The reshaping of crop breeding programs: How CGIAR genotyping and global partnerships are bridging gaps

1. Seeds of Change

Climate shifts, soil degradation and conflicts threaten food security in many countries worldwide. Every day, thousands of people struggle to find ways to ensure a stable food supply amid an uncertain future. For agricultural scientists, the pressing question is how their work can help minimise the impacts of these risks. Plant breeding, through improving the genetic makeup of crops, aims to increase agricultural production but also plants to become more resistant to diseases and pests - those that are currently problematic, and those that, although once considered dormant, could become future threats. Meanwhile, constant efforts are necessary to preserve crop diversity and ensure stable genetic foundation. CGIAR, and in this case CIMMYT, through Breeding Resources Initiative, as well as the Crops to End Hunger Program, funded by GIZ, supports a network of partnerships encompassing national institutes from Latin America, Africa, Asia, and Europe. This network is especially significant in the area of genotyping services where national partners work closely with CIMMYT to explore potential partnerships.

2. The Global Network

Halfway across the world, in the bustling city of Pergamino in Argentina, Maria Laura Federico implemented maize DArTag mid-density genotyping to unlock the genetic diversity of more than 500 inbred lines from the National Agricultural Technology Institute (INTA) temperate maize (*Zea mays* L.) breeding program. This research leveraged the latest advances in genotyping, helping maize breeders to better understand the genetic diversity, degree of relatedness and population structure of the existing and working germplasm, thereby facilitating breeding decisions.

In Brazil, several researchers from EMBRAPA (Brazilian Agricultural Research Corporation) have successfully genotyped various crops including maize, sorghum (*Sorghum bicolor* (L.) Moench), potato (*Solanum tuberosum* L.), and wheat (*Triticum* sp.). With the support of Breeding Resources, Claudia Guimarães was able to genotype over 300 maize elite lines and accessions with the DArTag panel aiming at germplasm organization and gene discovery. Using the same maize mid-density panel of markers, Gloria Boakyewaa Adu, the lead maize breeder at CSIR- Savanna Agricultural Research Institute (CSIR-SARI) in Tamale, Ghana, sought knowledge on which maize varieties could tackle the devastating fall armyworm (FAW) pest in West Africa. In Zimbabwe, and with support from the Accelerating Breeding Initiative, Ronica Mukaro, from the Department of Research and Specialist Services (DR&SS), Zimbabwe, is profiling maize varieties with QC KASP markers, to study their heterozygosity and improve their genetic purity.

In Europe, Mirjana Jankulovska and Nasya Tomlekova, from the Faculty of Agricultural Sciences, Ss Cyril and Methodius University, Macedonia and the Maritsa Vegetable Crops Research Institute, Bulgaria, respectively; are leading the bean's genetic research in their respective countries and initiated their genotypic activities through Breeding Resources, aiming to understand the genetic diversity contained in their germplasm to employ further genomic selection in their breeding programs.

Similarly on rice, the lead researcher Fernanda Simões, from the Instituto Nacional de Investigação Agrária e Veterinária, (INIAV), Portugal, also started the genotypic activities using Breeding Resources' services to address the diverse heterotic groups on landrace materials.

In wheat, CIMMYT's molecular breeding team, led by Susanne Dreisigacker, along with BRS, not only accomplished the development of the DArTag mid-density panel for hexaploidy wheat (*Triticum aestivum* L.) but also extended this technology to tetraploid durum wheat (*Triticum durum* L.). At the Borlaug

Institute for South Asia (BISA), the DArTag panel for bread wheat is being used to verify the identity of specific wheat translocation lines with an enhanced ability of Biological Nitrification Inhibition (BNI). This advancement can support all wheat breeders from CIMMYT and ICARDA, as well as all national program partners working on wheat.

CIMMYT knowledge will support project collaborators, including one led by Professor Emma Mace from The University of Queensland (UQ), Australia, and funded by the Bill and Melinda Gates Foundation (BMGF). This project aims to modernise breeding pipelines across target crops in the Ethiopian Institute of Agricultural Research (EIAR). As part of this broader modernisation endeavour, UQ and EIAR partnered with Breeding Resources to deploy Kompetitive Allele Specific PCR (KASP) makers linked to rust resistance in wheat, demonstrating an excellent example of merging expertise and resources as part of a global network.

3. Speaking one language to bridge differences

Preparing and delivering a one-day intense training in genotyping at Addis Ababa, Ethiopia, allowed Ethiopian partners working on wheat at the Debrezeit and Kulumsa Agricultural Research Centers, to revisit concepts on genetics and statistics, and be introduced to genotyping cost-benefit analysis. The training also highlighted how the wheat global program is utilizing the molecular markers to advance and fasten their contributions to food security.

EIAR Crop Research Director Dr. Fekadu Gurmu, speaking about the importance of new technologies for the Ethiopian breeding programs (right side); to a group of 15 Ethiopian scientists targeting wheat production in different regions of Ethiopia and acknowledging how genotyping can be used to accelerate decisions in their breeding programs (left side) during the 'Genotyping and Logistics Training', Addis Ababa, Ethiopia on 24th July 2024 (photos by A.L.G.-O.).

The training showcased how partners can introduce genetic markers in their breeding programs to accelerate the development of crops with desired traits, particularly rust tolerance. The exchange of knowledge was exhilarating, where breeders, pathologists, and bioinformaticians had a surge of inspiration and enthusiasm.

The key takeaway: it is not just about the technology itself but the partnerships that enable its application and dissemination. By working together and including different generations and genders, these global efforts are creating new paradigms in accelerating agricultural solutions.

4. Planting the Future

Ethiopian partners returned to their research stations with renewed hope and practical knowledge. With the support of our global network, the course participants connected with the CIMMYT Global Wheat Program (GWP) molecular Lab and Biometrics Unit to set up a pilot initiative to introduce the use, for the 1st time, of the wheat diagnostic genetic markers to detect rust-tolerant alleles in their national wheat cultivars. This effort will allow further selection of better wheat cultivars adapted to Ethiopian conditions. Furthermore, partners are now able to receive assistance from global experts in setting up not only a routine use of molecular markers in their breeding programs, but also have access to biometrics expertise from CIMMYT. This was only possible through the partnerships between CGIAR, CIMMYT and the University of Queensland. The success of this collaboration set the stage for a broader implementation and may extend the partnership to other crops of national, regional, and continental interest.

5. Harvesting Success

In maize, Maria Federico was able to pave the way for the development of genomic prediction models for resistance to prevalent fungal and viral diseases. From South America to Africa, this year, Gloria Adu published the first study on the diversity of West African maize, derived from CIMMYT and IITA germplasm, that shows great potential to resist the devastating effects of fall armyworm attacks, and which can destroy up to 100% of maize fields (Adu et al., 2024). Her ongoing work focuses on identifying new loci that can provide even greater resistance to the fall armyworm pest. The ultimate goal of these efforts is to provide robust performance in maize produced by national partners and distribute it to farmers in South America, Africa, and

beyond. This achievement will empower farmers to have better choices and solutions to their day-to-day challenges.

6. Partnerships are key

One may ask, what ties all these stories? The answer: the common challenge of limited funding to initiate genotyping activities as a routine practice in national breeding programs.

Through CGIAR and, specifically, with support from Breeding Resources, many breeding programs are now gaining the opportunity to use genotyping services for the first time and to establish enduring, trusted partnerships with the organization. Each program and region has a different relevance and priorities, but the non-exclusion principle is applied. As the sun sets over any thriving field, we reflect on the journey that has transformed breeding communities and on the broader impact, our work aims to achieve.

The genetic revolution in breeding programs is not just about science; it is mainly about the connections forged across continents, the shared knowledge, and the collective effort to build a more resilient, sustainable, and peaceful future through agriculture. As new challenges arise, each partner should remember that the spirit of collaboration will continue to be the key to thriving and succeeding.

In the end, it is clearer that the future of agriculture can be shaped by both technology and the powerful partnerships that enable its continuous advancement.

Resources:

- News story: Crops to End Hunger Case Studies in Africa and Beyond: Supporting CGIAR Partners through Genotyping Services

- Adu, G.B., Awuku, F.J., Garcia-Oliveira, A.L., Amegbor, I.K., Nelimor, C., Nboyine, J., *et al*. (2024). DArTseq-based SNP markers reveal high genetic diversity among early generation fall armyworm tolerant maize inbred lines. *PLoS ONE*, 19(4): e0294863. https://doi.org/10.1371/journal.pone.0294863mn

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Main image: Depicting the diverse partners around the world supported by CGIAR Breeding Resources Initiative on genotyping in 2024. Maria Federico (EEA Pergamino INTA, Argentina), Cátia Santos (INIAV, Portugal), Ronica Mukaro (DR&SS, Zimbabwe), Cláudia Guimarães (EMBRAPA, Brazil), Gloria Adu (CSIR-SARI, Ghana), Nasya Tomlekova (MVCRI, Bulgaria), Mirjana Jankulovska (SsCMU, Macedonia) and Rut Duga (EIAR, Ethiopia) (from top left; photos from authors).

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Online version of this story: https://www.cgiar.org/news-events/news/the-reshaping-of-crop-breeding-programs-how-cgiar-genotyping-and-global-partnerships-are-bridging-gaps/