DRAFT FOR DISCUSSION

Generation Challenge Programme

Partnerships in modern crop breeding for food security

White paper on GCP Research Initiatives

SEPTEMBER 2012

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GCP Sunset and transition strategy

The Generation Challenge Programme (GCP) is a 10-year CGIAR initiative, focusing on crop improvement in developing countries with an emphasis on drought tolerance. Designed in two five-year phases (2004–2008 and 2009–2013, with 2014 as a transition year for orderly closure), its mission is to use genetic diversity and advanced plant science to improve crops by adding value to conventional breeding for drought-prone and harsh environments. This is achieved through a network of more than 200 partners (as of 2011) drawn from regional and national research programs, the CGIAR and academia, and through capacity enhancement to assist developing-world researchers to tap into new genetic diversity and access modern breeding tools and services.

Closing GCP will include evaluating the Programme's performance and impact, identifying the lessons learnt and positioning GCP's products and legacy in a sustainable manner in the R4D landscape, to fulfill our commitments with partners, stakeholders and funders.

Achieving this objective will require assessing which of GCP's objectives are going to be fully completed by the end of the Programme's lifetime, and how related products will remain accessible. It will also require identifying – based on demand – which elements of our current effort will complement and add value to other efforts through an extension after December 2014, building on GCP's legacy. To conduct this exercise, the different GCP's activities have been divided into segments or major outputs and a white paper has been drafted by the GCP Management Team, in collaboration with external experts and with the input from partners, to assess these segments in the context described above.

The white papers

The research product line components of the GCP are as follows:

1. Genetic stocks
2. Genomic Resources
3. Informative molecular markers
4. Cloned genes
5. Molecular Breeding

At this stage, the white papers are really a first analysis for internal use.[1] They are expected to evolve over time, shaped by progress made during GCP's remaining time and by the evolution of international agricultural research for development, particularly in terms of the 'moving landscape' of socio-economic, political and environmental issues in which operate the research portfolios of the CGIAR Consortium of International Agricultural Research Centres and related

[1] This GCP white paper, like the others in this series, is not a conclusive, static document. Instead, it will continue to grow and evolve as the processes of evaluation and deliberation advance toward GCP's end in 2014.

CGIAR Research Programmes (CRPs). Each white paper is designed to contribute to GCP's orderly closure in 2014 by considering the following three questions.

1. What research assets will be completed by the end of GCP's lifetime in December 2014?
2. What research assets can best continue as integral components of the new CGIAR Research Programmes (CRPs) or elsewhere?
3. What research assets may not fit within existing institutions or programmes and may require alternative implementation mechanisms?

Outputs have been achieved through: a) collaborative work among a broad network of partners in regional and country research programmes, the CGIAR and academia; and b) capacity enhancement to assist developing-world researchers to tap into new genetic diversity and access modern breeding tools and services. The following narrative offers an overview applicable to all 13 papers.

The evolution of the GCP research portfolio

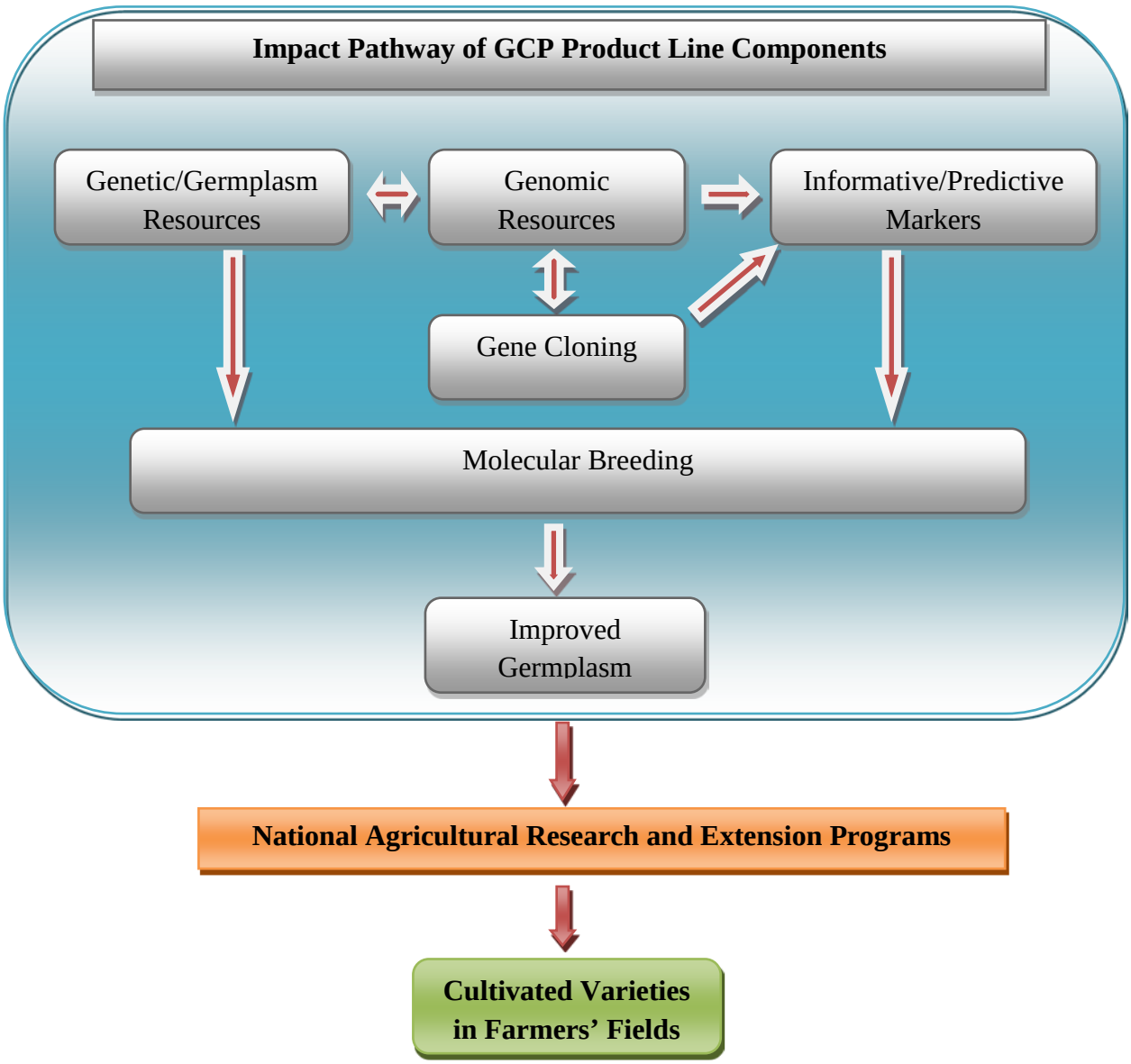
The Generation Challenge Programme (GCP) was created by the CGIAR in 2003 as a time-bound 10-year program with the objective to explore plant genetic diversity and apply advanced genomics and comparative biology to advance the breeding of the main staple crops grown by resource-poor farmers in drought-prone and other harsh environments. An extension of one year has been granted and the program will close at the end of 2014. The life of the GCP can be described in two phases, complimentary and overlapping in some activities but differing in focus.

Phase 1 was a period of discovery research and network development primarily directed towards: 1) analyzing the genetic diversity in international crop genetic resources to extend this knowledge to improve major crops for drought tolerance and other related traits of importance; and 2) strengthening the capacity of NARS and to apply the tools of genomics, molecular biology, and bioinformatics to increase the efficiency of their breeding programs.

Phase 2 builds on a set of focused research components and an integrated service component recommended by the 2007 CGIAR External Program Mid-term Review. Research components aim to demonstrate that molecular breeding approaches can have a significant impact on crop productivity in developing countries. The service component is a vehicle for dissemination of knowledge and technology, enabling broad access to 1) crop genetic stocks and breeding material, 2)molecular, genomics and informatics technology and information,3) cost-effective high-throughput laboratory services, and 4) capacity building programs. Both research and service components are now largely consolidated in the Integrated Breeding Platform (IBP) project. In phase 2 the GCP has a focused research agenda which includes nine Research Initiatives that are crop-trait- and region-specific, most of them led by scientists in developing countries, and serve as user cases for the IBP. All RIs are driven by the overarching goal of developing resources for the efficient development of improved germplasm in resource-limited countries. As part of the transition process of the CGIAR reform, these RIs have been embedded and described as appropriate to each of the crop CGIAR Crop Research Proposals (CRP).

Research activities extended beyond GCP's lifetime shall be managed by the CRPs in keeping with their respective strategies.

The cross cutting research activities of the GCP and respective products, that are common to most of the RIs, can be divided into 5 components and as the following figure will illustrate, each component is linked to another in various ways to form a chain of products ultimately leading to improved germplasm and impact.



Lessons learnt

Genomic and genetic resources

- As much attention should be given to the utilisation of genomic resources as is being dedicated to their development.
- An accurate system led by CGIAR Centers for curating maintaining and distributing genetic stocks is needed to ensure their quality and impact in a sustainable way.
- Emerging technologies should not be adopted until adequately proven and accepted.
- Outsourcing of sequencing and genotyping is more efficient and cost-effective for routine activities.

Integrated Crop Breeding

- Adoption of integrated breeding approaches in developing countries is limited by lack of human and physical resources, inadequate high-throughput genotyping capacity, unreliable phenotyping practices and protocols, and poor information management systems and analytical tools.
- Sharing of improved germplasm is highly desirable but movement is a serious challenge to collaborative projects due to varied quarantine and import regulations, as well as implementation of policies.
- Breeders must be supported by mentors for adoption of molecular breeding to succeed.

Crop Information Systems

- Standardization of crop research data management systems, structures and protocols is needed when working as a large network building on data sharing and information/expertise exchange.
- The development of breeder-focused user-friendly, informatics tools is only possible through a close interaction between potential users and developers.

Capacity building

- Capacity building is most effective by a mix of integrated training to individuals and teams.
- Capacity building must be associated with specific project activities and product delivery goals.

Product Development and Delivery

- Product development should be demand-driven while keeping abreast with advances of……
- It is important to create awareness and promote the use of our products to maximize impact (i.e GCP Product Catalogue.)

Parnerships and Community

- Research partnerships are of highest value where there is an equitable allocation of research resources to developing country partners.
- Community-building requires significant investment of time and effort to facilitate community interaction as well as to attract and retain community members. It must be a bottom up approach

Contractual compliance and Intellectual Property issues

- Collaborators' compliance with contractual obligations is essentially voluntary since legal enforcement is limited.
- Although usually committed to producing freely accessible international public goods, collaborators may be unable to deliver due to superseding national laws.

Conclusion synthesis

We anticipate that all GCP's objectives for genomic resources, cloned genes, and informative markers will have been achieved by December 2014 and we consider our mission accomplished for these.

The creation of genetic stocks typified by reference sets was a core activity of the GCP particularly during its first phase. However, most GCP's objectives have been achieved for genetic stocks particularly for novel allele discovery studies (reference sets, CSSLs, NILs, etc). We anticipate, however, that some finishing of the development, characterization and selection of breeding lines from genetic stocks expressly developed in phase 2 for breeding as MAGIC, Backcross NAM and RIL populations will be required (Table 1). Underlying this is the continuing and evolving need to identify new alleles and haplotypes in all strategic crops to improve cultivated germplasm but the CRPs have the explicit strategic objectives and advantages in their proposals mandating the exploration, analysis and utilization of CGIAR genebank resources. These genetic resources have in many cases already led to and will continue to lead to improved germplasm through the use of molecular breeding.

Only nine years ago genetic studies of many crops, particularly so-called "orphan" crops, had few, if any, genomic resources. At this writing, however, genotyping resources for all target crops are easily accessible. Moreover, high-throughput marker technologies and all target crops now have sufficient genomic resources to conduct meaningful genetic studies and molecular breeding. Many informative marker products are in use already in breeding programs for drought and biotic traits, some of them derived from genomic resources, some others identified from segregating improved material. Further, all informative markers required for the successful completion of all Research Initiative breeding objectives will have been developed by the end of 2014. Informative, indeed predictive, gene-based markers, have been

developed to great success for aluminum tolerance in sorghum and maize and tolerance to low phosphorous in rice as a result of gene cloning projects for Altsb, ZmMATE1 and Pup1 genes, respectively. In fact, the gene cloning objectives per se were substantially completed in the first phase of GCP. The development of gene specific markers for efficient introgression of these genes following this work was made possible by gene cloning and this work has been completed as well. The continuance of these product lines will be left to CRPs who will incorporate all residual activities of remaining projects into their workplans ; a new entity is not required.

Most GCP germplasm projects are also anticipated to deliver their expected research projects by the end of 2014. However, germplasm development for some crops (viz. cassava) will require some continuance (Table 1). In any case, to achieve impact by farmers benefiting from the germplasm improvement anticipated, work programs need to transition pre-breeding and improved lines into a development phase which will require additional cycles of evaluation and progression. The continuance of these residual genetic stock and improved germplasm activities will be embedded in CRP workplans. No need is perceived for an additional entity to manage these products. Since all partners will be involved including NARS, continuance offers an excellent opportunity for CRPs to foster, maintain and strengthen the partnerships

Table 1 Anticipated on-going genetic stocks and improved germplasm activities and their estimated costs for continuing following the closure of GCP

Crop	Primary on-going activities post-2014	Estimated Cost implications (US$)
Cassava	**Genetic Stocks:-** Reference collection multiplication of stocks, virus indexing, tissue culture storage **Improved Germplasm:-** Evaluation and progression of MARS populations for development of drought tolerant lines. Progression of derived biotic and drought trait improved lines.	100,000 – 150,000 50, 000 – 100,000
Legumes		
a. Beans	**Genetic Stocks:-** Finishing MAGIC population development, evaluation, line selection, progression and development **Improved Germplasm:-** Most products to be integrated into ongoing TL2. Progression of Andean germplasm lines improved for drought tolerance	50,000 – 75,000 50,000 – 100,000
b. Chickpeas	**Genetic Stocks:-** MAGIC population selected line evaluation, progression and development **Improved Germplasm:-** Most products to be integrated into ongoing TL2. Progression of drought tolerant chickpea breeding lines developed through MABC/MARS	10,000 – 30,000 25,000 – 50,000
c. Cowpeas	**Genetic Stocks:-** MAGIC population selected line progression and development Multiplication of RILS **Improved Germplasm:-** Most products to be integrated into ongoing TL2. Progression of advanced breeding lines and local varieties improved for drought tolerance	10,000 – 30,000 25,000 – 50,000
d. Groundnuts	**Genetic Stocks:-** Evaluation of synthetics, cross evaluations, line progression **Improved Germplasm:-** Most products to be integrated into ongoing TL2. Progression of elite Lines incorporating wild favorable alleles from groundnut synthetics for drought tolerance, rosette and rust resistance.	25,000 – 50,000 50,000 – 100,000
Maize	**Genetic Stocks:-**None foreseen **Improved Germplasm:-** Progression of highly drought tolerant elite Asian inbreds and derived lines	 25,000 – 50,000
Rice	**Genetic Stocks:-** Finishing MAGIC population development, evaluation, line selection, progression and development **Improved Germplasm:-** Completion of least 4 bi-parental MARS populations and progression derived lines improved for drought and biotic traits.	25,000 – 50,000 100,000 – 150,000

Crop	Primary on-going activities post-2014	Estimated Cost implications (US$)
Sorghum	**Genetic Stocks:-** Completion of Backcross NAM development. Progression of RILs incorporating the Altsb gene for aluminium tolerance. **Improved Germplasm:-** Completion of MARS program and progression of derived lines improved for drought and biotic traits. Progression of derived lines from Backcross NAM for wide adaptation. Progression of lines derived from RILS incorporating Altsb for aluminium tolerance.	50,000 – 100,000 50,000 – 100,000
Wheat	**Genetic Stocks:-**None foreseen **Improved Germplasm:-** Progression of progeny identified and selected for drought tolerance from MARS populations. Progression of Elites lines with superior water use efficiency from backcrossing programs. [Note: India & China]	 50,000 – 100,000

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