The CGIAR Generation Challenge Programme at 6

From discovery to application and impact in crop improvement

Food security in the developing world continues to be one of the greatest global challenges of our time, now exacerbated by the ongoing global financial crisis, and the unpredictable vagaries of climate change. Created by the CGIAR in 2003 as a time-bound 10-year programme in two phases (2004–2008 and 2009–2013), the goal of the Generation Challenge Programme (GCP) is to increase breeding efficiency, targeting traits for drought-prone and harsh environments. GCP supports a vibrant community of researchers and stakeholders from more than 200 diverse institutions, including universities, CGIAR Centres, and our main target users and stakeholders – country research programmes and civil society organisations. Through this wide range of partners, GCP links basic science with applied research, helping to weave an effective and interactive community of crop researchers at both global and regional levels. By both capacity-building and assisting developing world researchers to tap into a broader and richer pool of plant genetic diversity, GCP strives to ensure that crops improved by cutting-edge science will reach farmers in the developing world.

Enlisting and banking on nature by tapping natural crop diversity

The germplasm banks of the CGIAR were originally conceived purely for conservation but breeders now realise the high value of also studying these collections and how they perform under different field conditions, because genetic variation allows plants to adapt and blossom in harsh environments. For this reason, collections of crops and their wild cousins are a valuable source of new genes for agriculture. To bring this diversity down from the shelf for breeding, GCP-supported researchers analysed naturally occurring genetic diversity for 19 important food crops.

Delivering the promise of molecular breeding by providing the right tools

The key is in the genes: Science now has the key for bringing the fruits of nature's genetic diversity to bear in the shortest possible time – molecular breeding. Studying a plant's genetic code to identify carriers of desired qualities saves both time and money compared to conventional breeding, in which breeders identify desired qualities purely from observation of plant growth. But this straight-to-the-genes breeding requires certain sophisticated tools, which scientists collectively term 'genomic resources'.

Equal footing for food security: At GCP's founding, these genomic resources – including molecular markers – were unevenly distributed across crops, and in fact almost completely lacking for 'orphan crops'* such as legumes which are, however, critical in balancing diets and providing smallholder income in developing countries. Within the span of Phase I, GCP filled this gap, and in conjunction with collaborative efforts outside GCP, genomic resources for molecular breeding are now available for all of GCP's 19 mandate crops. Of special note is GCP's effort to develop genomic resources for historically under-resourced crops (see Table 1). These new tools will immensely enhance breeding efficiency as has been demonstrated by the private sector.

The reference sets, a suitable pool of new genes for agriculture: Using pedigree information and the new genomic tools to characterise germplasm bank accessions, 'reference sets' have been identified for GCP crops. 'Reference sets' refers to a few hundred accessions widely representative of each crop's own genetic diversity (magnitude of several thousand accessions stored in genebanks). This effort conducted during Phase I unlocked some of the diversity conserved in CGIAR genebanks, providing easy access to a broad set of new genes in a manageable number of accessions, and shall have impact on crop productivity within the next decade. To identify these genes, it is important to further characterise the reference sets under different target environments, and a steadily increasing demand for some of the reference set accessions clearly demonstrates their relevance to breeders, as evidenced at the International Crops Research Institute for the Semi-arid Tropics (ICRISAT, see Table 2). Over the last two years (2008–2009), ICRISAT has distributed 20 sets across 10 countries as follows: chickpeas (6 sets, 4 countries); groundnuts (6,5); pearl millet (1,1); and sorghum (7, 6). As another demonstration of interest by breeders in these GCP products, some of the accessions from the reference sets are now extremely popular, generating an exceptional demand for a few reference set accessions, as in the example from the International Rice Resesearch Institute (IRRI) in Figure 1. In Phase II, GCP will strive to better characterise in the reference sets new genes for drought tolerance for several target crops – mainly for sub-Saharan Africa, and for South and Southeast Asia.

* A collective term for crops that have not received the research attention afforded to crops grown in wealthier regions, particularly major cereals such as rice, maize and wheat.

Table 1: Crops whose diversity array technology (DArT) marker systems were supported by GCP in Phase I, and developed at DArT Pty Ltd. The table indicates the total number of markers, the average number of polymorphic markers per accession, how many times the markers have been used (as of December 2009) and the partners who contributed to developing the tools.

Crop	Markers (total)	Number of times used	Markers (accession)	GCP partner(s)
Cereals				
Sorghum	20,000	>1,000	2,500	ICRISAT, Agropolis–CIRAD
Pearl millet	7,680	96	1,500	ICRISAT, Agropolis–IRD
Legumes				
Chickpeas	21,500	300	5,400	ICRISAT
Groundnuts	15,360	300	5,000	ICRISAT, EMBRAPA, Agropolis–CIRAD, ISRA
Other crops				
Potatoes	20,000	300	9,000	CIP, INIA and other members of the Consortium of Potato Breeders of S America
Sweet potatoes	7680	96	2,000	CIP
Cassava	18,000	450	2,500	Bioversity, CIAT, RFCRC
Yams	6,890	94	2,500	IITA, Agropolis–CIRAD,
Coconuts	7,680	130	400	CIRAD
Musa	15,360	300	5,000	Bioversity/CIRAD

CIAT = International Center for Tropical Agriculture; CIP = International Potato Center; CIRAD = Centre de coopération international en recherche agronomique pour le développement, France; EMBRAPA = Brazilian Agricultural Research Corporation; IITA = International Institute of Tropical Agriculture; INIA = Instituto de Investigaciones Agropecuarias, Chile; IRD = Institut de recherche pour le développement, France; ISRA = Institut sénégalais de rcherches agricoles, Senegal; RFCRC = Rayong Field Crops Research Center, Thailand

Table 2. Examples of trait-specific germplasm identified by ICRISAT using the reference set approach, and distributed to country and other research programmes as of December 2009.

Crop, country and partners	Traits
Groundnuts	
China: Chinese Academy of Agricultural Sciences, Wuhan	Productivity, disease resistance, quality
India: University of Agricultural Sciences (Bangalore, Dharwad); Punjab Agricultural University, Ludhiana; and other partners in India	Disease resistance, confectionery, early maturity, productivity, quality traits, drought tolerance
Vietnam: Vietnam Agricultural Science Institute Hanoi; Oil Plant Institute of Vietnam	Productivity in target environment
Thailand: Department of Agriculture Chatuchak target environment	Productivity and disease resistance in
Pearl millet	
India: All-India Coordinated Pearl Millet Improvement Project, Jodhpur	Productivity and fodder
Pigeonpeas	
Dubai, UAE: International Center for Biosaline Agriculture	Productivity in target environment
India: Indira Gandhi Krishi Vishwavidyalaya, Raipur; Indian Institute of Pulses Research, Kanpur	Yield and yield attributing traits; donor sources for productive and yield attributing trait for hybridisation

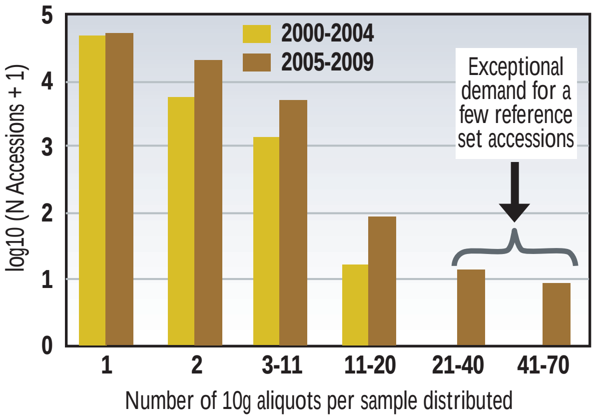

Figure 1: Frequency and pattern of seed distribution at IRRI, in 2000–2004 (before GCP) and in 2005–2009 (after GCP)
Source: IRRI

Locating the genes to rapidly increase crop productivity

While drought continues to be GCP's priority problem, other crop problems have not been neglected, since crops may survive drought but succumb to other afflictions.

Within a relatively short time – given the complexity of the task and the multiple partnerships involved – some of GCP's products from Phase I are already in the hands of breeders and will soon be on their way to farmers' fields. For example, in Phase I, GCP supported the successful identification of aluminium toxicity gene in sorghum and the gene for improving phosphorus uptake and salt tolerance in rice. This single step serves the dual purpose of providing genes to improve breeding, while also generating new knowledge for geneticists to improve other cereals like maize and wheat. The aluminium tolerance gene cloned in Phase I has already been introduced into Brazil's elite sorghum and will be transferred to Africa in Phase II. As a result of this research, markers are now being used by breeders to improve rice for salt tolerance in Bangladesh and for low-phosphorous soils in Indonesia, and are being tested elsewhere as well, including in The Philippines and India. A recent economic analysis on molecular breeding for rice varieties tolerant to salinity and low phosphorous in target Asian countries (as mentioned above) concluded that the molecular breeding method saved an estimated minimum of between two and three years of breeding time, resulting in significant incremental benefits in the range of USD 50 to 500 million (see: http://www.generationcp.org/sp5_impact/sp5main).

As another example of products on the way to farmers, molecular breeding has produced *Striga*-resistant cowpea varieties for Africa that are now being crossed into farmer-preferred varieties, through farmer–researcher participatory selection and trials. Initially focusing on Burkina Faso, the work will expand to Niger and will ultimately benefit cowpea farmers across West and Central Africa. *Striga* is a prolific and parasitic weed that also afflicts other crops, and these crops too will benefit from work with the *Striga*-resistant gene in cowpeas.

Genomic regions conferring drought tolerance have been characterised for several cereals and legumes during Phase I, new breeding traits have been identified, and the screening methodology has been improved. Phase II will build on these discoveries. The focus of most breeding activities will be molecular breeding for drought tolerance, and the use of tools to stack elite alleles from contrasting parental lines to develop improved germplasm.

Pipelines and platforms to make it happen: accessing the technology and ensuring delivery

Capacity-building and data access

Access to technologies for molecular breeding in developing countries is absolutely critical for the sustainability and use of GCP products. Since its inception, GCP invested heavily in capacity-building, and, more recently, in platform development. Throughout Phase I, capacity-building served broad-based needs through open calls for fellowships, and support to applied research teams to enhance both human capacity and physical infrastructure. As a result, an increasing number of projects are now led by developing country researchers, as more GCP products stream down the research–delivery pipeline from exploration and discovery to application and breeding.

Bioinformatics and information systems are the heart and arteries of any research network and particularly so for GCP which is dispersed across many disciplines and locations. In Phase I, GCP developed infrastructure to network diverse databases, and supported tools and standards for integrating and analysing data from different sources and disciplines. Making data from GCP projects publicly available is crucial, and GCP established procedures and infrastructure for storing and publishing quality data for reuse as global public goods for use by all.

In mid-2009, GCP established a public Integrated Breeding Platform as an online one-stop shop with centralised and functional access to modern breeding technologies, value-added germplasm, marker service laboratories, data management and analysis tools. By providing access to efficient marker technology and related services, this platform is expected to overcome several logistical and technological bottlenecks in using molecular breeding in developing countries.

To ensure impact, each GCP project is designed with clear impact indicators in mind and product Delivery Plans are identified and articulated at project inception. These plans are conceived jointly with product users, thereby taking into account local needs and priorities. GCP also has an established policy requiring that data from all GCP-funded projects be in the public domain for access and use by all.

Perspectives and strategies for delivery and impact

Phase I was defined by exploration and discovery, and Phase II will facilitate wide distribution of advanced breeding technologies. This will be achieved through platforms, by guaranteeing access to, and distribution of, GCP products in a user-friendly and sustainable manner, and through Challenge Initiatives (CIs) which will support applied research. The seven CIs are crop- and trait-specific with clear target countries for each. The two platforms on molecular breeding and genetic resources will serve as vehicles for dissemination by enabling broad access to, and proactive dissemination of, crop resources, technologies and information, including research data. The anticipation is that impact in CI target countries will not only spread beyond these countries but also demonstrate effective models that can be used in other countries and regions.

GCP has engendered a vibrant community that has cultivated and nurtured extensive and effective partnerships, and established an even broader network of R&D participants to support and help realise GCP objectives. The first GCP External Programme and Management Review conducted towards the end of Phase I captures this 'people' essence of GCP in its conclusion: *"Perhaps the most important value of GCP thus far, is the opportunities it has provided for people of diverse backgrounds to think collectively about solutions to complex problems and in the process to learn from one another."* Building a solid community is a major impact indicator: by the end of Phase II, GCP aims to facilitate and empower a solid community of developing country breeders who routinely use molecular breeding to improve crop productivity and contribute to food security and poverty alleviation in the developing world.

Cowpeas are an important crop in sub-Saharan Africa, and nearly three-quarters of the global cowpea cropping area lies in West and Central Africa. Cowpeas are remarkably drought-tolerant, but many farmer-preferred varieties are however highly susceptible to insect pests, disease, and the parasitic weed, *Striga*. "Drought may be the most persistent problem in this region, but without improved resistance to pests like *Striga*, even the most drought-tolerant crops don't stand a chance," observes Satoru Muranaka (pictured, in a cowpea–sorghum field), a crop physiologist at the International Institute of Tropical Agriculture.


Jennifer Nelson

Healthy plants that resist cassava mosaic disease (CMD) overshadow a stunted susceptible plant at the Umudike experiment station in southeastern Nigeria. CMD is the worst threat to cassava in sub-Saharan Africa, where more than 85 million tonnes are produced annually, accounting for nearly half of global production. In Phase I, GCP supported research to improve cassava productivity by drawing genes from its wild cousins, and helped to equip Nigeria's National Root Crops Research Institute's (NCRCI) laboratory for molecular breeding. "This GCP project is exactly the kind of collaboration we are looking for," said Kenneth Nwosu, NCRCI's Executive Director. "We gain important links to international agricultural research institutes as well as regional partners, which strengthens our core business of conducting research to benefit Nigerian farmers." From this work, four varieties have been submitted for farmer evaluation trials (which are the last phase of pre-release trials), with one expected for release in 2010, and a second one projected for 2011. In the project, NCRCI collaborated with the International Center for Tropical Agriculture (CIAT), the Brazilian Agricultural Research Corporation (EMBRAPA), Crop Research Institute (Ghana) and the National Crop Resources Research Institute (Uganda).


Emmanuel Okogbenin

Md Sazzadur Rahman

In Bangladesh's rice-growing coastlands, nearly one million hectares are affected by saline soils, more pronounced in the dry, winter, pre-monsoon months. Even during the monsoons, many areas in the coastal south are affected by salinity due to deliberate inundation with brackish water for shrimp farming. And that is not all: in late 2007 and mid-2009, southwestern coastal areas were devastated by cyclones which destroyed embankments and swept in tidal surges of salty water, endangering the livelihoods of nearly quarter of a million people. In Phase I, GCP invested in an IRRI-led project to breed salt-tolerant rice, in collaboration with the Dhaka University and the Bangladesh Rice Research Institute (BRRI). This variety will be suitable for growth in the monsoon season as well, and – even more importantly – also in areas around and close to shrimp farms, which currently remain fallow. As such, any rice cultivation in the shrimp fields or moderately saline areas in the monsoon season would bring in 'bonus' dry-season livelihood earnings. One of the rice varieties under development combines salt-tolerance with a farmer-preferred variety. Seeds have been multiplied at BRRI and will be tested in farmers' fields in the monsoon season of June–October 2010. Another variety is for the dry winter season, and seeds for multiplication and field trials are projected for handover to BRRI around November 2010. In this picture at BRRI, Nirmal Sharma and Jamal emasculate the first backcross population of a cross-combination for a second backcross.

Further reading

Generation Challenge Programme (2007). *Partner and product highlights 2006*. Mexico DF, Mexico.

Generation Challenge Programme (2006). *Research highlights 2005*. Mexico DF, Mexico.

Glaszmann JC, Kilian B, Upadhyaya HD and Varshney RK (2010). Accessing genetic diversity for crop improvement. *Current Opinion in Plant Biology* 13 (2):167–173. DOI:10.1016/j.pbi.2010.01.004.

ICRISAT (2009). *Mini core collections for efficient utilisation of plant genetic resources in crop improvement programs*. Information Bulletin No 78. Patancheru, Andhra Pradesh, India.