Crop scientists at ICRISAT are striving to achieve disease resistance, stress tolerance and nutritional improvement in our mandate crops. Modernization of the breeding programs aims to increase rate of genetic gain by focusing on improving components of the Breeders’ Equation. This includes rapid generation advancement methods, utilization of data-driven decision-making digital platforms, molecular tools and advanced phenotyping technologies. These are the key areas of focus for enhancing productivity and boosting varietal development in a demand-driven approach.
Modernizing breeding: THE ICRISAT PLAN

- Regional Crop Improvement Hubs
- RapidGen
- Digitalization and data analytics
- Structured multilocation trials
- Seed inventory management and mechanization
- Optimized breeding schemas
- Advanced molecular tools

Market-driven product profiles

Market-oriented improved varieties

Capacity building
An efficient and advanced crop breeding program contributes to higher genetic gains. Our breeding programs are designed to be focused, agile, cost-effective, and efficient. Here’s how we are staying ahead of the curve.

**Why?**
Modern breeding programs contribute towards food security by increasing rate of genetic gain in farmers’ fields and overall farm productivity.

**Why now?**

**Food security:** Maintaining a steady growth of sustainable food production is critical to achieving the UN Sustainable Development Goal of Zero Hunger (UN SDG 2) by 2030.

**Climate change:** Breeding climate-resilient crops that can give high yields in a changing climate is the need of the hour.

**Nutrition:** With over 640 million inhabitants in the semi-arid tropics, we need crops that are nutritious and environmentally resilient.

**Why us?**
We work in the semi-arid tropics, home to over 2.5 billion people, most of whom are smallholder farmers. Our crops are grown in these regions and conditions, making them the staple food for many people.

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**Regional Crop Improvement Hubs (RCIH)**

*Regional Crop Improvement Hubs set up in India, Zimbabwe in Eastern and Southern Africa (ESA) and Mali in West and Central Africa (WCA) to stimulate and support breeding programs in the region. Each hub, led by a Regional Breeding Lead, to work across the disciplines of breeding, physiology, integrated crop management, and genomics and trait discovery for delivering better product faster.*

**2019 updates**

- Crop Improvement Operations Team set up
- Regional Breeding Leads for Asia and ESA recruited
- Crop Improvement Operations Team Lead for Asia appointed
- Product Placement Lead for Asia and ESA appointed.

[https://www.icrisat.org/individual-crop-improvement-operations-merge-into-a-single-entity-for-greater-efficiency/](https://www.icrisat.org/individual-crop-improvement-operations-merge-into-a-single-entity-for-greater-efficiency/)

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**A short (hi)story**

In 1990, CCS Haryana Agricultural University (CCSHAU) released an early-maturing pearl millet hybrid HHB 67, which was rapidly adopted by farmers in north-western India and by 2002, was cultivated on approximately 774,000 ha in southern Haryana and central Rajasthan.

When Downy Mildew (DM) disease attacked it and started affecting crop yields, CCSHAU and ICRISAT together developed HHB 67 Improved, using marker-assisted back-crossing (MABC), among other techniques. This high-yielding, DM-resistant hybrid was released in 2005.

Most pests/diseases attack suddenly, with very little warning and little reaction time, e.g. Blast infestation in pearl millet in Asia and Africa in the past decade. Developing blast-resistant pearl millet is one of the top priorities due to demand from NARS breeders and seed companies.

Modernization of our breeding programs will enable responding to such threats on time, with quality and speed by utilizing and integrating latest tools and technologies.
2 Market-driven product profiles

Developing concept notes and product profiles with a focus on markets.

2019 updates

> 570 stakeholders consulted

- Three product concepts defined to complement NARS* activities in West Africa
- Two product profiles for groundnut identified
- Product concepts developed for pigeonpea (3) and chickpea (4) in ESA
- Consultation meetings held with partners.

https://www.icrisat.org/breeding-future-ready-crops/

*National Agricultural Research Systems (NARS)

3 Seed inventory management and mechanization

Accurate, faster operations with precise cataloging and use of mechanized tools.

2019 updates

- Further progress made on digitalization of seed inventory at ICRISAT Hyderabad
- Seed processing mechanization infrastructure purchased - expected to save US$ 300,000 within two years and hours of labor
- X-Ray Fluorescence facility set up at WCA for grain iron (Fe) and zinc (Zn) analyses in pearl millet, sorghum and finger millet
- Near Infra-Red Spectroscopy (NIRS) machines installed to quantify protein, oil, ash and oleic acid in groundnut
- HarvestMaster for grain weight and moisture content assessment
- Fully barcoded field plots and seed storage labels
- In ESA, genebank renovated and modernized; workspace optimized; standard operating procedures for infrastructure and safety guidelines developed.

Photo: M Magassa, ICRISAT
4 Optimized breeding schemas

Enhanced breeding schemas such as Single Seed Descent and General Combining Ability to increase selection accuracy and intensity while retaining sufficient levels of genetic diversity.

2019 updates
- Workshop held with Excellence in Breeding platform (EiB) for understanding simulation platform to evaluate various breeding schemas
- Increased breeding efficiency by adoption of Breeding Costing Tool in ESA.

5 Advanced molecular tools

Advanced technology for accurate prediction of genetic value for long-term gain.

2019 updates
- Several markers for traits in pigeonpea converted to High Throughput Genotyping (HTPG), expected to facilitate early screening, marker-assisted back-crossing (MABC)
- Improved efficiency of early generation selection in chickpea for Ascochyta blight
- Identified Single Nucleotide Polymorphism (SNP) markers in pearl millet for iron and zinc content
- Trait-based genotyping for shoot fly resistance, drought tolerance, fertility restoration in sorghum and blast resistance in finger millet.

Digitalization and data analytics

Data science, machine learning and artificial intelligence contribute to significant reduction in time taken to deliver varieties with desirable traits.

2019 updates

- Automated experimental design generation (crosses, trials, germplasm inventory) using Breeding Management System (BMS)
- Crosses made within BMS
- Digital data collection using tablets with appropriate software (e.g. FieldBook)
- Digitalized germplasm lists
- Barcodes for research plots to track seed and genotyping samples
- Genomic Open-Source Breeding Informatics Initiative (GOBii) database: data loading and development of user-friendly breeding tools
- Breeding view and GenStat software being utilized that enables analysis of unbalanced data and fitting mixed models.

RapidGen

Generation time is a game changer for achieving maximum genetic gains in crop plants. Generally, it takes seven to eight years to develop homozygous (identical) lines after hybridization with one crop generation produced per year. For instance, the Rapid Generation Advancement protocol (RapidGen) allows the production of six to seven generations of chickpea in a year under controlled glasshouse conditions.

2019 updates

- RapidGen streamlined in partnership with industry (Corteva Agriscience) and the University of Queensland, Australia
- Infrastructure set up for RapidGen Protocol Optimization and production for mainstreaming RapidGen in the Asia hub
- Effects of varying photoperiod and temperature for chickpea, pearl millet, sorghum and groundnut optimized
- Methods to enable high density sowing to produce healthy, viable seeds optimized for rapid generation cycling. These can be used at multiple stages of crop breeding programs
- Pearl millet and sorghum breeding programs to transition to RapidGen beginning 2020.

https://www.icrisat.org/new-chickpea-breeding-protocol-promises-to-bring-down-varietal-development-time-from-12-years-to-6-years/
Structured multilocation trials

Planned multilocation trials for data to accurately estimate yield, determine pattern of response for genotype/agronomic treatments and provide reliable guidance for selecting the best genotypes or agronomic treatments for planting in future years and at new sites.

2019 updates

- Increase in pearl millet varieties/hybrids from 100 to 150 in multilocation testing trials
- Advanced pearl millet lines evaluated at 15 locations in WCA representing target environments for three product concepts of Sahelian and Sudanian zones. Totally, 90 sites per season will be used
- Strategic multilocation trials for chickpea and groundnut carried out.

Capacity building

From genomics to operations to data analysis, capacity building among scientists, farmers, extension workers and other stakeholders is an ongoing process.

2019 updates

Breeding

- Leadership Training workshop on change management, team building and behavioral change in Arusha, Tanzania (30 participants)
- Excellence in Breeding Platform Annual Meeting in Amsterdam focused on modernization of CGIAR centers’ breeding programs
- Training on using digital seed catalog, seed roadmap, MEASURE\(^1\) platform for MEL platform (91 participants)
- Digitalization of breeding programs and data management (63 participants).

Genomics

- Training on next-generation genomics for crop improvement
- International workshop on genomic selection for crop improvement for participants from India, Australia and UK
- Organized 10K Chickpea Sequencing Initiative involving University College of London, BGI-Shenzhen and ICRISAT.

Data management

- Extended advanced data science support to 10 crops of the Indian Council of Agricultural Research (ICAR)
- Introduced digital interventions in NARS partners in ESA and WCA through Tropical Legumes III, HOPE\(^2\) and AVISA\(^3\) projects.

\(^1\)Monitoring and Evaluation of Agri-Science Uptake in Research & Extension; \(^2\)Harnessing Opportunities for Productivity Enhancement for Sorghum and Millets (HOPE); \(^3\)Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA)
Breeders' equation

What is genetic gain? The amount of increase in performance achieved in a generation through targeted selection determined in a crop breeding program by the following breeders' equation:

\[ \Delta G = \frac{i \times r \times \sigma_A}{L} \]

Genetic gain can be increased by:
- Enhancing selection intensity
- Increasing accuracy
- Increasing variance and/or
- Shortening the breeding cycle interval.

The initiative to streamline our crop improvement programs is a concerted effort to accelerate genetic gains in our mandate crops, resulting in faster delivery of varieties with higher yields, better nutritive value, stronger resistance to biotic/abiotic stresses and other desirable traits. These will help smallholder farmers in the dryland regions achieve financial and nutritional security, while causing minimal impact on the environment.

Acknowledgements

We thank our funders and partners for supporting us in our initiative to modernize breeding. We are confident that cutting-edge breeding programs can make a difference to smallholder farmers by providing them with climate-resilient, agro-ecologically adapted and nutritious crops.