Role of ICAR-NBPGR in PGR Management

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The National Bureau of Plant Genetic Resources (ICAR-NBPGR) was established by the Indian Council of Agricultural Research (ICAR) in 1976 with its headquarters at New Delhi. The chronology of events leading to the present day ICAR-NBPGR dates back to 1905 when Botany Division was established under the then Imperial Agricultural Research Institute.ICAR-NBPGR has been given the mandate to act as a nodal institute at the national level for acquisition and management of indigenous and exotic plant genetic resources (PGR) for agriculture, and to carry out related research and human resources development for sustainable growth of agriculture. The Bureau is also vested with the authority to issue Import Permit and Phytosanitary Certificate and conduct quarantine checks in seed material and vegetative propagules (including transgenic material) introduced from abroad or exported for research purposes. Besides having a 40 ha experimental farm at Issapur village (about 45 km west of Pusa Campus), the Bureau has a strong national network comprising Regional Stations/ Base Centers and ICAR Institutes/ SAUs that provide access to representative agro-ecological situations in the country.

Mandate: 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.

ICAR-NBPGR has its headquarters in New Delhi that hosts the second largest genebank in the world. The operations are administered by Divisions of Plant Exploration and Germplasm Collection, Germplasm Evaluation, Germplasm Conservation, Genomic Resources and Plant Quarantine in addition to the Units of Germplasm Exchange and Tissue Culture and Cryopreservation.ICAR-NBPGR has the network of 10 Regional Stations covering different agro-climatic zones to carry out PGR activities including collection, characterization, evaluation and maintenance of various crops as mentioned below:

- ***Shimla (Himachal Pradesh):*** Established in 1960; temperate crops.
- ***Jodhpur (Rajasthan):***Established in 1965; agri-horticultural crops germplasm of arid and semi-arid zones.
- ***Thrissur (Kerala):*** Established in 1977; agri-horticultural crops germplasm of southern peninsular region with particular emphasis on spices and plantation crops.
- ***Akola (Maharashtra):*** Established in 1977; agri-horticultural crops germplasm of central India and Deccan Plateau.
- ***Shillong (Meghalaya):*** Established in 1978; agri-horticultural crops germplasm of north-eastern region including Sikkim and parts of north Bengal.
- ***Bhowali (Uttarakhand):*** Established in 1985; agri-horticultural crops germplasm of sub-temperate region.
- ***Cuttack (Odisha):*** Established in 1985; agri-horticultural crops germplasm of eastern peninsular region with main emphasis on rice germplasm.
- ***Hyderabad (Telangana):*** Established in 1985; Quarantine clearance of agri-horticultural crops germplasm of Telangana, Andhra Pradesh and adjoining areas.
- ***Ranchi (Jharkhand):*** Established in 1988; germplasm of tropical fruits and other field crops of Bihar, eastern Uttar Pradesh, Jharkhand and West Bengal.
- ***Srinagar (Jammu & Kashmir):*** Established in 1988; agri-horticultural germplasm of temperate crops.

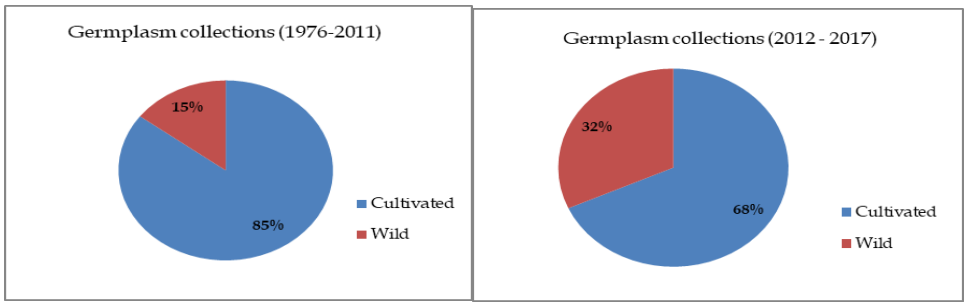
PGR are conserved in the form of seeds, vegetative propagules, tissue/ cell cultures, embryos, gametes, etc. in the Genebank. The National Genebank facility commissioned in 1997 has 12 long-

term storage modules, each with a storage capacity of 50,000 to 76,000 samples depending upon the size of seeds. Its cryopreservation facility contains six liquid nitrogen storage tanks (cryo-tanks), each having a capacity to hold 1,000 litres of liquid nitrogen. These six cryo-tanks have a total capacity to store 0.25 million samples. Thus, the National Genebank has a total capacity to store 0.85 to 1.25 million samples. This is one of the most modern Genebanks of the world.

The Bureau not only conserves PGR safely to meet the needs of future generations, but also provides these to the nation's crop improvement programmes to sustain continued advances in agricultural productivity and stabilize production. The Bureau works in close collaboration with several international institutes/ organizations through memoranda/ work plans developed under bilateral/ multilateral agreements. It exchanges plant germplasm with over 100 countries. The Bureau is gradually developing and strengthening the national plant genetic resources system by linking up the National Base Collection (kept under long-term storage at ICAR-NBPGR with National Active Germplasm Sites (NAGS) responsible for different crops where germplasm collections are evaluated and multiplied under field conditions backed by medium-term storage facilities. The various activities and achievement of the Bureau are presented here, briefly.

PGR Exploration and Collection

- To develop new varieties in various agri-horticultural crops for farmers suitable to different agro-climatic conditions, 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. Also, the trait-specific germplasm of various crops has been collected from diversity-rich spots (including the difficult unreached areas in different parts of the country).
- The institute has so far undertaken 2644 explorations and collected about 2.67 lakhs accessions of crop species and their wild relatives.
- **Focus on North-East and rescue missions**: In total, 165 explorations undertaken and a total of 9,698 accessions (cultivated- 6,622, wild- 3,076) collected. 45 exploration trips to North-Eastern Hill Region and five rescue missions to natural calamity affected areas of Uttarakhand were undertaken. Systematic explorations have been conducted in the remotest parts of the country including Mon district of Nagaland; Anjaw, Changlang and Tirap districts of Arunachal Pradesh; and Great Nicobar. Disturbed/insurgency-prone areas such as Bastar region in Chhatttisgarh; Gadchiroli in Maharashtra; and West Medinipur in West Bengal resulting in collection of 858 landraces of different agri-horticultural crops. Gap analysis, geo-referencing and diversity distribution mapping completed in nine crops.
- **Priority was given to the crop wild relatives (CWR)** which resulted in collection of 576 unique accessions which resulted in a significant increase in the share of wild species (32%) in the total collection.



Increased focus on CWR in germplasm collecting

PGR Exchange

- ICAR-NBPGR is the nodal agency for import and export of all PGR for research purpose, adhering to guidelines of National Biodiversity Act, 2002.

- ICAR-NBPGR is instrumental in introduction of several new crops in India such as soybean, sunflower, kiwi, tree tomato, oil palm, jojoba, guayule, hops etc. and aromatic plants like rose geranium which are getting popular in Himalayan states, Uttarakhand and HP.
- More than 10, 000 accessions of indigenous and introduced germplasm are supplied annually to the researchers throughout the country.
- 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 trial material (primarily from CG Institutes) are introduced into 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. This is now facilitated through online application for import permit (http://www.nbpgr.ernet.in/gep/). These introductions have been used both for direct release as varieties and in crossing programme as parents. Hundreds of such examples are available and some classical examples of use of exotic germplasm in varietal development is presented in Table 1.

Table 1. Use of introduced exotic germplasm in development of new varieties

Crop	Variety/Hybrid	Exotic Source
Rice	Annada	MTU-15 /YaikakuNantoku (China)
Barley	Clipper, Alfa 93, Rekha	Introduction from Australia
Chickpea	C104, L550	Rabat (Morocco)
	BG261, BG244	P9847 (Russia)
	BG267	USA 613 (USA)
Tomato	Kashi Hemant	Sel 18 / Flora Dade
	Punjab Kesari	EC 55055 / Punjab Tropics
	Punjab Chhuhara	EC 55055 / Punjab Tropics
Bottle gourd	Kashi Ganga	IC92465 / DvBG-151
Chilli	Co3	CA 856 (Srilanka)
Pea	Uttra	EC109185 / HFP4
Carrot	Pusa Yamdagni	EC 9981 / Nantes
Sweet potato	PusaSunehari	Porto Blanco /Wanrap) //Australian Cannanes (USA)
Squash	PusaAlankar	(EC 27050 / Selection No. PL.8)
Cauliflower	Pusa Snowball-1	EC 12012 / EC12013
Cowpea	Aseem	PusaPhalguni / EC 21622 (Philippines)
	Rituraj	PusaDofasali / EC 26410 (Mexico)
	PusaDofasali	PusaPhalguni / EC 21622 (Philippines)
Cluster bean	RGS 936	EC 248 / RGC 401

Not only the exotic germplasm introduced from other countries has helped in growth of Indian agriculture but several germplasm lines of Indian origin have helped in saving crops in other countries. Some of the classical examples of use of germplasm of Indian origin are as:

- The entire rice crop of Indonesia was threatened some decades ago by a growth-stunting virus. A gene transferred from *Oryzanivavra*from Odhisa saved rice crop against the virus.
- It was single gene from India for downy mildew resistance that saved the muskmelon crop in the United States
- Another gene from Indian that provided American sorghum resistance to greenbug insect had resulted in millions of dollars of annual benefit to American farmers
- Dr. William Saunders of Canada used wheat variety Hard Red Calcutta and released new series of wheat later called Marquis A and B which were early and resistant to rusts
- Recently in rice, *Sub1A* (from FR13A) and *PSTOL1* (from Kasalath) are being used globally to save rice from losses due to flooding and improving P use efficiency.

Plant Quarantine

- Introduction of planting material, including transgenics from other countries carries risk of entry of the associated pests (fungi, bacteria, viruses, insects, nematodes and weeds etc.). Hence, all genetic resources acquired from foreign countries are tested using plant quarantine measures (legislative measures) to prevent the entry of exotic pests and to avoid their spread to the fields.
- ICAR-NBPGR has been empowered under the Plant Quarantine (Regulation of Import into India) Order 2003 of the Government of India to carry out quarantine checks on the germplasm being exchanged meant for research purposes, including transgenics. It undertakes quarantine processing of germplasm meant for export and issues the Phytosanitary Certificate for the material meant for export.
- The quarantine has resulted in the interception of several pests of high economic significance including (>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.
- So far31,39,542 samples of various crops have been processed for quarantine clearance
- Infestation/ infection/ contamination detected in 1,61,723 samples of which 1,61,501 salvaged and 74 exotic pests intercepted.
- Any inadvertent introduction of any pest not present in the country could lead to serious economic losses to farmers and the country. Estimated losses that could occur, if any of the diseases/weeds was introduced in the country are given in Table 2.

Table 2. Probable annual losses due to various exotic pests, if introduced into India

Crop	Pest	Yield loss in exporting country (%)	Probable annual loss in India(₹in million) *
Wheat	*Monographellanivalis*(fungus)	3.0 to 52.4 (USSR)	1519.4
	Barley stripe mosaic virus	Up to 30.0 (USA)	
	Bromussecalinus(weed)	28.0 to 48.0 (USA)	
Soybean	*Bean pod mottle virus*	Up to 52.0 (USA)	261.9
	Peronosporamanshurica(fungus)	Up to 80.0 (USA)	
Cotton	*Anthonomusgrandis*(insect)	Up to 51.0 (USA)	221.4
Maize	*Maize chlorotic mottle virus*	90.0 (USA)	31.1
	High plains virus	Up to 100.0 (USA)	

*Losses based on the assumption that if only 0.1% yield loss occurs due to appearance of pest. The total yield and minimum support price have been taken for 2015-16, Source: http://eands.dacnet.nic.in/)

PGR Conservation

The Indian National Genebank (NGB) was established at ICAR-NBPGR to conserve the PGR for posterity in the form of seeds, vegetative propagules, *in vitro* cultures, budwoods, embryos/embryonic axes, genomic resources and pollen.The NGB has four kinds of facilities, namely, Seed Genebank (-18°C), 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.

The NGB with a capacity to conserve about one million germplasm in the form of seeds is currently conserving about 0.43 million accessions (Table 3) belonging to nearly 1,800 species. Over 12, 000 samples of seed, dormant buds, and pollen are cryopreserved (Table 4) and about 1,900 accessions are conserved in the *in vitro* genebank (Table 5).The NGB is supported by active partnership of other intuitions designated as the NAGS. The NAGS are responsible for maintaining, evaluating and distributing germplasm from their active collections to NGB and other user scientists.

Table 3. Germplasm conservation at ICAR-NBPGR Seedbank, (as of December 2017)

Crop / Crop Group	Number of accessions conserved
Cereals	1,61,816
Millets	58,443
Forages	6,925
Pseudo Cereals	7,295
Legumes	65,675
Oilseeds	58,571
Fibre	14,605
Vegetables	25,904
Fruits & Nuts	273
Medicinal & Aromatic Plants & Narcotics	7,929
Ornamental	653
Spices & Condiments	3,074
Agroforestry	1,642
Duplicate Safety Samples (Lentil, Pigeonpea)	10,235
Trail Material (Wheat, Barley)	10,771
Total	**4,33,779**

Table 4. Germplasm in Cryo-bank

Crop / Crop Group	Number of samples
Intermediate	6,398
Orthodox	3,725
Dormant bud	387
Pollen	522
DNA	983
Total	**12,039**

Table 5. Germplasm *in vitro* at NGB

Crop / Crop Group	Number of samples
Tropical fruits	420
Temperate fruits	315
Tuber crops	620
Bulbous crops	171
M&AP	153
Spices and industrial crops	240
Total	**1,919**

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 data on agronomic traits such as yield, quality, and tolerance to biotic and abiotic stresses. The germplasm is also evaluated for new traits using molecular tools to identify the genes to develop new varieties as per requirement of the farmers. Salient achievements are as:

- Approximately 10,000 accessions are characterized/ evaluated every year at ICAR-NBPGR and its regional stations. Till date, more than2.35 lakhs accessions of different agri-horticultural crops have been characterized and evaluated and passport data is available**.**
- Core sets have been developed in four crops viz., okra, mungbean, sesame brinjal and wheat to facilitate the enhanced utilization of germplasm.
- Genetic diversity in large collection has been determined using morphological and DNA fingerprinting markers in crops like rice, mungbean, banana, cashew, mango, oilseeds, brassicas, tomato, sesame, cucumber and cotton.
- Mega programme on characterization and evaluation 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.

DNA Fingerprinting and Development of Genomic Resources

- About 2,300 varieties in more than 35 crops have been fingerprinted so far (Table 8)**.** Also, the new varieties are being DNA fingerprinted to avoid any biopiracy by any unauthorized person or country.
- Established the National Genomic Resources Repository 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
- Newly identified genes (952) are also conserved in the form of DNA libraries, etc.

Table 8. Details of the crop varieties fingerprinted at ICAR-NBPGR

S. No.	Crop	No. of Varieties	S. No.	Crop	No. of Varieties
1	Rice	729	16	Safflower	26
2	Wheat	108	17	Saffron	13
3	Barley	54	18	Chickpea	77
4	Maize	140	19	Jute	31
5	Finger Millet	11	20	Oats	9
6	Sorghum	57	21	Pea	43
7	Pearl Millet	53	22	Lentil	25
8	Soybean	69	23	Mustard	42
9	Pigeonpea	49	24	Linseed	46
10	Mungbean	78	25	Cotton	116
11	Urdbean	76	26	Sunflower	7
12	Ricebean	4	27	Bittergourd	38
13	Mothbean	2	28	Mango	23
14	Cowpea	11	29	Cashew	105
15	Sesame	52	30	Tomato	30
Total: 2,195 (2015-17) DNA fingerprinting (status) for protection of over 6,440 released varieties of 52 species and native landraces to prevent unauthorized commercial exploitation.					

ICAR-NBPGR also has the mandate to carry out molecular profiling of varieties of agri-horticultural crops. This involves generation and utilization of molecular markers for molecular characterization of these crops. Although a lot of dominant multilocus marker systems such as RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism) etc. have been used, the preferred markers for molecular characterization are SSR (Simple Sequence Repeat) and SNP (Single nucleotide Polymorphism) markers owing to their codominant nature. Whereas a lot of molecular markers are available in crops like rice, wheat, maize, potato, cotton, soybean etc. there are others which despite being important contributors to the food basket are less worked at the genomics front.

Generation, validation and utilization of genomic resources is one of the major objective of ICAR-NBPGR. These resources are utilized for value addition to the plant germplasm resources harboured in the genebank and for generating molecular profiles varieties of agri-horticultural crops. The advent of next generation sequencing with improved chemistries and lower input costs have resulted high throughput data that can be mined for generating SSR and SNP markers.

- Genomic SSRs have been generated and validated at NBPGR in crops like okra, snake gourd and moth bean using NGS technologies in house. SSRs from transcriptome sequencing have been mined and validated in finger millet ,kodo millet, little millet and sponge gourd
- A novel gene targeted marker technique CBDP (CAAT Box-Derived Polymorphism) has been developed that can be used for various genotyping applications in plants. The technique exploits conserved CCAAT motif in the CAAT box region of promoter region of plant genes to generate markers. The concept has been validated in three different crops (Jute, cotton, linseed) representing five different species (*Corchoruscapsularis, C. olitorius, Gossypiumhirsutum, Gossypiumorboratum*) and linseed (*Linumusitatissimum*).
- A draft genome assembly of 480 Mb of black pepper (*Piper nigrum*) genome has been generated at NBPGR under the ICAR funded Consortium Research Platform on Genomics. A large number of genomic resources in the form of genomic and genic SSRs have been generated.
- A rice core consisting of 701 accessions has been developed from 6,984 accessions of North-Eastern region of India. This core was further characterized with 50K SNP chip of Rice for development of mini-core. Cluster analysis based on 50K SNP markers grouped 192 accessions of core into seven clusters. This analysis shows that the core developed from NE rice collection is very diverse and has captured maximum diversity present (Figure 1).
- DNA Barcoding loci rbcL, matK, trnH-psbA and ITS region alone and/combination of two loci identified 21 genomic species in *Oryza* and were used for establishing correct genetic identity of mis-labeled species. Two combined loci DNA barcodes (rbcL + ITS) gave better species delineation and proper barcode gaps for species identification in genus Luffa.
- DNA profiling services were rendered to various public and private sector organizations.A total of 558varieties belonging to 33 crops have been profiled in the last four years itself.
- Discovery of non-Kranz C4 photosynthesis in two cell layers (cross- and tube-cells) of pericarp in developing wheat grains. Named it as “Bose anatomy” in honour of his earliest works on C4 in Hydrilla reported in 1924 when C3 itself was not known.
- Technology has been developed for Identification of SRAP Markers Linked to the Single Dominant Resistance Gene against Tomato Leaf Curl New Delhi Virus in *Luffa cylindrica*Roem: Two sequence-related amplified polymorphism (SRAP) markers closely-linked to the ToLCNDV-susceptible gene in the susceptible parent and in a susceptible bulk population; and two SRAP markers closely-linked to the resistance gene in the resistant parent and in a resistant bulk population were found. These can be used for large-scale screening of genotypes of *L. cylindrica* for resistance against ToLCNDV at the seedling stage, and to accelerate the breeding of high yielding, ToLCNDV resistant varieties and hybrids.
- Qualitative and quantitative PCR and real-time PCR assays have been developed/ validated for detection of more than 50 events of 14 GM crops (brinjal, cabbage, cauliflower, cotton, maize, mustard, oilseed rape, okra, papaya, potato, rice, soybean, tomato, wheat).
- Rapid and cost-efficient assays have been developed for screening of GM crops employing a) visual and Real-time Loop-mediated Isothermal Amplification (LAMP) for rapid on-site detection; b) GMO Screening Matrix as decision support system, and c) ready-to-use TaqMan® Real-time PCR based Multi-target system.
- GM-free Conservation of Germplasm in National Genebank: Bt cotton has been commercially cultivated in India since 2002 and other GM events of cotton, brinjal, okra and maize were under field trials, hence, to ensure GM-free conservation of germplasm in the National Genebank, the adventitious presence of transgenes was monitored in ex situ collection including cotton (200 accns.), brinjal (150 accns.), okra (50 accns,), maize (100 accns) using PCR/real-time PCR-based markers. None of the accessions screened so far showed adventitious presence of transgenes based on tests conducted.

Germplasm Utilization

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

(Maruterusannalu), sorghum variety (Parbhani Moti), red okra (Aruna), Chinese potato (Nidhi), coriander variety (Sudha), and yam variety (Indu) a few to name. The NBPGR is 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 are getting increasingly popular in Himalayan states, Uttarakhand and Himachal Pradesh.

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. The PGR documentation is done in various forms including printing of books, crop catalogues, inventories, research papers, popular articles, pamphlets etc.In addition, NBPGR has developed mobile apps Genebank and PGR map in PGR Informatics which can accessed through NBPGR web pages, genebank.nbpgr.ernet.in and http://pgrinformatics.nbpgr.ernet.in/pgrmap/

- Two mobile apps "Genebank" and "PGR Map" have been developed to enhance access to PGR information with an easy user interface. The apps have been hosted on Google Play and App Store.
- "Genebank App" provides a dashboard view of indigenous collections (state-wise), exotic collections (country-wise), addition of accessions to genebank, etc. The app also helps generate routine genebank reports. The app uses databases live on the backend and hence always gives updated information.
- "PGR Map App" offers three benefits: "*What's around me*" helps user to obtain quickly the accessions that have been collected and conserved in the genebank from a particular location in India where the user is located at the moment; *"Search the map"* helps user to list the accessions that have been collected and conserved in the genebank from any selected location in India; *"Search for species"* helps user to map the collection sites of a crop species.
- Establishment of geo-informatics portal in PGR: A study to link germplasm to changing climatic regimes was earlier carried out with the funding of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). A web interface named PGR CLiM was also developed to access information *(www.nbpgr.ernet.in:8080/climate)*.

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. ICAR-NBPGR plays a vital role in germplasm registration. More than 900 potentially valuable germplasm of over 120 species of various crops registered so far. To facilitate smooth registration process, a fully online system of filing registration applications, their scrutiny, review and communications at every stage has been developed (http://www.nbpgr.ernet.in:8080/registration/). Details of the registered germplasm can be accessed at http://www.nbpgr.ernet.in:8080/ircg/index.htm.

All India Coordinated Network Project Potential Crops

This network programme is located at ICAR-NBPGR, New Delhi and has 13 main centers in different parts of the country. The major functions are introduction, evaluation, conservation, 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.

Grain amaranth (*Amaranthus* spp.), normally grown in the hilly region, was tested for cultivation in the plains after the inception of the network in mid 1980s in Gujarat. The crop of grain amaranth acclimatized well and was found suitable for cultivation during rabi season. Three varieties, namely, GA-1, GA-2 and GA-3 were released for cultivation in north Gujarat. Likewise, germplasm for some

other potential crops like quinoa (*Chenopodium quinoa),* faba bean (*Vicia faba*), etc,have been introduced and distributed to farmers.

Human Resources Development

- NBPGR faculty conducts 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. So far, more than 100 researchers from Bhutan, Colombia, Egypt, Fiji Islands, Ghana, Iran, Malaysia, Mauritius, Nepal, Nigeria, Papua New Guinea, Philippines, Saudi Arabia, South Africa, Sri Lanka, Taiwan, Thailand, The Czech Republic and Vietnam.

National and International Linkages

- Close collaborations with Bioversity International, ICARDA, IRRI, CIMMYT and other countries on genetic resources management and utilization
- Collaborations with all ICAR institute, state agricultural universities, CSIR institute, DBT,DST,DRDO etc. for germplasm trait-specific evaluation and utilization
- Memorandum of Understanding (MoU) was signed between the ICAR and the Royal Botanic Gardens (RBG), Kew, UK, to enhance capacities of both the institutions in research on conservation biology.
- ICAR-NBPGR and Forest Research Institute, Dehradun had signed a MoU for the conservation of seed bearing trees species of forestry importance.
- MoU of ICAR-NBPGR with CPCRI, Kasaragod and NRC Orchids has been operationalized for cryo-conservation of coconut and orchids germplasm ,respectively, at the National Cryogenebank, NBPGR.

ICAR-NBPGR for Safeguarding Nation's Future Food and Nutritional Security: Safety Duplicates

ICAR has taken a step forward in securing its crop genetic diversity by depositing 25 accessions of pigeonpea in the Svalbard Global Seed Vault. This was the first such deposit by India as safety duplicates in the global genebankwhich is jointly maintained and managed by Norway's Department of Agriculture and the Global Crop Diversity Trust under the ITPGRFA. A second deposit of 100 samples each of rice and sorghum was sent to Svalbard Global Seed Vault (SGSV) for safety duplication in 2016.

New Initiatives and Developments

- **Gap Analysis and Biodiversity Mapping using GIS tools:**Mapping of collected diversity followed by gap analysis 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.
- **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 initiatedwith 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 Bureaux.
- **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 DNA-based GMO screening, viz., Hexaplex PCR targeting six marker genes; Duplex TaqMan® Real-time PCR targeting P-35S and T-nos; Visual Loop-mediated Isothermal Amplification (LAMP) targeting eight transgenic elements; Real-time LAMP targeting eight transgenic elements; TaqMan® Real-time PCR based multitarget system targeting 47 targets.

Future Thrusts for ICAR-NBPGR

- Geo-referencing of all the indigenous germplasm and superimpose it with soil and climate maps.
- Targeted germplasm collection based on gap analysis.
- Evaluation of germplasm for target traits including biotic, abiotic stress, nutritional and processing traits.
- Strengthening of post-entry quarantine.
- Geo-referencing of perennial crop (fruit and forest tree) germplasm.
- Establishment of Field Genebank for semi-arid fruits at Issapur farm of ICAR-NBPGR.
- Establishment of clonal repository of temperate fruits.
- Generation of robust cores based on high throughput genomics resources and phenotypic traits in all the major crops.

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