transcription factor 1, diacylgylcerolacetyl transferase, toll-like receptors (1-10), heat shock protein gene 70.2, glucose transporter genes, etc.

Buffalo : Myostatin, osteopontin, growth hormone receptor, growth hormone releasing hormone receptor, leptin, ABCG2, milk caseins, lactoglobulins, interleukins, mammary derived growth inhibitor, beta lactoglobulin, heat shock protein 70, thyroglobulin, insulin like growth factor-1, calpastatin, heat shock protein 70, peptidoglycan recognition protein, haptoglobin, fatty acid synthase, calpain, calpastatin, lactoferrin, toll-like receptors 1-10 genes, leptin, stanniocalcin, nod-like receptors 1 & 2, ATP-binding cassette subfamily G member 2, CXC motif receptor 2, major histocompatibility complex DQ& DR, suppressor of tumorigenicity protein 7, pentraxin 3, serum amyloid A1, S100 calcium binding protein A8, tumour necrosis factor alpha, diacylglycerolacetyl transferase, etc.

Sheep : Boroola, growth hormone, type I intermediate filament wool keratin, B2C high wool sulphur protein, ovine cysteine and histidine rich protein, bone morphogenetic protein 15 beta-lactoglobulin, growth differentiation factor 8, calpain, β3 adrenergic receptor, growth hormone receptor, titin, calpastatin, fatty acid binding protein 3, prolactin receptor, diacylglycerol acyltransferase 1, etc.

Goat : Leptin, kappa-casein, beta-lactoglobulin, calpastatin, bone morphogenetic protein receptor IB, bone morphogenetic protein 4, growth differentiation factor 9, inhibin βB gene, G protein coupled receptor, kisspeptin, toll-like receptors- TLR2, TLR4, TLR5, TLR7 & TLR8, nod-like receptor, calpain 1, aralkylamine N-acetyltransferase, peptidoglycan recognition protein 1, fatty acid synthase, acetyl-CoA carboxylase alpha, SREBP cleavage-activating protein, peroxisome proliferator-activated receptor gamma, oxidized LDL receptor, prolactin, signal transducers and activators of transcription, diacylglycerolacetyl transferase, etc.

Yak and Mithun : Alpha casein, acytl co-A and lipoprotein lipase, thyroglobulin, MHC class II DQ and DR genes, TNF-alpha, haptoglobin, etc.

Functional Genomics

- Buffalo draft genome assembly constructed using the cattle genome (Btau 4.0 assembly) as a reference. The assembly has read depth of 17-19X. The buffalo assembly represents ~ 91%-95% coverage in comparison to the cattle assembly Btau 4.0.
- Establishment of transcriptome signature of buffalo mammary gland during lactation, involution and heifer physiological stages and identification of stage specific genes and pathways.
- Milk transcriptome profile of Sahiwal cows.
- Transcriptional profiling of fecundity related genes and folliculogenesis in Fec B carrier and non-carrier ewes as well as FecB carrier sheep under high and low nutritional regimes.
- Tissue distribution profiling of selected genes in buffalo and goat.
- EST libraries from buffalo mammary gland- More than 1200 sequences generated

- RNASeq based sequences from different tissues- (More than 20 lakhs); Dromedarian camel- 5.8 lakhs, Bactrian camel- 3.6 lakhs; Buffalo- 6.0 lakhs; Goat- 4.6 lakhs
- QTLs- Buffalo growth related, milk composition and milk yield QTLs identified on eight different chromosomes.
- Around 8.5 lakh SNPs generated from 12 breeds of buffalo.

Conservation of AnGR

- A total of about 1, 29,174 cryo-preserved semen doses representing 44 important and endangered breeds of seven species (Cattle, Buffalo, Goat, Sheep, Camel, Equine and Yak) are being maintained in the National Gene Bank.
- Animal Genomic Resource Bank is established which has collection of DNA samples of almost 80% of the Indian breeds of various livestock species.

In situ Conservation

- *In situ* model of conservation has been developed by providing technical inputs and incentives to the farmers/breeders in the breeding tract of respective breeds and has been adopted under Network Project through the State Agricultural and Veterinary universities/ State Animal Husbandry Departments/ ICAR Institutes and NGOs.
- Gaushalas located in Haryana, Gujarat, Rajasthan and Uttar Pradesh have been examined to advocate a proper prototype for recording, maintaining, enhancing and conservation of indigenous cattle breeds. A new model 10P was developed to produce young bulls from purebred cows in an open nucleus manner within the Gaushalas.
- A protocol for cryopreservation of caudal epididymal spermatozoa has been standardized in ovine.

Breed Registartion

Indian Council of Agricultural Research (ICAR) initiated a mechanism for "Registration of Animal Germplasm" by giving temporary authority to National Bureau of Animal Genetic Resources (NBAGR), Karnal in 2007. Subsequently in 2008, ICAR constituted a Breed Registration Committee (BRC) under the chairmanship of Deputy Director General (Animal Science), ICAR. This mechanism is the sole recognized process for registration of "Animal Genetic Resources" material at national level. Meetings of Breed Registration Committee are held from time to time and the applications received from stakeholders for the registration of their animal population as breed, are discussed. After including the newly registered breeds, total number of indigenous breeds now in the country is 160, which include 40 for cattle, 13 for buffalo, 26 for goat, 42 for sheep, 6 for horses & ponies, 9 for camel, 6 for pig, 1 for donkey and 17 for chicken.

The newly registered breeds: Kodi Adu goat, Chevaadu sheep, Nicobari pig, Kaunayen chicken

Patents applied for the technologies

i. A kit for parentage verification in Zebu cattle (Bos Indicus)

ii. A kit for parentage verification in camels (Single and Double Hump)

iii. A kit for Parentage Verification in buffaloes (Bubalus Bubalis)

iv. A kit for parentage verification in goats

v. A kit for parentage verification in Indian Ruminant Livestock

vi. PCR based DNA test for the differentiation of cattle and buffalo meat and milk

vii. QTLs for milk yield in buffaloes

viii. QTLs for somatic cell count in buffaloes

ix. QTLs for milk fat percent in buffaloes

x. QTLs for milk protein percent in buffaloes

Technologies Commercialized

i. A kit for parentage verification in buffaloes

ii. A kit for parentage verification in Zebu cattle (*Bos indicus*)

iii. A kit for parentage verification in camels (Single and double humped)

Services/Consultancies provided for

i. Breed registration of indigenous livestock/poultry populations.

ii. Literature on indigenous livestock in the form of Breed calenders, monographs, bulletins, leaflets etc.

iii. Cytogenetic screening of breeding males and DNA Testing for BLAD, Citru, FXID, DUMPS.

iv. Testing of cattle and buffaloes for the presence of A1/A2 allele.

v. High Performance Computing (HPC) system for bioinformatic, genomic, proteomic data analysis.

vi. DNA test for meat (cattle/buffalo) differentiation.

vii. Frozen semen of selected indigenous livestock breeds.

viii. DNA sequencing, microsatellite genotyping.

ix. Scientific training in the field of characterization and conservation of AnGR.

x. Planning and Policy making related to characterization an conservation of AnGR.

HRD /Awareness Programmes

NBAGR has been participating in some of the international programmes like:

- Preparation of Country Report on AnGR.
- National Plan of Action.
- FAO sponsored Regional Training Workshop.
- Guidelines for the Management of AnGR.
- SAARC-sponsored training programme

SAARC Training

Apart from this, to increase the awareness among stakeholders and their capacity building, the bureau has been regularly organizing the training programmes for the state AH officers, field functionaries, researchers in the field of characterization, conservation of AnGR, biotechnology, bioinformatics. Regular interactive meetings are held with state Animal Husbandry Departments to discuss their livestock breeding policies. So far, thrteen brain storming sessions have been held with different states to discuss the relevent issues. Trainings for the laboratory workers (technicals, attendents) have also been initiated.

Awards and Recognitions

Scientists of NBAGR have been recognized for their scientific contributions from time to time and were conferred with several institutional /individual awards, some of which are mentioned here:

- Biotech Product and Process Development and Commercialization Award
- Taradevi Modi Rashtra Utthan Award
- Rashtriya Vikas Jyoti Award
- Hari Om Ashram Trust Award
- Rafi Ahmed Kidwai Award
- Jawahar Lal Nehru Award
- Nature Conservator Award
- Young Scientist Awards
- Best Poster Presentation Awards

Academic Programmes

NBAGR is having Academic collaborations with many Indian universities including NDRI DU for which MOUs for training and research guidance of PG students as per ICAR guidelines have been signed. Under this programme, 16 Ph.D thesis and 164 M.Sc thesis/dissertitions have been submitted / awarded.

NBFGR: A Center for Aquatic Genetic Resource Management Research in India

Kuldeep K. Lal[1] and J.K. Jena[2]

[1]ICAR-National Bureau of Fish Genetic Resources (NBFGR), Canal Ring Road, Dilkusha, Lucknow - 226002, India

[2]Indian Council of Agricultural Research, New Delhi - 110012, India

1. Introduction

Efficient and sustainable utilization of aquatic genetic resources is considered as important to intensify aquaculture. Future need for intensification of aquaculture is necessary as it is expected that by 2030 additional 40 million tones will be required to meet the demand due to growing population and conscious towards use of health foods. Since the capture fisheries, especially marines are reached a plateau but aquaculture sector has grown close to 9 % per annum during the last two decades. However this is the result of intensification in the Asia-Pacific region. The intensification has also raised the serious concern due to limited availability of critical inputs and the adverse impact on biodiversity. Therefore, it has been hypothesized that the future course should be sustainable intensification of aquaculture, which produces more form less use of inputs and is biodiversity and environmental friendly. In this context the genetic resources have critical role to play especially the wild relatives of cultivable species.

With contribution of 5.3 million tonnes, aquaculture today shares over 55% of the country's fish production. Fisheries and aquaculture sector have been playing significant role in providing nutritional security for over 700 million Indian populations. The sector, besides known for its important role in livelihood security of coastal fishers and small-scale fish farmers, at present is recognized as an important industrial enterprise, providing precious foreign exchange.

Overexploitation of resources, habitat alterations, pollution of water bodies, destructive fishing, reclamation of river beds, construction of dams, entry of exotics and above all impact of climatic change have been leading to severe threat to both biodiversity and ecosystem stability in inland and coastal waters. Considering the enormous value of these aquatic ecosystems and the genetic resources they possess, it is necessary that due importance is given for their sustainable management and utilization.

2. Fish species diversity

A database on Indian fish diversity comprising of 2936 indigenous (1887 marine, 113 brackishwater and 936 freshwater and 462 exotic finfishes. In addition, the database also is available with consolidated lists of freshwater fishes found in the Western Ghats and north eastern hill region biodiversity hotspots. Checklists of macro fauna and flora of Gulf of Mannar Biosphere Reserve (3,065 species) and the Ramsar Site-Vembanad Lake (185 species) have been prepared.

The warmwater species those form the major fisheries in Indian waters are major and minor carps (*Labeo rohita, L. calbasu, L. bata, L. fimbriatus, Catla catla*, *Cirrhinus mrigala, C. cirrhosa, C. reba,* etc.*),* catfishes (*Clarias batrachus, Heteropneustes fossils, Sperata aor*, *S. seenghala, Wallago attu, Pangasius pangasius, Silonia silondia, Bagarius bagarius, Rita* rita*, etc.*), murrels and other important species (*Channa striatus, C. marulius, C. punctatus, Anabas testudineus, Chitala chitala, Notopterus notopterus*, etc.). There are many small west-flowing rivers originating from the Western Ghats are rich in fish diversity and harbour several endemic species.The aquatic resources in Himalayas, sub-Himalayan zone and mountains of the Deccan, with the water temperature remaining between 0 to 20°C are considered as coldwaters. The waterbodies of high altitude, especially the hill-streams possess a limited number of species diversity and most of them are small-sized. Important commercially important indigenous coldwater species are mahseers (*Tor tor, T. putitora, T. mosal, T. khudree,* etc.*)* and snowtrouts (*Schizothorax* and *Schizothoraichthys* species).

The important brackishwater fish species those distributed in major estuaries and brackishwater lakes are mullets, milkfish, pearlspots and seabass. Among the shellfishes, the shrimps (*Penaeus monodon, Fenneropenaeus (Penaeus) indicus*) and crab (*Scella serrata*) form the commercially important groups. The marine fisheries resources include commercially important finfish species like sardine, mackerel, tuna, seer fish, pomfrets, polynemids, Bombay duck, anchovies, Silver bellies, carangids, perches, catfishes, ribbon fishes, sharks, scates and rays; and shellfishes such as marine shrimps, lobsters and crabs.

3. Genetic resource conservation and management

Sustainable aquaculture growth warrants an equilibrium between use and conservation of natural resources. Conservation of aquatic biodiversity is important from the fact that bulk of our fish production still comes from the wild. Genetic resources can be viewed as genetic differences at three hierarchical levels of organization, *i.e.*, species, populations and individuals. At the highest level, species consist of populations that are reproductively isolated from populations of other species. Genetic isolation occurs because of geographic or behavioural isolation and, together with local adaptation, leads to evolution of novel genetic traits. As the process of speciation usually occurs in millions of years, once species are lost, several million years are required for species diversity to recover. Hence, it is necessary to have species-specific conservation and management plan. A species becomes prominent in conservation planning for a number of reasons: i) when it is declining due to anthropogenic stress in natural waters, ii) when it is crucial for the general well-being of it's ecosystem, or when it is endangered and chosen for recovery by special management measures. Sound knowledge about its biology, biogeography and genetic diversity, therefore is necessary for conservation of a declining species. At the population level of organization, the identification of discrete stocks has been a major theme in fisheries research. Further, the largest store of genetic variability in most species exists as genetic differences among individuals within a population. This variability arises from the physical assortment of genes among offspring during reproduction. Conservation of this genetic variability is the basis of effective population size, which has access to random mating and usually much smaller than census size. It has been shown that the loss of genetic variability happening due to drift is greater in small populations than in large populations. Hence, the goal of preserving genetic variability in a population coincides with the goal of maintaining large ecologically sound natural populations.

4. Conservation and Management Approaches

Several arguments have been posed to support the notion that the conservation of genetic resources is important in various settings and the justifications for conserving genetic diversity are necessary to ensure the future adaptability of natural populations; to preserve life-history, behavioural and morphological traits that ensure sustainable fisheries; to promote the use of genetic resources in commerce and medicine; and to conserve genetic diversity for cultural reasons. The fish genetic resource conservation and management in the country, therefore, involve several approaches, as follows.

4.1. Exploration of natural water bodies and documentation of fish diversity

Knowledge of species and communities can reveal crucial facts necessary for the management of ecosystems and habitats. In spite of the fact that the biodiversity assessment of most of the major river systems has been underway since last one century, several tributaries, rivulets and hill streams, especially in Western Ghats and North-eastern hilly regions have remained unexplored or under explored. In recent years over 40 species has been discovered only in these two regions of the country. Continued exploration of different water bodies are necessary to document not only the availability of fish species, but also to record their distribution and abundance pattern on time and spatial scale, so as to draw effective management/conservation plan in case of any threat to a particular species.

Identification, cataloguing and prioritization of species are important tasks in conservation. Availability of databases for finfish and shellfishes at country level and also at basin levels are necessary prerequisite for development of any genetic resource management plan. The database on Indian fish diversity developed by NBFGR is updated regularly to include newly described species and those exhibit new distributional ranges. In addition, it is being revised with the addition of crustaceans (prawns, shrimps and crabs) and molluscs. In addition, the availability of the databases on freshwater fishes of the Western Ghats and north eastern region, different states (Peninsular India - Kerala, Karnataka, Tamil Nadu and Maharashtra) and major rivers expected to help in conservation and management of resources of the region. Checklists of macro fauna and flora of Gulf of Mannar Biosphere Reserve and the Ramsar Site-Vembanad Lake have been prepared which would help in sustainable utilization and management of resources of the region. However, more efforts are necessary to develop databases for all major river basins and other important water bodies of the country.

Considering the constraints of limited availability of taxonomists in the country and inherent difficulties in conventional methodologies for species identification through morphology and meristic characters, new approaches like x-ray of hard structure and scanning microscopy have also been used. DNA based approach, popularly known as "DNA Barcoding" - DNA sequence analysis of a uniform target gene (Cytochrome Oxidase-I of mitochondrial genome) is the most recent and reliable approach to discriminate eukaryotic species including fish. The technique has been used globally to identify fishes and resolve taxonomic ambiguity, including discovery of new species. Barcoding offers a simple, rapid and reliable means of identification for not only of a fish, but of a fish fragments, eggs and larvae. NBFGR in recent years has barcoded more than 600 finfish species from freshwater and marine waters. This could be of great utility in sustainable exploitation, management and conservation of Indian fish species.

4.2. In situ conservation

In situ conservation is defined as conservation of species in its native habitat and invariably needs the conservation of ecosystems, natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings. In the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (Convention on Biological Diversity, Article 2) becomes native tract for the *in situ* conservation.. These programmes aim to develop strategies for the conservation of fish germplasm resources in their natural habitat through the integration of knowledge on fish and habitat diversity, habitat utilization, life history traits as well as human interference and other socio-economic issues. The major advantages of *in situ* conservation are: (i) continued co-evolution wherein the wild species may continue to co-evolve with other forms, providing the breeders with a dynamic source of resistance that is lost in *ex situ* conservation, and (ii) national parks and biosphere reserves may provide less expensive protection for the wild relatives than *ex situ* measures. Such conservation efforts can be meaningful only with people's participation through mass awareness programmes and involving the stake holders. In India, the protected area covers about 5.2% of the total land area, including 5,456 sites, and nine threatened fish species inhabiting these areas (IUCN).

4.3. Captive breeding and ranching programmes

Captive breeding programmes have become the major tool used to compensate the declining fish populations and simultaneously to supplement as well as enhance yields of wild fisheries. While commercial breeding and seed production has been achieved in major carps, a few minor carps and barbs (*Labeo fimbriatus, L. gonius, Puntius sarana*) and catfishes (*Clarias batrachus*), greater thrust is yet necessary for development of protocol for mass-scale seed production of several other important candidate species for aquaculture diversification. Several of these are threatened in their natural habitat too, which include *Chitala chitala, Ompok pabo, O. pabda, O. malabaricus, Labeo dussumieri, Semiplotus semiplotus, Clarias dussumieri, Channa diplogramme, Nandus nandus, Barbodes carnaticus*, *Puntius sarana,* etc. Considering the increased popularity of ornamental fish at household level and to curb indiscriminate exploitation from wild, captive seed production and rearing technology of 15 indigenous species having export potential such as *Pristolepis marginata, Horabagrus nigricollaris, Chela fasciata, Danio malabaricus, Puntius filamentosus, P. fasciatus* and *Mesonemachilus triangularis* have been standardized by the College of Fisheries, Kochi in a joint programme with NBFGR. However, captive breeding and domestication of more native species such as *Puntius denisonii*, *P. chalakkudiensis*, *Labeo nigriscens* and *Channa barca* need to be developed on a priority basis.

For a successful stocking programme, it is necessary that the genetic structure of the original wild population is determined. With the help of hypervariable molecular markers such as microsatellites, general information about the genetic diversity of fish populations can be established. This information can guide in decision making regarding source of broodstock to be used for ranching purposes. By ensuring that the stocked population is represents same genetic makeup as the wild population, reintegration of the stocked fish will likely be more successful and deviations from the original genetic structure will be minimal. NBFGR in a joint programme with the RARS, Kumarakom, Kerala successfully carried out stock-specific, breeding-assisted river ranching of two fishes (*Horabagrus brachysoma* and *Labeo dussumieri*) in Kerala; the landings of *H. brachysoma* after two years increased from 1.8% to 11 % and that of *L. dussumieri* showed an increase from 0.68% to 3.9% of the total-landings from the Vembanad Lake and adjacent rivers in the state.

4.4. Live Germplasm Resource Centers

A ***Live Germplasm Resource Centers*** can help to rehabilitate the threatened fish species through using captive breeding technology and restocking to assist species-specific recovery programmes. Such ***Live Germplasm Resource Centers*** can contribute to recovery and utilization of genetic diversity and can be uses in conservation programmes and genetic enhancement. NBFGR has established a ***Live Germplasm Resource Centers*** at Lucknow holding species of high conservation significance and with the objectives of (i) collection of threatened, endangered, and rare fish species and management of their stocks under farm conditions, (ii) study of growth, maturity, survival, and adaptability of these species in controlled conditions, and (iii) study of the life history traits of the threatened species as a tool for *in situ* and *ex situ* conservation. A strategic action plan has been made by NBFGR to establish five regional live gene banks in collaboration with other ICAR fisheries research Institutes and NGOs under the Consortium Research Platform (CRP) project of ICAR during the 12th five year plan.

4.5. Cryopreservation of fish gametes

Storage of fish spermatozoa, eggs and embryos without loss of viability is of considerable value in aquaculture and conservation. The fish sperm cryopreservation needs development of species-specific protocols. Such protocols are developed through experimental standardization of various parameters, after the captive breeding protocol is developed. This becomes a bottleneck due to protracted breeding season and low domestication of most of the aquatic species, especially marine fishes. Nevertheless, in all such cases, time available in a year for conducting experiment is small and determined by breeding cycle of the species. In view of the constraint, it is essential that candidate species for sperm cryopreservation are prioritized. Species-specific sperm cryopreservation protocols have been developed for over 30 fish species including*, Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo dyocheilus, Oncorhynchus mykiss, Salmo trutta fario, Cyprinus carpio, Tenualosa ilisla, Tor khudree, Tor putitora, Labeo dussumieri, L. dero, Horabagrus brachysoma, H. nigricollaris, Barbodes carnaticus, Puntius sarana subnasutus, Garra surendranathanii, Clarias batrachus, Heteropneustes fossilis, Ompok malabaricus* and *Gonoproktopterus curmuca.* Inadequate milt production or asynchronization in maturity of two sexes being an issue for induced breeding in several cultivable species, cryopreserved sperm can be effectively utilized to overcome from such milt related problems.

Fish gamete cryopreservation research still faces an important challenge in the form of long-term storage of fish eggs and embryos except the minute fertilized abalone eggs. Owing to large size, large amount of yolk and tough chorion or zona radiata with a low permeability coefficient, egg and embryo cryopreservation of teleosts and crustacea have not met with success anywhere in the world so far.

4.6. Tissue and cell line banking

Tissue banking is a fast mode of storing the biological material for longer durations and it can be used to retrieve genetic information and genetic manipulation studies in future. Tissue repository accessions unlike sperm banking protocol do not require species-specific protocol and at NBFGR, emphasis is given to build up tissue accessions of endemic fish species of the biodiversity hotspot regions such as the Western Ghats and North-eastern region. Nearly, 15000 tissue accessions of freshwater and marine fish species collected from mainland and island ecosystems are maintained in the tissue bank. NBFGR is also planning to establish a network of researchers across the country so that tissue accessions of all fish from different ecosystems can be made.

Development of fish cell lines, embryonic stem (ES) cells and germ cells from Indian fishes and cloning technology as an alternative to long-term storage of finfish eggs and embryos has been emphasized. Successful protocols for grafting of embryonic cells to host embryos, for germline transmission of desired genome can be instrumental in evolving effective programmes for production of transgenics and rehabilitation of endangered species. Significant success has been achieved in development of fish cell lines, especially from different tissues of commercially important and indigenous fish species by different laboratories in the country including NBFGR. A national Repository for Fish Cell Lines has been developed at NBFGR with the financial assistance of Department of Biotechnology (DBT), Govt. of India which possess over 50 fish cell lines.

4.7. Genetic characterization

The primary objective of the genetic characterization is to assess the distribution and pattern of genetic variability at intra as well as inter-specific level populations, through the use of identified genetic markers. The first priority for such research is identification of appropriate genetic markers to assess the genetic diversity. The conclusions from genetic diversity data have varied application in research on management and conservation of fish species, to understand the pattern of migration of fish stocks, nature of breeding populations and also in taxonomy/systematics. Several marker types are highly popular in aquaculture/fisheries genetics. In the past, soluble proteins, gene products (allozymes) and mtDNA markers have been popular; more recent marker types that are finding service in this field include restriction fragment length polymorphism (RFLP), randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), microsatellites, single nucleotide polymorphism (SNP) and expressed sequence tag (EST) markers. The choice of markers is crucial in achieving precise information that is useful for desired application. Concerted effort has provided description of genetic variation and population structure for 24 prioritized fish species from their major range of natural distribution. These species include *Tor putitora, Catla catla, Cirrhinus mrigala, Labeo rohita, L. calbasu, L. dero, L. dyocheilus, L. dussumieri, Clarias batrachus, Chitala chitala, Tenualosa ilisha, Puntius denisonii, Horabagrus brachysoma, Gonoproktopterus curmuca, Channa marulius, Etroplus suratenesis*, *Notopterus notopterus, Harpodon nehurus, Rachycentron canadum, Pampus argenteus, Colia dussumieri, Panulirus homarus, Macrobrachium rosenbergii,, Fenneropeneaus indicus,* The study covered wide geographical area and used microsatellites, allozyme & RAPD markers. Distinct population structure was observed in many of these species indicating that propagation assisted restoration programmes must be stock-specific to replenish declining populations. The taxonomic status of endangered mahseers,in India was validate using mitochondrial markers. The study provided first evidence of extended distribution of T.putitora lineage in the rivers originating from central plateau. *T. tor* was discovered beyond Narmda river in the Godavari river system. The study could successfully rediscover *T. mosal* in its type locality, as valid species, coninhabiting with golden mahseer in tributaries of Ganga river system. *Tor malabaricus* from the Western Ghats was revalidated by mitochondrial and nuclear gene sequence analysis, RAPD assay and morphometric measurements.

The routine population genetic studies using neutral/type II molecular markers, though useful in devising conservation strategies, reveals little about the adaptive side of the evolutionary coin.. The link of “population genomics” with aquaculture will be capable of providing large-scale facilities for conducting controlled experiments, allowing the establishment of the ‘missing’ links between DNA polymorphisms, trait architecture and environmental driver of evolution. Population genomics can be broadly defined as the simultaneous study of numerous functional gene loci or genome regions often using genome scans that examines genetic divergence at these loci within and among populations in time and space to identify and to separate locus-specific effects (such as selection, mutation and recombination) from genome-wide effects (such as drift or bottlenecks, gene flow and inbreeding).The degree of genetic divergence is often measured using fixation indices such as F_{ST}, with larger index values representing greater differentiation between populations. The two main principles of population genomics are that (i) *neutral loci* across the genome will be similarly affected by demography and the evolutionary history of populations, and (ii) the loci under selection will often behave differently and therefore reveal ‘*outlier*’ (adaptive) patterns of variation. A major programme that cover population genomics of *Tenualosa ilisha* is making progress.Accordingly, there is large interest in demonstrating adaptive population divergence at the molecular level, as well as in identifying the genetic architecture of local adaptive traits conferring fitness advantages to resident individuals of species that are in aquaculture. Under the programmes on functional genomics, genes associated with immune response and hypoxia tolerance were studied in *Clarias batrachus*.Efforts have been initiated in NBFGR to decipher the whole genome sequence information and on population genomics of prioritized species in a consortium mode.

4.8. Impact of exotics and Development of quarantine facilities

While exotic silver carp and common carp have shown their potential as important candidates in carp polyculture systems, their accidental entry or deliberate introduction into some of the reservoirs, have caused severe threat to the indigenous fish fauna. Entry of tilapia all across the country and its overpopulation found to affect the fisheries of several reservoirs and lakes in Tamil Nadu, Kerala, Karnataka and Rajasthan, and also several river systems, including the Ganga. The African catfish, *Clarias gariepinus* has caused serious concern due to its highly predatory and cannibalistic feeding habit. The species has been reported from several open waters including the River Ganga in recent years thereby posing serious threat to the natural biodiversity.

Entry of several exotic pathogens with the regular import of germplasm into the country, especially fish/shrimp seed and ornamental fishes has been a concern over the years due to lack of adequate quarantine facilities in the country, which have been posing incidence of serious disease threat. While a few quarantine facilities have been created in recent years by the Government of India and by private entrepreneurs, much more such facilities need to be created. To safeguard our indigenous fish genetic resources from infectious exotic diseases and to develop effective protocols for fish quarantine, NBFGR is actively engaged in the upgradation of facilities and expertise. The NBFGR has already developed the rapid diagnostic capability for detecting the eleven fish OIE listed pathogens using molecular and immunological tools. The bureau has also succeeded in developing monoclonal antibodies against rohu, which will be extremely useful in serodiognostics for pathogen surveillance in aquaculture of Indian major carps.

5. Conclusion

The diverse fish germplasm of the country - a rich biological wealth, needs effective management strategies for sustainable utilization in future years and also posterity. Prospects for the conservation of fish germplasm and future strategy have to be drawn up based on past growth and the potential for future expansion, taking into consideration likely availability of funds, infrastructure and trained manpower, the impact of research data monitoring on fish germplasm and resource conservation. Maintaining the genetic health of the fisheries wealth is equally important for up-scaling aquaculture production and sustaining the fish yield from natural waters. Therefore, conservation needs must be aimed towards preserving existing biodiversity and also the evolutionary processes that foster biodiversity. The conservation of fish diversity and aquatic resources of the country requires concerted efforts by integrating capture, culture fisheries and environmental programmes using latest technological innovations. A holistic strategy is necessary to be in place to tackle the issues in inland and marine fisheries pertaining to biodiversity loss and depletion of fish stocks. It is expected that research programmes on the priority areas in consortia mode involving different research organizations, developmental agencies and other stakeholders would generate meaningful information with respect to sustainable utilization of fish genetic resources and management fisheries.

ICAR-National Bureau of Agriculturally Important Microorganisms

Anil Saxena

Director, ICAR-National Bureau of Agriculturally Important Microorganisms, Mau Nath Bhanjan, Uttar Pradesh - 275103, India

Microbes are a vital living component in agriculture playing an important role in the overall well being of the agro-ecosystem as well as crops, animal and human health. India is home to billions of microbes, many of which are found nowhere else in the world. Interest in the exploration of microbial diversity has been spurred by the fact that microbes are essential for life since they perform numerous functions essential for the biosphere that include nutrient cycling and environmental detoxification. The exploited microbial activities are augmentation, supplementation and recycling of plant nutrients, so vital to sustainable agriculture. Microbial diversity and its richness to the environment provide a huge reservoir of resources, which we can utilize for our benefit. Therefore, cataloguing and preservation of agriculturally important micrflora, become necessity of the present time for judicious microbial resource management, bio-prospecting and fundamental scientific research. The importance of microbes in various spheres of agriculture was realized by the Indian Council of Agricultural Research and as a result ICAR- National Bureau of Agriculturally Important Microorganisms (NBAIM) was established by the council in the IXth Five Year Plan in the year 2001 under the aegis of Department of Agricultural Research and Education (DARE), Govt. of India. The Bureau started functioning at Old NBPGR Building, New Delhi. The ICAR-NBAIM shifted on 1, June 2004 to the campus earlier occupied by the National Institute of Sugarcane and Sugar Technology (NISST) at Kushmaur, Mau Nath Bhanjan, Uttar Pradesh. During the XIth plan, ICAR- NBAIM was designated as a Recognized Repository under the National Biodiversity Act (2002) for storing microbial wealth in India and in 2014, the Bureau acquired ISO 9001:2008 certification. It is among one of the premier organizations of agricultural and microbial biotechnology prioritizing its responsibilities in the area of collection, isolation, conservation, management and utilization of agriculturally important microorganisms (AIMs) in the country. ICAR- NBAIM functions under the administrative control of the Crop Sciences Division of the ICAR.

The mandate of the ICAR-NBAIM is "*To act as the nodal Institute at national level for acquisition and management of indigenous and exotic microbial genetic resources for food and agriculture, and to carry out related research and human resource development, for sustainable growth of agriculture*".

The Bureau is engaged in the multifarious activities in the area of microbial diversity, biological control, microbial genomics, preservation and maintenance of microbial cultures. The Bureau is also engaged in supply of pure cultures to various research organizations and provides microbial identification services. Developing the technical and scientific skills among the researchers, scientists, students and industry people through education and training for the molecular identification and characterization is among the prime aims of the Bureau and it is making significant progress in this area with commendable dedication.

The Bureau has fully established instrumentation facilities and working laboratory infrastructure to work in the domain of collection and conservation of microorganisms, microbial biotechnology, genomics and bioinformatics, proteomics and metabolomics, plant microbe interactions, microbe mediated alleviation of biotic and abiotic stresses and development of microbial bioformulations. NBAIM has established and strengthened National Agriculturally Important Microbial Culture Collection (NAIMCC) which is an affiliated member of World Federation of Culture Collection (WFCC). NAIMCC has state-of-the-art facilities for short term and long term conservation of microorganisms with more than 6500 preserved accessions of fungi, bacteria, actinmoycters, cyanobacteria and archaea. The Bureau is domain partner for High Performance Computing System (HPC) and development of Bioinformatics grid at the Bureau. The HPC infrastructure has been established at NBAIM to cater the need of high performance computing in the field of agricultural bioinformatics and computational biology.

The Bureau is coordinating a mega-network project on 'Application of microorganisms in agriculture and allied sectors' formulated in Xth Plan to strengthen the R&D efforts on various microbe based technologies that can be utilized to increase crop production, utilize agrowaste, manage abiotic stress, biocontrol of important insect pests and post harvest technology. It also seeks to strengthen research in the area of microbial diversity, identification and genomics.

Milestones in the Journey of a Decade

Microbial diversity

The NBAIM since its developmental phase has played an important role in isolation, preservation and characterization and utilization of Agriculturally Important Microorganisms (AIMs), microbial biodiversity and systematics. To explore and conserve the microbial diversity of country, the Bureau has successfully completed several exploratory missions and extensive surveys for the collection of samples from different habitats. From being a bureau primarily concerned with microorganisms today NBAIM plays a key role in the overall management of microbes in India. Some rare types/ endangered species of microbes of agricultural importance have been isolated and preserved. Over 1800 fungal species of Indian origin is under the process of repatriation from CABI, UK of which 1100 cultures have already been repatriated. Some useful AIMs available at NBAIM consists of (i) biocontrol agents: *Trichoderma* spp., *Paecilomyces thermoascus, P. lilacinus, Beauveria* spp., *Gliocladium verens, Verticillium* spp.; (ii) biopesticides: *Beauveria* spp., *Metarhizium* spp., *Paecilomyces* spp., *Verticillium* spp., *Nomurea* spp.; (iii) plant growth promoters: *Pseudomonas fluorescens, Bacillus subtilis* (iv) potential enzymes/antibiotics/toxins producers: *Fusarium pallidoroseum, F. oxysporum, Pencillium citronum, Aspergillus sp. (v)* entomopathogenic: *Beauveria* spp., *Metarhizium* spp., *Verticillium* spp., *Nomuraea* spp.; (vi) egg parasitic fungi: *Paecilomyces lilacinus, Verticillium chalamydosporium*; (vii) mycoparasitic fungi: *Gliocladium* spp. (vii) bacteria possessing nematicidal and insecticidal properties: *Bacillus brevis, Paenibacillus alvei, Brevibacillus laterosporus;* (viii) biofertilizers: **s**pecies of *Rhizobium, Azospirillum* and *Azotobacter.* Software designated as 'MicroNBAIM' was developed for the digitization of microorganisms. Digitization of data of about 30,000 fungal species was carried out under NATP funded project on "**Digitization of fungal species of Indian Origin"** under UK-CABI work plan". The first catalogue of strains at NBAIM repository is published with all the details of microbial cultures, their source, the name of the depositor, the media required for growth and growth conditions.

Extreme environments represent a unique ecosystem which harbour novel microbial flora. India is one among 12 mega-biodiversity countries and 25 hotspots of the richest and highly endangered eco-regions of the world. Samples were collected from several extreme environments and a huge database and baseline information on native microflora was generated. *Penicilliopsis clavariiformis* AP, a rare salt tolerant fungus reported for the first time from India was identified through polyphasic taxonomy. Based on the sequencing some of the rare isolates identified were *Acinetobacter venetianus, Exiguobacterium indicum, Exiguobacterium lactigenes*, *Vibrio metschnikovii, Alishewanella sp., Pseudomonas frederiksbergensis, Planococcus donghaensis, Paenibacillus terrae, Arthrobacter sulfurous, Rhodococcus qingshengii, Microbacterium oxydans*, *Rhodococcus qingshengii, Bacillus drentensis, Bacillus pocheonensis, Bacillus aestuarii, Bacillus arbutinivorans, Thalassobacillus devorans, Halomonas campisailis*, *Marinobacter alkaliphilus, Marinobacter hydrocarbonoelasticus, Halomonas variabilis, Alteromonadales bacterium, Nitrinicola lacisaponensis, Chromohalobacter salexigens, Marinobacter aquaeolei, Ochrobactrum sp.* and *Tsukamurella sp.* Bacterial species tolerant to high salinity (25% NaCl), high (90°C) and low temperature (4˚C) and acidic pH (4) were identified. Novel psychrotolerant species of fungi viz. *Thelobacter* sp., *Asordina sibutii*, *Geomyces* sp., *Penicillium* sp., *Ulocladium consortiale* and *Ulocladium* sp. were also identified.

***Fig:** Colony morphology of bacteria isolated from extreme environments*

Diversity analysis of northern Indo-Gangetic plains clearly indicated that the soils do have a population of *Bacillus* isolates and fluorescent *Pseudomonas* in high numbers but the isolates/strains have lost the ability to express plant growth promoting attributes. This study provided some microbiological reasons for the reduction in productivity under rice- wheat cropping system in IGP. Majority of the actinomycetes isolated from the country belonged to different species of *Streptomyces* and few to *Micromonospora* and *Nocardia*. First systematic diversity analysis study on methylotrophs in the country was taken up and led to the identification of many novel species. The diversity of *Bacillus* and predominant genera has been mapped by this Bureau and novel *cry* genes with insecticidal properties have been deciphered.

Nutrient management, growth promotion and biocontrol

Microorganisms are pool of genetic resources for application in agriculture, and correspondingly they confer huge variety of functions beneficial to plant. The Bureau has made significant progress in this direction and has developed bioformulations to be used as biofertilizers, biocontrol agents, abiotic stress alleviators, agricultural residue decomposers etc. Four psychrotolerant bacteria identified as *Pseudomonas arsenicoxydans* P1; *Pseudomonas koreensis* P2, *Pseudomonas koreensis* P3 and *Paenibacillus dendritiformis* P4 were developed as plant growth promoting bacteria that could remarkably enhance dry biomass in chickpea, maize and wheat. Coinoculation of two strains *Bacillus subtilis* and *Arthrobacter* sp. were identified for alleviation of the adverse effects of salinity on wheat growth. A biopriming technique was developed for the coating of rice seeds with potential cyanobacterial strains (*Plectonema boreanum, Anabaena doliolum, Nostoc commune* and an equi-proportional mix-culture of these three strains) and field trials on eight rice varieties led to an increase of 5.3 to 7.9% in grain yield among different varieties. Besides using individual microorganisms, consortia based formulations are also developed for growth and yield enhancement in vegetables, cereals and pulses. Three bioformulations of *P. fluorescens, T. harzianum* and *T. viride* namely Eco-Pesticide (Talc based bioformulation of *Pseudomonas fluorescens*); Eco-Green Fungicide (Vermi-based bioformulation of *T. viride*) and Green Fungicide (Talc based bioformulation of *Trichoderma harzianum*) respectively, were developed successfully and found effective against a number of soil and seed borne pathogens. A fly ash based bioformulation of *Trichoderma harzianum* and *Bacillus amyloliquefaciens* named 'Bio Pulse' has been developed and evaluated for control of *Fusarium* wilt in chickpea. Treatment with formulation could suppress wilt disease by 40% and increased the grain yield by 15% in chickpea on farmers' field. Two bacterial consortia consisting of P solubilizing bacteria, siderophore and IAA producing bacteria named 'BIOGROW-I' and 'BIOGROW-III' were evaluated for growth promotion and nutrient management in cereals, tomato and chickpea. In tomato, 25-30% increase in yield was recorded besides significant improvement in nutritional quality as evident from enhanced content of lycopene and β-carotene.

***Fig:** Evaluation of Biogrow on tomato*

The Bureau has set up a bioformulation unit and geared up to commercialize the bioformulations to the farmers. It was set up for the supply of liquid inoculants: NPK providing consortium; BioGrow; P solubilizing bacteria; K solubilizing bacteria; Zn solubilizing bacteria and *Rhizobium* for different pulse crops. Many of the microbe based technologies are in the process of validation through linkages developed with many of the crop Institutes of ICAR; SAUs and AICRPs.

***Fig:** Liquid formulations of bioinoculants supplied from ICAR- NBAIM*

Molecular markers and microbial genomics

Development of molecular markers for the diagnostics of different pathogens and beneficial microorganisms has been one of the important activities with remarkable achievements. DNA based diagnostic kits were developed for the identification and ecological monitoring of *Bacillus*, *Pseudomonas, Alternaria, Colletotrichum, Fusarium udum* and *Macrophomina phaseolina*.

In the past years, the Bureau has completed the draft genome sequencing of *Mesorhizobium ciceri* strain Ca181. This was a first attempt in the country to sequence the genome of the bacterium. Recently, the draft genome sequencing of *Pseudomonas koreensis*, *Brevibacillus borstelensis* and Staphylococcus *xylosus* strain has also been completed.

The High Performance Computing (HPC) facility has facilitated various genomic, metagenomic and proteomic data analysis, compilation and storage. Comparative analysis and functional genomics profiling of 84 cyanobacterial genomes were conducted using different parameters to establish linkage between functional pathways and gene networks with ecological adaptation in these organisms. The facility has also facilitated metagenomic data analysis of 25 wheat rhizosphere soil metagenomes in collaboration with ICAR-CABin, IASRI, New Delhi.

The Bureau is conserving the genomic resources of microorganisms and established the Microbial Genomic Resource Repository (MGRR). Over 10000 accessions of genomic DNA, clones, plasmids, vectors and gene constructs from various sources are being maintained under MGRR.

Capacity Building

The Bureau has a very strong component of capacity building of researchers, scientists, faculty members of universities and research students in the areas of microbial molecular biology, biotechnology, genomics, proteomics and bioinformatics. More than 1,000 researchers have been trained in different National and International trainings conducted by the Bureau in the last decade. Specialized training in the area Microbial diversity and identification; diversity analysis of extremophiles; DNA sequencing; Bioinformatics in conservation of microorganisms; bioinformatic tools; detection of viruses were carried out. Capacity building and awareness programs for the local farmers led to the development of their skills in the bio-organic farming, applications of biological inputs in the farms, *in situ* conservation of microbial diversity in the agricultural farms, promotion of low-input farming practices, reduced use of chemical fertilizers and microbe-mediated plant growth promotion.

Recognitions

- NBAIM was designated as a Recognized Repository under the National Biodiversity Act (2002) for storing microbial wealth in India and in 2014, the Bureau acquired ISO 9001:2008 certification. NAIMCC is an affiliate member of World Federation of Culture Collection (WFCC).
- The Bureau is coordinating a mega-network project on 'Application of microorganisms in Agriculture and allied sectors' formulated in Xth Five Year Plan to strengthen the R&D efforts on various microbe based technologies.
- The Bureau is recognized by Central Insecticide Board and Registration Committee (CIB & RC) for DNA fingerprinting of microbial strains registered and to be registered as biopesticides.
- Ganesh Shankar Vidyarthi Hindi Patrika Award for ''Sukshma Jeev Darshan'' in 2013-14

Patents filed

1. A method of high throughput fungal DNA template preparation and uses thereof. [Indian Patent Office No. 1170/DEL/2015]- Applicant: ICAR
2. A method of detection of *Alternaria* spp. and uses thereof. [Indian patent office No. 1287/DEL/2015.] Applicant: ICAR

Future Plans and Way Ahead

Agriculture faces the unprecedented challenge of securing food supplies for a rapidly growing human population, while seeking to minimize adverse impacts on the environment. Recent reports indicate that crop growth and yield are adversely affected by abiotic and biotic factors including weather (rain, heat and temperature), soil conditions (water, pH and nutrients), insect populations, disease incidence and management practices (cultivar, irrigation, fertilization and rotation). These factors represent the principal cause of crop failure, decreasing average yields for major crops. A better understanding of the different conditions and features of the interrelationships in the soil-plant microorganism system is needed to improve the efficacy of plant growth promoting inocula applications in the field. Most microbial inoculants developed to date have been designed for annual crops (mainly legumes, cereals, and some vegetables etc.). However, there is an increasing demand from other allied sectors such as fruit and vegetable production, and particularly from organic farming and integrated production systems, where synthetic chemical inputs are not allowed. Soil-less and protected crops can also be an emerging market for commercial inoculants, where the predictability of microbial applications should be higher than in open fields due to the use of inert substrates and controlled growth conditions. The selection of specific strains for all these crops can further expand the market for inocula and support the shift in agriculture toward more sustainable production systems. The future challenges in selecting microbes for agricultural application are related to the attempts at alleviating biotic and abiotic stress conditions in crops (i.e., drought, salinity, inorganic, and organic pollutants) and improving food quality. Improvements in the production process for consortia of microbial inocula, the development of new carriers based on nanoparticles, optimization of application devices and of the time of application for poly-annual crops, are all issues requiring further research to widen the implementation and efficient use of microbes in agriculture.

Though a good number of culture collections exist in India, still coverage of microbial diversity is sparse. The enormous functional microbial diversity across the country also needs to be deciphered, documented, properly conserved in repositories and utilized to interweave microbes in agriculture and other sectors. Especially, developing the strategies to tap the uncultured microbial diversity and to culture them under laboratory conditions are some of the major challenges for the Bureau in the area of microbial diversity.

The ICAR-National Bureau of Agricultural Insect Resources: Spotlighting the Pivotal Role of Insects in Agro-ecosystems

Chandish R. Ballal

Director, ICAR-National Bureau of Agricultural Insect Resources, Bellary Road, Bengaluru, India

The ICAR- National Bureau of Agricultural Insect Resources (NBAIR), formerly National Bureau of Agriculturally Important Insects (NBAII) is located at Bangalore, in the same premises at which the Commonwealth Institute of Biological Control (CIBC), Indian Station was established in 1957. The advent of the CIBC Indian station marked the beginning of organized and systematic biological control research in India. During this period, our knowledge of natural enemies of crop pests and weeds increased manifold. In 1987, the CIBC Indian station was closed to be replaced on the same campus by the headquarters of the All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP-BC&W) (launched in 1977, originally housed in the Indian Institute of Horticultural Research, Bangalore, under the aegis of the Indian Council of Agricultural Research).

The centre was named the Biological Control Centre and the entire programme functioned under the administrative/financial control of the National Centre for Integrated Pest Management (ICAR), New Delhi. In 1993, during the eighth Five-Year Plan, the project was elevated to the independent Project Directorate of Biological Control (PDBC), with its headquarters in Bangalore. PDBC became the nodal agency in the country spearheading biological control research with 16 centres spread across the country. The Directorate at Bangalore carried out basic research on the biosystematics of important groups of insect bioagents. The reference collection maintained at PDBC was catalogued in the form of a technical bulletin which is also available in a retrievable, electronic format. In addition to systematics, research work at PDBC was intensified on strain development, molecular characterization, standardisation of mass production technologies for bio-agents and semiochemicals leading towards insect and disease management in agricultural and horticultural crops. The National Bureau of Agriculturally Important Insects (NBAII), a re-oriented organisation of the erstwhile PDBC came into being during the XI Plan in 2009. In the twelfth Five Year Plan the Bureau was re-named the National Bureau of Agricultural Insect Resources (NBAIR) to act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites and spiders) for sustainable agriculture. This institute is also recognized as a National repository for insects, spiders and mites by the National Biodiversity Authority, Govt of India.

The ICAR-NBAIR caters effectively to the needs of students, researchers and the farming community of our country. In spite of being the youngest Bureau in ICAR, NBAIR has shouldered the onerous task of documenting *in toto* the agricultural insect and related arthropod diversity of the country including associated organisms. It is a matter of pride for NBAIR as this young Bureau has been adjudged the best Institution under the small institution category and won **the Sardar Patel outstanding ICAR Institution Award 2015**.

NBAIR is also mandated to play a major role in capacity building, dissemination of technologies; in conducting on-farm validation of biocontrol strategies, forging linkages with commodity based crop research Institutes, AICRPs/ AINPs.

The major objectives of ICAR-NAIR are:

- To explore, identify, characterize, conserve and utilize the biodiversity of beneficial insect resources
- To act as the nodal agency for national and international exchange of beneficial insects
- To develop digitized inventories, information storage and retrieval systems
- To undertake consultancy and human resource development for exploitation of insect resources
- To create public awareness, flag policy issues and enable framing of guidelines for harnessing beneficial insect resources.

The above research objectives of the Bureau are accomplished under three divisions: Division of Insect Systematics, Division of Molecular Entomology and Division of Insect Ecology, each division holding specific mandates. The Division of Insect Systematics focuses on: Augmentation of collections and maintenance of a national repository; biosystematic studies on insects, spiders and mites using traditional and molecular approaches and DNA barcoding; generation of checklists, catalogues, illustrated field identification guides and digitization of collections, networking of institutions and individuals working on biosystematics and identification services. The Division of Molecular Entomology focuses on whole genome sequencing of some important insects and entomopathogenic nematodes; gene and allele mining for the selection of genes of specific interest and their utilization; RNAi technology for IPM; genome sequence repository for useful genes; endosymbionts and determination of their functional role; use of bioinformatics tools and development of genomic databases. In order to fulfil its mandated activity on bio-intensive management of insect pests, the Division of Insect Ecology has taken up the work on classical biological control, biosecurity threat perception with action-plan for alien pests; utilization of agriculturally important arthropods for the management of insect pests; development of protocols and designs for the establishment of state of art mass production units for beneficials; research on effect of climate change on pests and natural enemies; role of pollinators in crop productivity; role of semiochemicals for insect pest management and on virus-vector dynamics.

The NBAIR with its core capabilities in biosystematics, ecology, molecular profiling of arthropods, biological control and bioinformatics of insects of agricultural significance has succeeded in the identification of more than a hundred new species, development of web based identification tools for several insects of agricultural importance; development of DNA barcodes for around 725 insects and their resources and development of twenty two widely used databases on different aspects of Indian insects. In addition to the above, it has developed production protocols for 150 insects and related resources, which besides providing support to entomological research, also enables the management of pests through biological means. NBAIR houses the largest repository of 118 beneficial and other insects and 584 microbials, which are supplied throughout the country for research and biocontrol of pests. This Bureau strives to popularise the concept of non-chemical methods of pest management through field demonstrations on the utilization of promising parasitoids, predators and insect derived resources in different agroecological zones of the country. The ICAR-NBAIR is the sole institution in the country combining an array of entomological capabilities from the identification of insects – be they pests or natural enemies – to the development and formulation of strategies for the management of crop pests utilizing non-pesticidal means.

NBAIR has been successful in implementing programmes for the biocontrol based management of the papaya mealybug, eucalyptus gall wasp, sugarcane woolly aphid, borers in rice and sugarcane, to cite a few examples. Twenty one novel technologies have been developed for pest management and transferred to 18 commercial enterprises. These successes have imbued in us the optimism to garner and develop more farmer and environment friendly technologies to manage several of the pests.

The following are the farmer friendly technologies developed by NBAIR:

- Multiple insecticide tolerant strain of the egg parasitoid, *Trichogramma chilonis*
- High temperature tolerant strain of the egg parasitoid *Trichogramma chilonis*
- Pesticide tolerant strain of the aphid lion, *Chrysoperla zastrowi sillemi*, an important predator of sucking pests
- Novel insecticidal WP formulations of *Heterorhabditis indica* for the biological control of white grubs and other soil insect pests
- Novel insecticidal WP formulations of *Heterorhabditis indica* for the biological control of white grubs and other soil insect pests
- Novel wettable powder formulation of *Pochonia chlamydosporia* as bionematicide against plant parasitic nematodes
- Liquid formulation of *Bacillus thuringiensis*
- Closed system for mass production of predatory mites (*Neoseiulus indicus*)
- EugaLure: A dispenser for the monitoring of eucalyptus gall wasp (*Leptocybe invasa*)
- Bioformulation of salinity tolerant *Trichoderma harzianum* with biocontrol potential
- Bioformulation of carbendazim tolerant *Trichoderma harzianum* with biocontrol potential
- Powder based formulation of *Bacillus megaterium* as growth promoter and management of bacterial wilt disease
- A plant volatile based attractant for enhanced attraction of fruit fly
- Promising plant growth promoting strain of *Bacillus megaterium* for vegetable crops
- A simple technique of rearing brinjal shoot and fruit borer, *Leucinodes orbonalis*
- A semi solid formulation of dispenser for trapping mango fruit fly (*Bactrocera dorsalis*) for surveillance
- Protocol for designing lure for impregnating parapheromone 4[4-acetoxy] phenyl-butanone to attract male flies of *Bactrocera* spp. attacking cucurbit crops for mass trapping and monitoring its population
- Control release dispensers for semiochemicals
- Mass production of *Trichogramma chilonis* and *Trichogramma embryophagum* using *eri* silkworm (*Samia cynthia*) eggs.
- A herbal based repellant for termites on woody trees
- Sealer cum booster for the management of borer pests in coffee

This young Bureau is moving forward with a broad vision. It is geared up to community analysis of the biodiversity of insects in agricultural and natural ecosystems and is aiming at establishing a repository of at least one lakh identified and curated Indian insects, besides barcodes and other relevant bioinformation. Of these, at least 10-12% would be of direct agricultural importance, while the others will have indirect ecological impacts on these economically important insects and on crop production. This calls for long term and intensive biosystematic studies involving the collection and naming of the 70,000 odd species that remain to be discovered as well as studies on the over 60,000 species already known in our country. The Centre for Insect Bioinformatics at NBAIR is expected to be an international hub for access to information on all aspects of entomological research and development.

ICAR-NBAIR will continue its quest for new and useful insects and their resources, and aiming at documenting our vast insect biodiversity to foster safe farming for residue-free agricultural products compatible with “green IPM” efforts in India. The IAC 2016 is a perfect platform for researchers working on all aspects of biodiversity to come together, discuss and deliberate on future collaborations and global networking with a single aim of saving life on earth in all its forms and keeping natural ecosystems functioning and healthy.

Natural Resource Management Cluster

India is one of the most vulnerable countries to climate change, and is impacted by livelihood issues, low food security, health risks, and dwindling ecological resources. Adapting to climate change is a rapidly growing challenge, particularly for developing countries like India. Over the years, climate change has become tangible, affecting people's lives worldwide. Even though greenhouse gas emissions have reduced significantly – climate change impacts, such as gradual temporal and spatial shifts in resources as well as drought, floods, severe weather events and sea-level rise, are likely to result in food shortages, increases in vector-borne diseases, infrastructure damage and the degradation of natural resources. Most importantly, the poor will be affected disproportionately. Hence tackling climate change is perhaps the greatest environmental challenge that we face today. The Natural Resource Management (NRM) cluster of GIZ seeks to address the pressing needs of rural India in the context of climate change through a range of projects and programmes fostering rural innovation and business models, knowledge networks in Indian agriculture, food security, and promoting environmental benefits of MGNREGA works. In different fields of action, GIZ supports its Indian partners at the national level covering nearly all the states of India in the topics of climate change, rural development and agriculture, e.g. through policy formulation and implementation, testing, demonstration and integration of innovative concepts, strategies and technologies as well as strengthening human capacities, dissemination of information, knowledge and use of IT.

Currently, projects/programmes in the NRM Cluster are:

- Indo-German Environment Programme in Rural Areas (IGEP-RA)
  - Climate Change Adaptation in Rural Areas of India (CCA-RAI)
  - Umbrella Programme for Natural Resource Management (UPNRM)
  - Climate Change Adaptation in the North Eastern Region (CCA-NER)
- Climate Change Knowledge Network in Indian Agriculture (CCKN-IA)
- Remote Sensing-based Information and Insurance for Crops in Emerging Economies (RIICE)
- Environmental Benefits through the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA-EB)
- Special Initiative One World – No Hunger
  - Green Innovation Centres for the Agriculture and Food Sector (GIAE)
  - Soil Protection and Rehabilitation for Food Security (Soil Protection)
- Development and Management of NAMAs in India (NAMA)
- Global Carbon Market (GCM)
- Support to the National Institute for Climate Change Studies and Actions (NICCSA)

Indo-German Environment Programme in Rural Areas (IGEP-RA)

Climate change has long-lasting impacts on our natural resources, economic activities, food security, health, society, and physical infrastructure. India's economy is especially vulnerable to the effects of climate change since it relies heavily on climate-sensitive sectors such as agriculture, forests, tourism, animal husbandry, and fisheries. Climate change adaptation measures are, thus, of central importance in order to ensure the protection of rural livelihoods, the expansion of the country's natural resource base, and sustainable development. The Indo-German Environment Programme in Rural Areas (IGEP-RA) supports its national-level partners, the Ministry of Environment, Forest and Climate Change (MoEFCC), the National Bank for Agriculture and Rural Development (NABARD), and the Ministry of Development of North Eastern Region (MoDONER), in almost all the key aspects of addressing climate change. These aspects are: assisting in policy formulation; introducing new concepts, strategies, technologies, and methodologies; and changing entrenched behavioural patterns while also strengthening human capacities.

The objective of the programme is to ensure public and private natural resource management interventions so as to improve India's natural resource base, minimise the risks of climate change, and enhance productivity and income in rural areas. The programme aims to contribute to improved livelihoods and adaptive capacities of vulnerable rural communities in India and aligns itself to the Government of India's National Action Plan on Climate Change (NAPCC). It also focuses on integrating the issue of climate change adaptation into various sector policies, with the aim of reducing the risks and enhancing the adaptive capacities of the most vulnerable sectors and groups within the population. The programme focuses on concrete adaptation measures and supports the upscaling of successful adaptation approaches through national and international climate funds.

Climate Change Adaptation – North Eastern Region (CCA-NER)

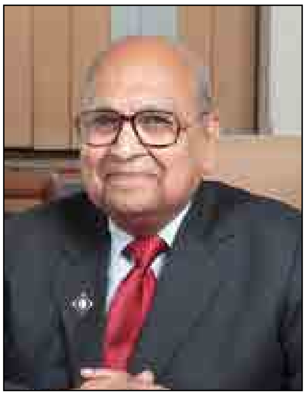
CCA-NER aims at improvement in the sustainable and climate resilient management of natural resources (forest, water, soils) in the five states of NER (Meghalaya, Sikkim, Nagaland, Mizoram, Arunachal Pradesh). CCA-NER is set to facilitate the SAPCC implementation through the development of concepts and detailed proposals in three partner states in forestry and water resources management and agriculture sectors, implementation of replicable and productive measures so as to increase average annual household income, benefitting women and men equally, and ensuring that the existing and/or the new development and sector policies and programmes integrate climate change adaptation priorities – based on the SAPCCs – in the North Eastern Region.

The results expected on completion of CCA-NER component of IGEP-RA are:

- Implementation of 3 priority climate change adaptation measures have been started with a total budget of 10 Mio. EUR based on the respective SAPCCs in the 3 partner states in NER, focusing on agriculture, forestry and water resources management, implemented by relevant public institutions including civil society and private sector participation.

- 8 replicable, productive measures for the promotion of resource-efficient and climate-resilient organic agriculture generates an increase in the average annual household income by 20% for 7000 households, of which women and men benefit equally.
- 5 existing and/or new development and sector policies and programs integrate climate change adaptation priorities based on the SAPCCs in the North Eastern Region.
- An implementation-oriented knowledge network of public and private institutions in the field of climate change adaptation including gender topic is established in the North East Region of India.

MAHYCO - An Overview



Maharashtra Hybrid Seeds Company Private Limited, popularly known as Mahyco is the pioneer of high quality hybrid and open pollinated seeds in the country. Founded in 1964 by Padma Bhushan Dr. B. R. Barwale, Mahyco is one of the largest private sector seed companies in India. Mahyco is engaged in research, development, production, processing and marketing of over 115 products including cotton, cereals, oilseeds, fiber crop and vegetables. It has to its credit 21 notified research varieties. Through the use of cutting edge technology and intensive research activities, Mahyco has revolutionized the agrarian face of the country. The company has a state-of-the art R&D centre at Dawalwadi near Jalna in Maharashtra, with an on- going hybrid breeding program in over 30 crop species. Apart from the main R&D centre in Jalna, Mahyco has three research centres and 18 other location offices distributed across the country with over 150 scientists engaged in the research programs. The ISO 9001-2008 certification awarded to Mahyco is the largest multi-location certification in India covering 59 locations.

Mahyco was the first seed company worldwide to successfully commercialize F1 hybrid cotton based on GMS/CMS system. It was also the first private enterprise in India to produce and market hybrids in sorghum, pearl millet, wheat, sunflower and many vegetables. In 2002, Mahyco strengthened its product offerings by releasing India's first GM crop - Bt Cotton. Mahyco has a long track-record of supporting and participating in innovative research and initiatives in agriculture in partnership with public institutes and private companies.

Mahyco produces its seeds through a network of more than 2 lac contract farmers in different states. Its products are purchased by more than 1 crore farming families out of estimated twelve crore farming families across India. Mahyco is proud of making a significant difference to social-economic wellbeing of these valued customers through its technology driven quality seeds.

Our Products

Row Crops (Cotton and Field Crops): Mahyco is a market leader when it comes to the share of cotton seeds sale in the market. In the field crop market Mahyco produces a variety of crops like rice, mustard, wheat, bajra, jowar, sunflower, castor to name a few.

Vegetable Crops: Mahyco is a market leader in many vegetable hybrid seeds and has a large product range of vegetable crops like bhindi, chilli, tomato, brinjal, gourds, beetroot, cabbage, radish, cucumber etc.

Our International Presence

Mahyco has set up its own organizations in Singapore, Vietnam and recently acquired a controlling stake in Quton, the largest Cotton seeds company in Africa. Having had the successful experience of contributing to small holding farmers in India, Mahyco will be taking its learning to geographies of similar farm structure in Asia & Africa.

With its product presence in Asia, Africa, USA, Middle East and Europe (more than 20 countries), Mahyco is making a major expansion in exports and has the strength and momentum to truly become a global organization in the near future.

Our Philosophy

Mahyco remains unchanged at its core despite its growth and expansion. Driven by the belief that farming challenges can be addressed only by science led innovations, Mahyco is on a mission to make India not only self sufficient in food production, but also a major global exporter of agricultural produce.

Awards & Recognition

2016 Dr. B.R. Barwale conferred with the Maharashtra Corporate Excellence (Maxell) Lifetime Achievement Award for his outstanding contribution towards the development of the agriculture sector in the country.

2014 Chamber of Marathwada Industries & Agriculture (CMIA) honoured Dr. B R Barwale for his contribution to the development of the Marathwada region and agriculture sector in the country

2013 The Association of Biotechnology Led Enterprises (ABLE) recognizes Mahyco for outstanding contribution to the Indian agriculture sector.

2011 Dr. B.R. Barwale felicitated by Nagari Satkar, Jalna for contribution to regional agriculture, health and education.

2010 Degree of D.Litt. awarded to Dr. B.R. Barwale by Babasaheb Ambedkar Marathwada University in Aurangabad

2006 Dr. B.R. Barwale receives the Honorary Fellowship Award from The Indian Society for improvement in cotton cultivation. Dr. B.R. Barwale receives the Chirmule Award for outstanding contribution to the Indian agriculture sector.

2003 Mahyco receives the first National Award for Biotech Product Commercialization.

2002 The Doctor of Science (Honoris Causa) degree awarded to Dr. B. R. Barwale by Tamil Nadu Agricultural University.

2001 Dr B.R. Barwale receives **'Padma Bhushan'** for contribution to the agriculture sector and economy of India.

1999 Business Week magazine recognizes Dr. B.R. Barwale as 'The Star of Asia'.

1998 Dr. Barwale was aptly felicitated with 12th **'World Food Prize'**. Dr. B.R. Barwale recognized as the Father of the Seed Industry in India by the Crop Science Society of America.

1996 Honorary Life Membership to International Seed Trade Federation (FIS) to Dr. B.R. Barwale for role in developing India's seed industry.

1990 Awards from the International Seeds and Science Technology (ISST) and the Federation of Indian Chambers of Commerce and Industries (FICCI)

1989 National Award for R&D from the Indian Ministry of Science and Technology

1973 Marathi Vignan Parishad award to Dr. B.R. Barwale for his contribution to Maharashtra & the agriculture sector

Association of Biotechnology Led Enterprises

APPLYING BIOTECHNOLOGY TO ENABLE HIGHER FARM PRODUCTIVITY, SAFER FOOD AND A SUSTAINABLE ENVIRONMENT

Association of Biotechnology Led Enterprises(ABLE) – ABLE is a not-for-profit pan-India forum that represents the Indian Biotechnology Sector. It was launched in April 2003, after industry leaders felt a need to form an exclusive forum to represent the Indian Biotechnology Sector.

ABLE-AG- Association of BiotechLed Enterprises (Agriculture Focus Group) consists of 11 leading biotechnology companies focused on research and development of innovative agriculture Biotechnology products for the benefit of farmers, consumers and the nation and is a part of ABLE.

ABLE-AG aims to accelerate the pace of agricultural growth in India by enabling strategic alliances between researchers, the Government and the global biotech industry to increase crop productivity, help meet domestic food security, and contribute to the inclusive growth.

Our Objectives

- Create an enabling environment for the development and adoption of superior biotech traits that can enhance productivity of Indian agriculture with safe and sustainable agricultural practices
- Create a platform to facilitate constructive dialogue with different stakeholders, and to explain benefits of the technology, the difficulties faced by technology providers and the need for an enabling environment that is required for healthy growth of safe technology in India
- Work with the government on various policies related matters, and ensure that the views of the industry are incorporated in the formulation of different policies of the government in relation to agricultural Biotechnology
- Emerge as an influential voice of the industry

Background

Agricultural biotechnologies offer benefits for insect protection, weed management, yield enhancement, drought and flood tolerance, nutrition enhancement, healthier oils and more. Technologies based on recombinant-DNA science such as molecular diagnostics and Marker Assisted Selection (MAS) are readily applied and accepted, but those based on Genetic Modification (GM) needs far more elaborate testing, and so takes much time to develop products.

So far, Bt cotton is the only GM crop commercialized in India (from 2002) which has been accepted widely. Since the introduction of Bt cotton, India has tripled in cotton production and has become the largest producer in the world.

Several products from both private and public sector institutions are being tested for safety and efficacy before commercialization under the strict regulatory system existing in the country. Since the technology is delivered to farmers in the form of improved seeds, the impact can be seen rapidly when such seeds are adopted. Through this technology, farmers are offered in-seed benefits for several novel and impactful traits across relevant crops and agro-ecological regions. The consumers also benefit because of healthier products such as food with healthier oils and essential nutrients like vitamins. GM technology can also prevent post-harvest losses, and can provide novel industrial raw materials and neutraceuticals. The enhanced productivity brought about through a variety of technologies also ensures that no virgin land and forests need to be diverted for agriculture, thereby ensuring conservation and biodiversity.

ASSOCIATION OF BIOTECHNOLOGY LED ENTERPRISES- AGRICULTURE FOCUS GROUP

10A, 10th Floor, Vandhna Building, 11Tolstoy Marg,
New Delhi -110001, Phone – 011-23731127
Visit us @ www.ableag.org
Email Id: infoagri@ableindia.org.in

@ABLE_AG ABLE-AG

Rasi Seeds (P) Ltd. - Profile

Rasi Seeds (P) Ltd. was established in 1973 Mission to **Create a Scientific Evolution Complementing Nature** and with the aim to serve the farmers by developing high quality seeds. Rasi Seeds is well recognized as the leader in Cotton hybrids. In addition to Cotton we produce hybrids in Maize, Rice and Pearl millet. Our company has made tremendous impact on cotton production by the development and distribution of transgenic *Bt* cotton hybrid seeds by adoption of both Bollgard I and Bollgard II technologies. To cater to the needs of farming community, we have developed 52 *Bt* cotton hybrids, out of which currently, about 7 hybrids are cultivated in nine Indian States. With determined efforts, Rasi has emerged as a leader in *Bt* cotton distribution across the different cotton growing regions of India and was recognized by BIOSPECTRUM as "**Bio-Agri Company**" of the year in 2007.

Research and Development is a critical area in the innovation process, hence we have constant investment in technology and future capabilities which is being transformed into new products, processes, and services. The company has well established Biotechnology Research & Development facilities at Attur, Tamil Nadu and Research & Breeding facilities in various locations across India. The R&D centre has well equipped infrastructure that includes research farms of 200 acres and 55000 sq.m transgenic greenhouses, and state of the art Biotechnology laboratories.

Rasi R& D comprises of three main components such as **Breeding, Biotech and Regulatory division**, which operates in interdisciplinary mode. The core activities comprise of Molecular Breeding, Genetic Transformation, Doubled Haploid and Molecular Diagnostics.

A modern Biotech facility was created for research work in Molecular Breeding, Transgenic Crops production, Crop Viral Diagnostics and Analytical lab functions with young and talented scientific staffs. The new facility has laboratories for Germplasm Conservation, Insect Bioassay, Genetic Transformation, Cell biology, Molecular Breeding, library, documentation etc., that cover an area of 40,000 sq. ft.

We understand that molecular breeding is the key to support the existing conventional breeding activities and we focus on three major crops *viz*. Cotton, Rice and Maize. The main research areas includes Germplasm characterization through DNA-based markers, DNA fingerprinting of proprietary lines, Marker-assisted selection in Cotton, Rice and Maize, *Bt* gene expression and quantification in Cotton, and development of molecular markers for genetic purity in seeds. Molecular breeding for BLB and BPH resistance in rice and MABC for Trait introgression is carried out in Rice crop. The lab has been equipped with all the advanced facilities including several instruments for genotyping and automated liquid handling system.

We are well known for our significant contribution in making Indian farmers adopting the *Bt* cotton technology, we have realized the impact of transgenics and started our own pipeline activities in transgenic crops. Our Genetic Transformation Laboratory conducts research on development of transgenic crops by transferring *Bt* genes in Rice and Brinjal to protect against Insect borer pests. We are also developing transgenic Bhendi (Okra) by incorporating viral resistance genes to protect against Bhendi Yellow Vein Mosaic disease, in Cassava to protect against Cassava Mosaic disease and in Cotton to protect against Cotton Leaf Curl Virus.

Our molecular diagnostics division works in parallel with the transgenic division for the transgenic related molecular activities such as gene construct development, transgene tracking through PCR, copy number analysis through southern blotting, copy number and gene expression analysis using qRT-PCR, protein expression studies using Western blotting, virus characterization and diagnosis. To undertake Insect bioassay activities, we have well equipped bioassay lab with focus on activities including diet based insect rearing and maintenance of lab cultures.

The future thrust of our center would be on marker-assisted breeding using DNA markers for several important traits in crops such as Cotton, Rice, Maize and Vegetable crops. This will involve integration of crop breeding and biotechnology including bioinformatics. We plan to intensify our transgenic research in different field crops and vegetables for agronomically important traits besides quality traits.

Institutional Collaborations

Adopting user friendly novel technologies through a specialized network has become the hallmark of Rasi. To acquire more cutting edge technologies, Rasi has focused Public-Private-Partnership mode with different International and National Institutions. We have made alliance with University of Ottawa, Canada, National Research Centre for Plant Biotechnology (NRCPB-ICAR),for Insect resistance technologies and for viral resistance technologies, collaboration with Madurai Kamaraj University (MKU) and Tamil Nadu Agricultural University (TNAU).

Recently Rasi has entered research collaboration agreement with Evogene Ltd, Israel – a world leading developer of improved plant traits, such as yield and drought tolerance on improving key traits in Rice. To strengthen the Maize market share, we have acquired the entire Maize business of Bayer Bioscience in India.

Awards and Recognitions

The Chairman of Rasi Seeds (P) Ltd., Dr.M.Ramasami is recognized for his sincerity and commitment to serve the farming community across the country which has won him lot of laurels and to quote a few:

1. In 2011, The Indian Society for Cotton Improvement has awarded Honorary Fellowship to Dr.M.Ramasami in appreciation of his outstanding contribution to the development and popularization of Extra Long Staple Bt cotton in India.
2. “Life Time Achievement Award - 2009” conferred by Cotton Research Development Association, Haryana.
3. The Oldest and Prestigious Tamil Nadu Agricultural University (TNAU) has conferred Doctor of Science (Honoris Causa) to him for his contribution to Agricultural Development in 2008.
4. “Bio Excellence 2008” Award from Karnataka Government.
5. “Bio-Agri Company of the Year 2007” Award from Bio Spectrum.
6. “Person of the Year Award” for the year 2006 from Bio Spectrum.
7. “Leadership Award” was conferred by Monsanto Company during 2005.
8. “DSIR National Award for R&D Efforts in Industry (2005)” by Government of India, Ministry of Science and Technology for promoting Bt cotton in India.
9. “Velan Semmal Award” from Tamil Nadu Agricultural University (TNAU) in the year 2004.

Rasi Seeds shares a special bond of trust with Indian farmers. Its commitment to serve the Indian farmers will certainly make this bond stronger and take the company to new heights.

Conviron, Canada - Blue Star Engineering & Electronics Ltd., India

Conviron was founded in 1964 and is a leading innovator and the world leader in the design, manufacture and installation of plant growth chambers and rooms. Conviron's specialized equipment precisely controls light, temperature, humidity, carbon dioxide and other gases, as well as other environmental conditions. Conviron products can be found in more than 80 countries, with many of those products forming part of large scale plant growth facilities, designed and supplied entirely by Conviron and its nearly 180 employees world wide.

At Conviron, our corporate approach is rooted in our philosophy of building solid client partnerships. As such, our relationship extends indefinitely - far beyond the commissioning and sign-off phase. During the entire operational life of the facility, we would be at your side to make modifications and adaptations to equipment as needs change and as new technologies emerge, offer advice and guidance should changes to the overall facility ever be contemplated, and of course to address any technical issues that may arise.

Much of Conviron's success comes from its ongoing commitment to research and development, and its readiness to develop custom solutions for its clients. With plant growth equipment representing more than 90% of our overall business, our staff of over thirty specially trained engineers, technicians and controls experts focus almost exclusively on controlled environment equipment for plant growth applications. Through its innovative design and manufacturing expertise, Conviron has established itself as an industry leader on a global scale with products that are proven, reliable, and robust. As an ISO9001 company, Conviron's products meet universally recognized quality and safety standards.

For many of our clients, the equipment supplied by Conviron represents only a portion of a larger development project, often including the construction of a major facility. The ability of our expert installation crews to work closely with local and other on-site trades and contractors has proven invaluable by our customers. Recognizing that in the field of research time is of the essence, Conviron assigns a Project Coordinator to each project to ensure that all aspects, from the initial sale, to engineering, manufacturing and installation, are completed on schedule. Having supplied most of the world's largest plant growth facilities, we understand what's required to deliver a successful facility, on time and on budget.

Conviron recognizes that as a partner in research, our obligation extends far beyond the design and manufacture of equipment. We offer ongoing service support both directly through our in-house service technicians and through a worldwide network of distributors and specially trained service partners. In this way, customers can be assured that their service requirements are being met both during and beyond the warranty period.

Headquartered in Winnipeg with an 85,000 square foot production facility, Conviron maintains sales/services offices in the United States, UK, Germany, Australia, China and Canada, with international distributors and service partners around the world. The company is privately owned, which ownership has remained consistent since its inception.

In India, Conviron is represented by Blue Star Engineering & Electronics Ltd (Blue Star E&E) which is an engineering company headquartered in India, with pan India presence. Blue Star E&E offers advanced technology products as well as turnkey engineering solutions that cater to several industries in the country. It is the exclusive distributor in India for many globally renowned manufacturers of hi-tech professional electronics equipment and services, as well as industrial products and systems.

In India, in collaboration with Blue Star Engineering & Electronics, Conviron has executed various prestigious projects, which include the Prestigious National Gene Bank at National Bureau of Plant Genetics Resources, Nee Delhi. Apart from this, The National Phytotron Facility at IARI , New Delhi was designed, manufactured and supplied by Conviorn and has been serving the scientists for well over 20 years. Apart from this, various prestigious national level institutions like NIPGR - New Delhi, NABI - Mohali, NBRI - Lucknow, CIMAP - Lucknow, RCB - Faridabad, IISER - Mohali, University of Delhi, CPRI - Shimla, CCMB - Hyderabad, ICRISAT - Andhra Pradesh, to name a few, have Conviron installation.

Apart from this, various multinational companies like Monsanto India Ltd., DuPont India and Bayer CropScience Ltd., etc have chosen Conviron as their preferred partner in research in India.

Blue Star E&E has been providing installation, warranty and after sales services for all Conviron Chambers sold in India. Blue Star E&E has a team of Conviron trained Engineers who has been providing world class after sales services for Conviron Chambers.

Contact details for **Conviron - Blue Star Engineering & Electronics** in India are:

Mr. K Venkatesan
General Manager
9940132087
kvenkatesan@bluestarindia.com

Sanjeev Sehgal
Regional Manager
9871097737
sanjeevsehgal@bluestarindia.com

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APPLYING BIOTECHNOLOGY TO ENABLE HIGHER FARM PRODUCTIVITY, SAFER FOOD AND A SUSTAINABLE ENVIRONMENT

ABLE Association of Biotechnology Led Enterprises

The collective face of the Indian Biotech Industry

AGRICULTURE FOCUS GROUP

ABLE-AG - Association of Biotech Led Enterprises - Agriculture Focus Group is part of ABLE and consists of

11 LEADING BIOTECHNOLOGY COMPANIES

focused on R&D of innovative agriculture Biotechnology products for the benefit of

FARMERS, CONSUMERS and the NATION

ABLE-AG aims to accelerate the pace of

AGRICULTURAL GROWTH IN INDIA

STRATEGIC ALLIANCES

between researchers, the Government and the global biotech industry to increase by enabling

CROP PRODUCTIVITY

help meet domestic food security, and contribute to the growth

Create an enabling environment for the development and adoption of superior biotech traits that can enhance productivity of Indian agriculture with safety and sustainable agricultural practices

Creating a platform to facilitate constructive dialogue with different stakeholders and create awareness among different stakeholders on use and benefits of various biotech traits and tools that are available in the country

Work with the government on various policies related matters, and ensure that the views of the industry are incorporated in the formulation of different policies of the government

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Association of Biotechnology Led Enterprises- Agriculture Focus Group, Flat No. 10-A, 10th Floor, Vandhana Building 11, Tolstoy Marg, New Delhi-1100 01

Visit us @ www.ableaq.org

Mail to infoagri@ableindia.org.in

Rasi Seeds (P) Ltd.
RASI SEEDS
Field Crop Division
HyVeg
Vegetable Seed Division
Customer Centricity
Operational Efficiency
Product Excellence
Corporate office : 174, Sathyamurthy Road,
Ramnagar, Coimbatore - 641009
Tamil Nadu, India.
Ph : +91-422-2233844
Fax : +91-422-2233845
E-mail : rasimail@rasi.in
Web : www.rasiseeds.com
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