Integrated Breeding Platform

Accessible cutting-edge crop breeding tools and services

In the last decade, the private sector has benefitted immensely from molecular breeding (MB). A private sector-led 'gene revolution' has boosted crop productivity in developed countries, by applying and combining the latest advances in molecular biology and information technology with accurate plant phenotyping.

In contrast, MB adoption is still limited in the public sector, and hardly used at all in developing countries. Major bottlenecks in these countries include shortage of well-trained personnel, inadequate requisite infrastructure, and lack of information systems with adaptable analysis tools – quite simply, resource-limited breeding programmes. As a result, the developing world has not benefited from this revolution.

The Integrated Breeding Platform (IBP) is envisioned as a sustainable, web-based, one-stop shop for information, analytical tools and related services to design and carry out integrated breeding projects. IBP will boost crop productivity and resilience for smallholders in drought-prone environments by exploiting the economies of scale afforded by collective access to cutting-edge breeding technologies and informatics hitherto unavailable to developing-country breeders.

Molecular breeding

Molecular breeding (MB) is the generic term used to describe several modern breeding strategies, such as marker-assisted selection (MAS), marker-assisted backcrossing (MABC), marker-assisted recurrent selection (MARS) and genome wide selection (GWS).

MB allows stacking favourable alleles, or genomic regions, of target traits in desired genetic background thanks to the use of polymorphic markers. This increases genetic gain per crop cycle and reduces the number of selection cycles, hastening the delivery of improved crop varieties to farmers.

A GCP *ex-ante* evaluation of rice-breeding projects in Asia and cassava-breeding projects in Africa found that the use of markers shortened development time for new improved cultivars by several years and, despite higher start-up costs, brought savings and higher value over time (GCP, 2010).

The Generation Challenge Programme (GCP) of the Consultative Group on International Agricultural Research (CGIAR) is building the IBP in collaboration with 14 initial 'user cases' (see table and map) – breeding projects for eight crops in 32 developing countries in Africa and Asia. This ensures IBP development is driven by real breeder needs and its interface is user-friendly. IBP is proposed to open up to additional users from 2012, with full unfettered access scheduled for 2014.

Generation Challenge Programme

CULTIVATING PLANT DIVERSITY FOR THE RESOURCE-POOR

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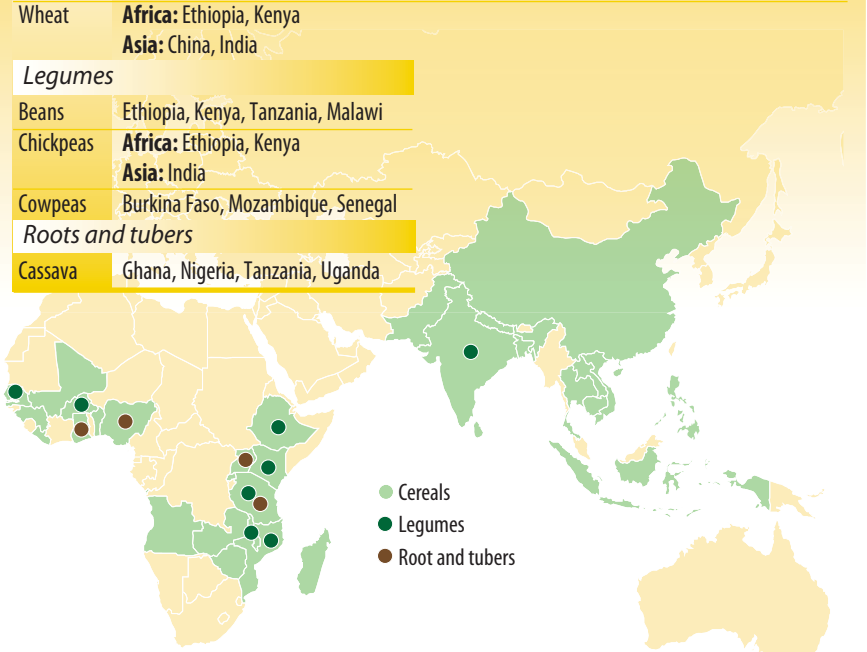
Cereals

"This virtual platform aided by the information and communication technology revolution will help to overcome some of the challenges facing developing-country breeders, by providing them with convenient and cost-effective access to genomic resources, advanced laboratory services, and robust analytical and data management tools," says Jean-Marcel Ribaut, GCP Director.

"With the IBP, cutting-edge technologies will no longer be largely the preserve of private companies big enough to invest in infrastructure and capacity on their own," observes IBP Project Manager, Graham McLaren. "Access to top-notch informatics tools to support breeding logistics, data collection and management, analysis, and decision modelling will in turn lead to an accumulation of accessible quality-assured public crop information."

Initial user cases: 8 crops across 32 countries

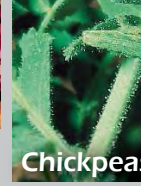
Cereals	
Maize	**Africa:** Angola, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe **Asia:** China, India, Indonesia, Thailand, The Philippines, Vietnam
Rice	**Africa:** Benin, Burkina Faso, Ethiopia, Gambia, Ghana, Guinea, Liberia, Madagascar, Mali, Mozambique, Nigeria, Rwanda, Senegal, Tanzania, Uganda **Asia:** Bangladesh, Cambodia, China, India, Indonesia, Laos, Nepal, Pakistan, Sri Lanka, Vietnam
Sorghum	Mali
Wheat	**Africa:** Ethiopia, Kenya **Asia:** China, India
Legumes	
Beans	Ethiopia, Kenya, Tanzania, Malawi
Chickpeas	**Africa:** Ethiopia, Kenya **Asia:** India
Cowpeas	Burkina Faso, Mozambique, Senegal
Roots and tubers	
Cassava	Ghana, Nigeria, Tanzania, Uganda



Capacity development is an integral part of the project, encompassing training and support in using molecular breeding techniques and markers, designing breeding strategies, quality data management, information analysis and decision modelling, phenotyping protocols, and protection of intellectual property.

By providing forums and other community tools via a user-friendly portal, IBP will stimulate the development of crop- and discipline-based communities of practice (CoPs). The CoPs will promote application of molecular breeding techniques and utilisation of facilitative information management technologies, enhance data and germplasm sharing, and generally advance modern breeding capacity by linking CGIAR Centres and advanced research institutes with developing-country breeding programmes and research organisations. They will also facilitate and accelerate a paradigm shift to a more collaborative outward-looking, technology-enhanced approach to breeding.

The project is funded by the Bill & Melinda Gates Foundation, the European Commission and the United Kingdom's Department for International Development. The IBP Business Plan envisions the platform carrying on as a sustainable CGIAR service supported in part by annual fees paid by members of a formal IBP user community. Strategic guidance is provided by the Scientific and Management Advisory Committee (SiMAC) – comprised of leading professionals drawn from relevant fields, many from the private sector.

The Platform

The IBP has three broad components (see Figure 1): a web-based portal and helpdesk, an open-source information system incorporating an adaptable breeding workflow system, and breeding and support services.

Portal: Scheduled for inauguration in 2011, the portal will be the online gateway through which users select and download tools and instructions, order materials and procure laboratory services. The portal's helpdesk will facilitate its use and ensure access for users who cannot efficiently use the web interface, by providing the elements they need via email, CD and other offline media.

Information System: The centrepiece of the fully operational IBP will be the Configurable Workflow System (CWS) – an integrated software system for managing logistics, data, analysis, simulation and decision-making for integrated plant breeding projects through a user-friendly graphical user interface (see Figures 2). As the informatics workbench for all users of the Platform, the CWS will comprise of interconnected automatic and manual data capture and quality assurance tools, comprehensive analytical toolboxes, state-of-the-art simulation tools, and advanced decision-support tools. It will be customisable for different crops and breeding strategies, and will have both web-based and virtual appliance versions.

Services: The service component is at this time the most advanced component of the IBP. Brokerage of molecular marker laboratory services is firmly established and capacity development activities are well underway – incorporating both intensive training and support with infrastructure for selected field sites. Other priority services under development in collaboration with user cases are design and analysis for experiments, and assistance with drawing up breeding plans.

Figure 1: The Integrated Breeding Platform at a glance

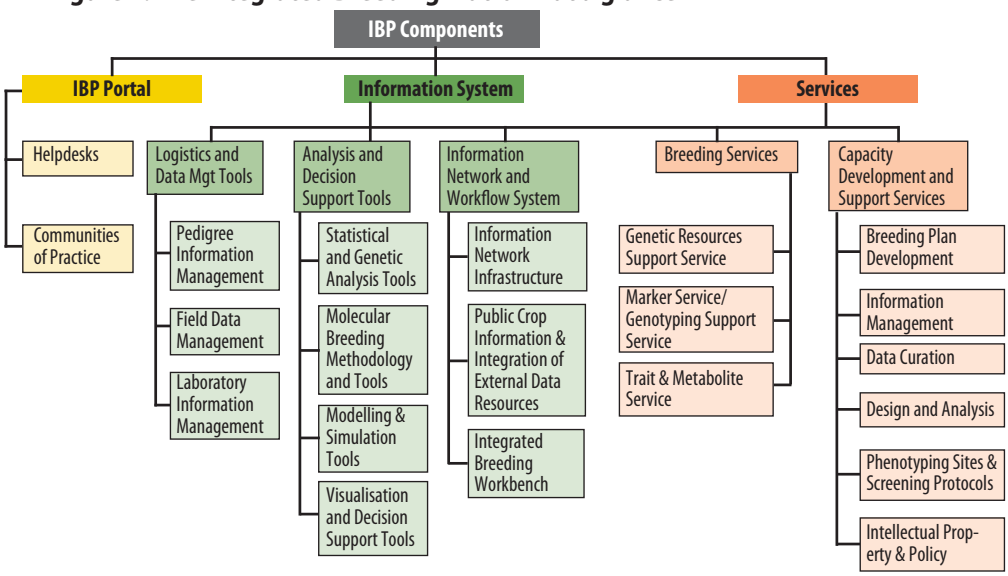


Figure 2: Overview – Configurable Workflow System

Integrated Breeding Configurable Workflow System

Breeding Activities

Project Planning	Germplasm Management	Germplasm Evaluation	Molecular Analysis	Data Analysis	Breeding Decisions
• Open project • Specify objectives • Identify team • Data resources • Define strategy	• Parental selection • Crossing • Population development	• Experimental design • Fieldbook production • Data collection • Data loading	• Marker selection • Fingerprinting • Genotyping • Data loading	• Quality assurance • Trait analysis • Genetic analysis • QTL analysis • Index analysis	• Selected lines • Recombines • Recombination plans

WorkBench Administration & Configuration System	Integrated Breeding Management System	Integrated Breeding Field Trial Mgt System	Genotypic Data Management System	Statistical Analysis System	Decision Support System
• WorkBench Administration App • Project Configuration App • D-base Backend	• Breeding Manager App • Genealogy Manager App • Query Manager App	• Trial Fieldbook App • Environment Characterisation System App	• Sample Management Application	• Data Mgt App • Phenotypic Data Analysis App • Molecular Genetic Analysis App • Selection Indices Apps	• Breeding Decision Support Apps (MAS, MABC, Cross Prediction) • MARS Decision Support App • Simulation Apps

Analytical Pipeline

Breeding Applications

Legumes

Roots and tubers

How it will work

A valuable by-product of using this common system will be the accumulation of well-documented, readily accessible, high-quality breeding data and information for integration and publication by the Crop Lead Centres of the CGIAR as part of a public network of crop breeding information, essential for accurate predictive breeding.

"It would be unrealistic to project that large-scale molecular breeding activities will be conducted in developing countries in the near term," Dr Ribaut cautions, "However, the exponential development of genomic resources, the ever-declining cost of marker technologies, the emergence of platforms for accessing molecular breeding tools and support services, the increasing public–private partnerships and needs-driven demand for improved crop varieties to counter the global food crisis, are all grounds to predict that molecular breeding will have a significant impact on crop breeding in developing countries."

Initial user cases: 14 breeding projects

Crop	User Case/Project	Countries/regions	Leader (Funder)
Cereals			
1. Maize	1. Drought-tolerant maize for Africa	Angola, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe	CIMMYT (BMGF)
	2. Drought-tolerant maize for Asia	China, India, Indonesia, Thailand, The Philippines, Vietnam	CIMMYT (GCP)
2. Rice	3. Stress-tolerant rice for poor farmers in Africa and South Asia	**Africa:** Benin, Burkina Faso, Gambia, Ghana, Guinea, Mali, Nigeria, Senegal, Ethiopia, Madagascar, Mozambique, Rwanda, Tanzania, Uganda **South Asia:** Bangladesh, India, Nepal	IRRI (BMGF)
	4. Green super rice for poor farmers of Africa and Asia	**Africa:** Liberia, Mali, Mozambique, Nigeria, Rwanda, Senegal, Tanzania, Uganda **Asia:** Bangladesh, Cambodia, China (Sichuan, Yunnan, Guangxi and Guizhou Provinces), Indonesia, Laos, Vietnam, Pakistan, Sri Lanka	CAAS–IRRI (BMGF)
	5. Improving drought tolerance for rice in Africa	Burkina Faso, Mali, Nigeria	ARC (GCP)
3. Sorghum	6. Yield improvement of sorghum in Africa through marker-assisted recurrent selection	Mali	CIRAD (Syngenta/GCP)
4. Wheat	7. Molecular marker technologies for faster wheat breeding in India	India	PBI–UoS (ACIAR)
	8. Durable rust resistance in wheat	China, Ethiopia, Kenya	USDA–CIMMYT (BMGF)
	9. Breeding and selection strategies to combine and validate quantitative trait loci for water-use efficiency and heat tolerance	India	IARI–ICAR (GCP)
	10. Breeding and selection strategies to combine and validate quantitative trait loci for water-use efficiency and heat tolerance	China	CAAS–ICS (GCP)
Legumes			
5. Beans	11. TLI: Improving common bean (*Phaseolus vulgaris* L) productivity for marginal environments in sub-Saharan Africa	Ethiopia, Kenya, Tanzania, Malawi	CIAT (BMGF/GCP)
6. Chickpeas	12. TLI & TLII: Improving chickpea (*Cicer arientinum* L) productivity for marginal environments in sub-Saharan Africa and Asia	Ethiopia, Kenya, India	ICRISAT (BMGF/GCP)
7. Cowpeas	13. TLI: Improving cowpea (*Vigna unguiculata* L) productivity for marginal environments in sub-Saharan Africa	Burkina Faso, Mozambique, Senegal	UC–R (BMGF/GCP)
Roots and tubers			
8. Cassava	14. Improving cassava yield in Africa's drought-prone environments	Nigeria, Ghana, Tanzania, Uganda	NCRCI (GCP)

Acronyms and abbreviations

ACIAR	Australian Centre for International Agricultural Research
ARC	Africa Rice Center
BMGF	Bill & Melinda Gates Foundation
CAAS	Chinese Academy of Agricultural Sciences
CI	Challenge Initiative
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
GCP	Generation Challenge Programme
IARI	Indian Agricultural Research Institute
IITA	International Institute of Tropical Agriculture
ICAR	Indian Council on Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICS	Institute of Crop Science
IRRI	International Rice Research Institute
NRCRI	National Root Crops Research Institute, Umudike, Nigeria
PBI	Plant Breeding Institute
TLI	Tropical Legumes Project I (BMGF-funded) led by GCP
TLII	Tropical Legumes Project II (BMGF-funded) led by ICRISAT
UC–R	University of California, Riverside
UoS	University of Sydney, Australia
USDA	United States Department of Agriculture

Pioneer users speak

Elliot Tembo works for Seed Co, a 70-year-old enterprise developing and marketing diverse crop seeds in Zimbabwe with operations in 13 other countries across Africa. Mr Tembo is also a member of the IBP User Committee representing the private sector. He is particularly keen to complement conventional breeding techniques with molecular tools to expedite breeding. "The IBP can assist Seed Co identify appropriate marker service providers and generate valuable genotypic data on our germplasm," he says. "And we can most certainly benefit from the data-management and analytical tools that the IBP is developing."

Prof Richard Trethowan of the University of Sydney, Australia, is involved in several user cases and leads a project supported by the Australian government. "We've used the informatics components of the IBP to establish the International Crop Information System (ICIS) at all project nodes and to maintain functional local databases," he reports. "Now we need the IBP to provide query tools to help make sense of our data. We have pedigree, phenotypic and molecular data in ICIS but the tools we currently have for combining and analysing these data to make better plant-breeding decisions are not effective."

The multi-crop GCP legume project in Africa, amongst other interventions, fosters modern approaches to accelerate the breeding of cowpea varieties with improved productivity in drought-prone environments. "The IBP is a critical resource for developing optimised marker-assisted breeding approaches for national agricultural research systems in Africa," comments Dr Jeff Ehlers, from the University of California, who heads the cowpea work. He anticipates that the IBP will facilitate processing of breeding data by supplying tools for genetic analysis, selection decisions, and for simulation and visualisation. He is particularly looking forward to the IBP phenotyping support services.

"With the community of practice, all that is gained will be shared," says Mrs Elizabeth Parkes of Ghana's Crop Research Institute, in reference to the community of practice (CoP) for cassava breeders in Africa. This CoP brings together researchers from Ghana, Nigeria, Tanzania and Uganda, with a view to strengthening the capacity of country breeding programmes to combine both conventional and molecular breeding. CoP breeders are linked with mentors from CIAT(Centro Internacional de Agricultura Tropical; the International Center for Tropical Agriculture), Cornell University, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária ; the Brazilian Agricultural Research Corporation) and IITA (International Institute of Tropical Agriculture). The members have benefitted from IBP's Genotyping Support Service (GSS) and received training on analysis of genotypic and phenotypic data. GCP is also funding several PhD students working on cassava breeding in all of the four CoP countries.

Taking a risk?

The principal ever-present risk associated with IBP is that of developing tools that do not meet user needs – reducing the entire venture into technology-push rather than demand-driven. This risk is mitigated by sustaining conversations between platform users and platform developers, and engaging with leading practitioners and institutes. The User Committee and the user cases embody this engagement, and the CoPs will reinforce it.

The risk of non-sustainability is real, but is being addressed by negotiating a long-term position for the Platform as a cross-cutting service in the future CGIAR, with allied concepts of a membership supported by dues.

The Platform ultimately aims to achieve and facilitate unhindered sharing of information, which means overcoming the traditional reluctance of researchers to share data. This is being addressed by ongoing negotiation and confidence-building measures, and an evolving management and regime that will give distinct privileges to those users willing to share their data.

Last but not least, researchers need to change their mindset, moving from an institute-centric to a cooperative approach under which good communication, concise documentation of activities and standardisation of approaches are critical.

Further reading

Ribaut JM, de Vicente MC and Delannay X (2010). Molecular breeding in developing countries: challenges and perspectives. *Current Opinion in Plant Biology* 13(2):213–218 (DOI: 10.1016/j.pbi.2009.12.011).

Generation Challenge Programme (2010). *Molecular and conventional breeding through an economic lens: facts and figures to shed light in a heated debate*. Brief, Generation Challenge Programme, Mexico DF, Mexico, 6 pp.

Fredenburg P and Nelson J (2007). *Partner and product highlights 2006*. Booklet, Generation Challenge Programme, Mexico DF, Mexico, 43 pp. See especially:

3: *Cassava poised for a sea of change*
7: *At home and to go* and *Molecular bonds*
10: *Pass the* Saltol

Visit **www.generationcp.org/ibp** for more information about the Integrated Breeding Platform.

About the CGIAR Generation Challenge Programme (GCP)

Created by the Consultative Group on International Agricultural Research (CGIAR) in 2003 as a time-bound 10-year Programme, the mission of the CGIAR Generation Challenge Programme (GCP) is to use genetic diversity and advanced plant science to improve crops by adding value to breeding for drought-prone and harsh environments. This is achieved through a network of more than 200 partners (as of 2010) drawn from CGIAR Centres, academia, regional and country research programmes, and capacity enhancement to assist developing-world researchers to tap into a broader and richer pool of plant genetic diversity. In this way, GCP strives to ensure that crops improved by cutting-edge research will reach farmers in the developing world. In Phase I (2004–2008), GCP worked on 18 crops, while in Phase II (2009–2013), the main focus is on improving seven key crops for drought-tolerance.

Funding: GCP's annual budget of about USD 15 million is supported by the generosity of various funders, most coming through the CGIAR. In Phase I, our major funders were the European Commission, the UK's Department for International Development and the World Bank. The Bill & Melinda Gates Foundation has become a major funder In Phase II, alongside these three continuing funders. Collectively, the four contribute about 90 percent of GCP's total income.

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April 2011

Crop photo credits: CIAT– beans, cassava; CIMMYT – wheat; ICARDA – chickpeas; ICRISAT – sorghum; IITA – cowpeas, maize; IRRI – rice