Report of the Final External Review of the Generation Challenge Programme

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We wish to especially thank GCP staff who responded patiently and willingly to our many requests for data, documentation, and clarification, including requests for information that might initially have seemed too detailed or peripheral for the purpose of this review. The responsiveness, and hospitality of GCP staff during the visit of two Review Team members to GCP headquarters at CIMMYT in October 2013 is greatly appreciated as well. The welcoming attitude of GCP staff, the excellent logistical and administrative arrangements made by GCP for our visits to Lisbon and Mexico, and the efficiency with which our in-person and Skype interviews were organized at GCP headquarters gave us first-hand experience of the professional, collegial and collaborative approach with which GCP staff undertake their work, even under tight deadlines and despite other pressing demands on their time.

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We are grateful too to the Executive Board, and especially its Chair Andrew Bennett, for seeking this independent external review of GCP through the IEA, and for giving the Review Team wide latitude through our TORs to explore all relevant programmatic and management aspects of GCP. Our interactions with members of the Executive Board in September at Lisbon and subsequently by Skype during the EB meeting in November are also appreciated. We thank EB members not only for sharing their views on GCP's strategy, programme and governance, but also for being receptive to our preliminary impressions of the Programme's achievements and challenges, and for helping us better understand the strategic considerations guiding the Programme as it moves towards closure in 2014.

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ACRONYMS AND ABBREVIATIONS

ACA	Amended Consortium Agreement (of GCP)
ACCI	African Centre for Crop Improvement (at University of KwaZulu Natal, South Africa
AfricaRice	Africa Rice Center
Al	aluminium
AltSB	major Al tolerance gene in sorghum cross BR007 x SC283
ARI	Advanced Research Institute
BAC	bacterial artificial chromosome
B&MGF	Bill & Melinda Gates Foundation
BCNAM	backcross nested associated mapping
BecA	Biosciences East and Central Africa
BGI	Beijing Genetic Institute
BLUP	Best Linear Unbiased Predictor
CAAS	Chinese Academy of Agricultural Sciences
CBSD	cassava brown streak disease
CC	Consortium Committee (of the GCP)
CCER	Centre-Commissioned External Review
CGIAR Consortium	CGIAR Consortium of International Agricultural Research Centers
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
CoP	Community of practice
CMD	cassava mosaic disease
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
CP	Challenge Programme (of the CGIAR)
CPWF	Challenge Programme on Water and Food
CRP	CGIAR Research Programme
CSSL	Chromosome segment substitution line
DArT	Diversity arrays technology
DEEDI	Department of Employment, Economic Development and Innovation (Queensland,

	Australia)
DNA	deoxyribonucleic acid
DTMA	Drought Tolerant Maize for Africa (Project)
EB	Executive Board (of the GCP)
EC	European Commission
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
EPMR	External Programme and Management Review
EST	expressed sequence tag
FAO	Food and Agricultural Organization (of the United Nations)
GBS	genotyping by sequencing
GCP	Generation Challenge Programme (of the CGIAR)
GENESYS	platform or 'gateway' to plant genetic resources
GenStat	A statistical data analysis software developed by VSN International (VSNi)
GIS	geographical information system
GRiSP	Global Rice Science Partnership
GRM	General Research Meeting (of GCP)
GS	genomic selection
GWAM	genome-wide association mapping
GWAS	genome-wide association studies
HR	Human Resources
IARI	Indian Agricultural Research Institute
IB-MYC	Integrated Breeding Multi-Year Course (of GCP)
IBP	Integrated Breeding Platform (of GCP)
IBWS	Integrated Breeding Workflow System
ICAR	Indian Council for Agricultural Research
ICRAF	International Centre for Research in AgroForestry (now World AgroForestry)
ICRISAT	International Crop Research Institute for the Semi-arid Tropics
IEA	Independent Evaluation Arrangement (of the CGIAR)
IER	Institut d'Economie Rural du Mali
IITA	International Institute of Tropical Agriculture
IMAS	Improved Maize for African Soils, Project
IP	intellectual property
IPAC	Intellectual Property Advisory Committee (of the GCP)
IRRI	International Rice Research Institute
ISPC	Independent Science and Partnership Council (of the CGIAR)

JIRCAS	Japan Agricultural Research Centre for Agricultural Sciences
KARI	Kenya Agricultural Research Institute
KASPar assay	KBiosciences (now LGC Genomics) Competitive Allele-Specific PCR SNP genotyping systems
KNIME	Konstanz Information Miner, graphical interface and data integration software
LIMS	Laboratory Information Management System
M	million
MABC	marker-assisted backcrossing
MAGIC	multi-parent advanced generation backcrossing
MARS	marker-assisted recurrent selection
MAS	marker-assisted selection
MATE	family of multidrug and toxin extrusion transporters
MB	molecular breeding
M&E	monitoring and evaluation
MT	Management Team (of the GCP)
MTP	Medium Term Plan
MTR	mid-term review
NAM	nested association mapping
NARS	National Agricultural Research Systems
NIL	near isogenic line
NRCRI	National Root Crops Research Institute, Nigeria
P	phosphorus
PAC	Programme Advisory Committee (of the GCP)
PCR	polymerase chain reaction
PDC	Product Delivery Coordinator (of the GCP)
PI	Principal Investigator
PSC	Programme Steering Committee (of the GCP)
PSTOL1	gene underlying the major QTL for P-uptake efficiency in rice, Pup1
Pup1	phosphorus uptake 1 (QTL)
QAAFI	Queensland Alliance for Agriculture and Food Innovation, Australia
QTL	quantitative trait locus
RAP	Research Advisory Review Team (of the GCP)
RI	Research Initiative (of GCP)
RIL	recombinant inbred line
RNA	ribonucleic acid
Saltol	QTL in rice providing tolerance to saline conditions

SbMATE	MATE gene of sorghum (see MATE)
SDC	Swiss Agency for Development and Cooperation
SHC	Stakeholders' Committee (of the GCP)
SIDA	Swedish International Development Cooperation Agency
SiMAC	Scientific and Management Advisory Committee (of the IBP)
SME	small and medium enterprise
SNP	single nucleotide polymorphism
SP(n)	Sub-Programme (n) of GCP
SSR	Simple sequence repeat
TILLING	Targeting Induced Local Lesions in Genomes
TL1	Tropical Legumes 1 Project
TOR	terms of reference
USAID	United States Agency for International Development
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
WACCI	West Africa Centre for Crop Improvement (at University of Legon, Ghana)
WEMA	Water Efficient Maize for Africa, project
ZmMATE	MATE gene of maize (see MATE)

EXECUTIVE SUMMARY

This external review of GCP, commissioned by the Independent Evaluation Arrangement (IEA) of the CGIAR at the request of GCP's Management and Executive Board, with the consent of the GCP Consortium Committee, was undertaken about a year before Programme closure in December 2014. Although not an EC review, the EC entrusted the IEA to design and manage this independent review to obviate the need for an additional review. The review looks back on the evolution of the Programme and its component activities to determine whether or not it has met its objectives, and seeks to learn from one of the first multi-centre, multi-partner CGIAR programmes that were the predecessors of the current CRPs.

A key focus of the review was the extent to which the GCP provided support to genomics research and molecular plant breeding for developing country partners. The review also examined whether the GCP's thematic and partnership-oriented research approach was useful for delivering high quality scientific products, and what lessons this might have for the CRPs. The review makes suggestions and recommendations for future activities related to genomics research and molecular breeding, as well as governance and management related to GCP's closure and Phase 2 of the Integrated Breeding Platform (IBP).

The GCP was reviewed according to principles consistent with the CGIAR Policy for Independent External Evaluation and was managed by the IEA. A five-person Review Team was formed, comprising expertise on molecular breeding, genetic resources, management and governance, and monitoring and evaluation. The Review Team mainly worked virtually, through e-mail correspondence, but there were face-to-face meetings of some members in Mexico, Washington and Lisbon. The Review Team based its assessment of GCP's performance on extensive review of Programme documentation and other literature, interviews and discussions with individuals associated with the GCP and its partners and other stakeholders. Two extensive surveys were conducted, one among GCP stakeholders and the other on GCP governance and management.

Relevance: the Review Team concluded that the decade-long GCP Programme has been, and continues to be, highly relevant in terms of the extent to which stated objectives and activities of the GCP address the needs identified when the Programme was designed, and as they evolved. The Programme coherence and focus improved as it moved from Phase I, which was of an exploratory nature covering a broad range of crops, to Phase II with a reduced number of crops and clear product delivery focus. The GCP addresses problems in agriculture experienced by large numbers of the world's poor farmers who live in marginal and harsh environments and whose already precarious livelihoods are becoming increasingly threatened by climate change. The GCP, through its research consortium approach, has demonstrated how molecular breeding can be used to address important problems in mainstream crop improvement programmes that would be otherwise difficult to do. GCP management has been flexible in adjusting activities to changes in science. The crops and traits addressed by GCP were and continue to be highly relevant in current agriculture. Non-CGIAR partners, including ARIs, NARS, academia, regional and national research programmes, and private firms, have worked together in synergy to ensure that the Programme's mandate has remained relevant throughout its ten-year lifespan.

Quality of science: the Review Team considered that the exceptional number of scientific papers indicated scientific rigour in GCP. In the period 2005 through September 2013 the GCP published 489 scientific papers, and more are in press. This record, high despite the fact that much of the research Programme of GCP is dedicated to methodology development, is helped by ARI partners being part of the publishing culture. Around 90% of papers were published in international journals and 10% in journals with regional or national coverage, indicating a very wide distribution of information among the scientific community. The GCP has ensured accessibility to information by publishing papers in open access formats in 43% of the cases. The stakeholder survey results indicated that that GCP has helped raise scientific standards (95%) and improved science quality (97%). Quality of science, in terms of phenotyping and germplasm evaluation, improved considerably from Phase I to Phase II.

Results and effectiveness: the GCP has generated, or assisted in the generation of, results in many areas of plant science, *inter alia* in terms of information, tools, germplasm reference sets, molecular markers, and capacity building, all of which will facilitate crop breeding. Eleven crop varieties have already resulted from GCP's activities. The results and products of GCP have been delivered and communicated effectively through various channels and the research has largely been managed in an effective manner, overall providing good value for the investment. The effectiveness of research management has been enhanced through taking a partnership approach to problem solving.

Efficiency: the overall efficiency of the GCP Programme was deemed satisfactory. In the transition from Phase I of the Programme to Phase II there was a narrowing of focus – concentration on fewer crops – that improved efficiency in terms of funding and time allocations. Programme structure became more logical, which improved management efficiency, including that for budgets, staff and capacity building. The efficiency of project selection and coordination was affected by the type of project undertaken; projects resulting from competitive bidding were generally more efficient than those undertaken through commissioned research. Development of the IBP suffered initially from considerable inefficiencies. Although recognised as being an extremely useful tool for molecular breeders, and having the potential for high impact when completed and widely adopted, its early stages of design and management were stifled to some extent by not engaging with private sector experts in software design. The efficiency of initiatives for capturing, characterizing and exploiting genetic variation in germplasm held in genebanks was not as efficient as it could have been. Despite this, arguably the major contribution to GCP efficiency has been the emergence and fostering of a palpable 'GCP spirit', which has drawn together scientists from around the globe in a common endeavour.

Impact and sustainability. The nature of scientific research and particularly plant breeding, molecular and conventional, is long term. As such the long-term impacts are challenging to assess, and the GCP's impact is best assessed in terms of the increased efficiency and effectiveness of breeding. The GCP has had some impact in terms of the tools, information and germplasm it has generated and that have been used, and its capacity building efforts have contributed to this. Arguably one of the greatest potential impacts of the GCP is the IBP, which has not yet been completed. If and when widely adopted, it will improve the efficiency and effectiveness of molecular breeding on a large scale, ultimately generating substantial benefits for farmers through production and adoption of adapted crop varieties. Naturally, the research results published through GCP are also set to promote substantial impact, but it is too early to determine its magnitude. Sustainability

of the numerous components of GCP's legacy will depend on several issues, including whether they can be picked up and continued by CRPs and national programmes, whether funding can be secured and whether they remain relevant in the changing circumstances of global agriculture. The 'GCP spirit', which has contributed so much to the success of the Programme, although not sustainable because the Programme will end, might serve as an example to other programmes, including the CRPs. The risks to impact and sustainability of the products and results of the GCP are that they are not distributed, managed and used following GCP's sunset.

Governance and Management: the Executive Board and Consortium Committee, established for GCP Phase II, have worked well. The effectiveness and efficiency of fiduciary and administrative services provided by CIMMYT are highly satisfactory. Donor support, totalling US$167 million, mainly from the EC, DFID, B&MGF, the World Bank, and the CGIAR, has been very effective in helping ensure GCP's continuity and performance. Financial and human resources have been managed well. The GCP Management Team has been effective and worked closely with partners, successfully generating a shared commitment to partnership and collaboration. The management of risks has been taken seriously. Monitoring and evaluation is one area of GCP research management that has not been as effective as it could have been. It was insufficiently appreciated early enough in GCP's evolution that a robust monitoring and evaluation system would have provided the baseline data and set the milestones that would have allowed Programme effectiveness to be gauged better. Nonetheless, management of research, product delivery, communication and capacity building have all been handled effectively.

Lessons learned: the Review Team identified several science-oriented lessons, including several for partnerships and collaboration, enhancing quality of science, management of research, capacity building, communications, monitoring and evaluation, and development and management of projects such as the IBP. It also identified some governance and management lessons. Many of the lessons, suitably adapted, are relevant for the CRPs and if taken note of will promote efficiency and effectiveness of their operations.

Conclusion: the Review Team established that the GCP has performed well, has met the majority of its genetic enhancement goals and surpassed others, and will leave a formidable legacy of useful and accessible products and information. It has remained relevant throughout its ten-year duration. The Review Team considered that the GCP is approaching its impending closure logically, systematically, and with a view to maximizing its impact beyond closure by ensuring that key products, such as the IBP, are suitably positioned and supported to continue to deliver benefits that will ultimately impact the lives of some of the world's poorest farmers. Looking to the future, the Review Team is optimistic that GCP's investors, Consortium members, governance bodies, partners, and other stakeholders who have contributed significantly to GCP's progress thus far will remain fully committed to sustaining this successful Programme's considerable achievements and benefits over the coming years.

Finally, using the rating scale suggested by the EC, the Review Team rated the GCP's programme relevance, research effectiveness, impact and sustainability as highly satisfactory; research efficiency as satisfactory; and governance and management as highly satisfactory.

RECOMMENDATIONS

R1. The Review Team recommends that during 2014 GCP select 20 or so products with highest potential impact and develop a market and promotion strategy that strongly emphasizes their value and utility to targeted users. (Section 3.3)

R2. The importance of IBP is such that the Review Team recommends that early in 2014 GCP appoint a senior staff member who understands the plant breeding process, the CGIAR and the private sector, and also has software development and commercial skills to guide and manage the launch of final versions of IBP, oversee the development of hubs, and help finalize the workplan of IBP Phase 2. (Section 3.4)

R3. The Review Team recommends that to maximize the impact of GCP publications and products the website collection of published documents developed from GCP-sponsored molecular breeding research (2005–2014) is maintained on a CGIAR-sponsored website along with a means to query this collection. (Section 6.2)

R4. The Review Team recommends that GCP allocate funds from its reserves to ensure that PhD and MS theses in process at the end 2014 are completed, and request that the appropriate CRPs assume responsibility for oversight of those that continue beyond that date. (Section 6.3)

R5. The Review Team recommends that GCP begin discussions immediately with the crop-specific CRPs to take ownership of the most valuable of these as genetic resources for improvement of their mandated crops, and that these discussions be brought to a satisfactory close before the GCP sunsets in December 2014. (Section 6.4)

R6. The Review Team recommends that on-going costs associated with the maintenance of the GCP website and updating on-line of publication lists and the product catalogue be budgeted through 2018 as part of the GCP sunset financial strategy. (Section 6.4)

R7. The Review Team recommends the funding of Phase 2 of the Integrated Breeding Platform. (Section 6.5)

R8. The Review Team recommends that in early 2014 the GCP Executive Board and Management assess both long- and short-term options for governance and hosting of IBP Phase 2, prepare business plans for these options, and in consultation with interested parties (the CC, IBP partners, other stakeholders, the Consortium Board, and various potential donors) pro-actively pursue a suitable long-term option (such as a new cross-cutting CRP), while also deciding on (possibly-short term) governance arrangements for IBP Phase 2 that would take effect immediately upon GCP closure. (Section 7.5)

R9. Review Team recommends that the EB request its IP Advisory Committee to regularly provide specific advice on IP-related risks and potential liabilities as GCP moves toward closure in

December 2014, and that the EB systematically discuss these in 2014 and suitably advise GCP Management. (Section 7.6)

R10. The Review Team recommends that GCP give high priority to 'Risk management' on the agenda of the EB and MT as they respectively oversee and manage Programme closure and the transition of GCP activities to the CRPs and IBP Phase 2 governance bodies. (Section 7.7)

R11. The Review Team recommends that formal impact assessment of GCP genetic enhancement activities be undertaken in 2016–2017 using some of the 14 user case studies that form part of the IBP Phase 2. (Section 9.2)

1. INTRODUCTION

1.1. Introduction

This external review of GCP, commissioned by the Independent Evaluation Arrangement (IEA) of the CGIAR at the request of GCP's Management and Executive Board, with the consent of the GCP Consortium Committee (CC), was undertaken about a year before Programme closure in December 2014. Although not a European Commission (EC) review, the EC entrusted the IEA to design and manage this independent review to obviate the need for an additional review. The review looks back on the evolution of the Programme and its component activities to determine whether or not it has met its objectives, and seeks to learn from one of the first multi-Centre, multi-partner CGIAR programmes that were the predecessors of the current CRPs. The other four Challenge Programmes (CPs) have already been merged into the CRPs approved in 2010–2013.

The Review Team's terms of reference is provided in Annex 1, and an evaluation matrix listing questions that served as a rough guide to discussions in Annex 5. A key focus of the review is the extent to which GCP has provided support to genomics research and molecular plant breeding for developing country partners. In addition, the review examines whether the GCP's thematic and partnership-oriented research approach has been useful for delivering high quality scientific products, and what lessons this might have for the CRPs. It makes recommendations for future activities related to genomics research and molecular breeding, as well as governance and management.

1.2. Approach and Methods

The review of GCP adopted a consultative and transparent approach with internal and external stakeholders throughout the review process. The GCP has been reviewed according to criteria consistent with the Evaluation Policy and Standards of the CGIAR, covering relevance, effectiveness, efficiency, impact, sustainability and quality of science. The review was carried out in conformity with the CGIAR Standards for Independent Evaluation. An evaluation matrix (Annex 5) was prepared that served to promote discussion among Review Team members, and enabled them to identify the key questions and issues to be addressed. The Review Team based its assessment of GCP's performance on a mix of methods: (a) review of extensive documentation (Annex 4) and outputs produced by the GCP; (b) review of evaluation and strategic reports etc. on the GCP; (c) review of scientific articles (products of the GCP); (d) structured interviews of GCP staff and other key stakeholders (Annex 3); and surveys of partners, seeking the views of major GCP stakeholders through two specially designed surveys for research and for governance and management (Box 1.1). Triangulation of evidence and information gathered underpinned the validation of evidence collected and its analysis, and supported the Review Team's conclusions and recommendations.

A five-person Review Team (Annex 2) was formed, comprising expertise on molecular breeding, genetic resources, management and governance and monitoring and evaluation. The Review Team mainly worked virtually, through e-mail correspondence, but there were face-to-face meetings of

some members in CIMMYT, Washington and Lisbon.

For overall assessments of GCP performance (Chapter 8), the Review Team used the 4-point rating scale suggested by the EC, according to which: Highly satisfactory = fully according to plan or better; Satisfactory = on balance according to plan, positive aspects outweighing negative aspects; Less than satisfactory = not sufficiently according to plan, taking account of the evolving context, a few positive aspects, but outweighed by negative aspects; and Highly unsatisfactory = seriously deficient, very few or no positive aspects. The Review Team's assessment of the GCP's thematic areas and other aspects of performance, following the evaluation criteria are summarized in Annex 9.

Box 1.1: The stakeholder and the governance and management surveys

Two surveys were undertaken for this review by an independent consultant who pre-tested, launched and conducted the surveys, and analysed and reported their findings to the Review Team. These findings have been very helpful in supplementing the Review Team's own observations and analyses based on a detailed review of GCP documents and discussions with various stakeholders.

The stakeholder survey included questions on GCP relevance, effectiveness, products/outputs, efficiency, outcomes and impacts, partnership, sustainability and management. The governance and management survey included questions on satisfaction with governance, management, Consortium Committee, Executive Board, and the Management Team. The surveys also included open-ended questions, the responses to which were content analysed and categorized into themes. The number of respondents for the stakeholder survey was 159, and for the governance and management survey it was 40, representing a satisfactory response rate of over 40% for both the surveys.

For the areas covered by the stakeholder survey, overall performance scores were developed by taking the average agreement of all the survey items in each group. Composite scores were similarly developed for the areas covered in the governance and management survey.

The survey consultant's summary reports on the stakeholder survey and the governance and management survey are attached to this report, respectively as Annex 10 and Annex 11.

1.3. Limitations to the review

This review was limited by very few significant factors, the main one being the absence of a monitoring and evaluation component that might have been set up when the Programme was initiated. This meant that adequate background and baseline data were not available against which effectiveness could be accurately gauged. The other major limitation was no fault of the Programme, but resulted from the nature of the impact pathways associated with agricultural research and plant breeding. Both are long-term endeavours and the impacts they generate take a long time to become evident and measurable. It is moreover difficult, if not impossible, to separate out the precise effects of specific interventions, in this case those of GCP, from other changes that inevitably occur in parallel over long periods of time. It is even difficult to assess the impact of concrete products generated by research and plant breeding such as publications, improved germplasm and tools such

as the IBP. These invariably take long times to have a discernible impact and when they do their impacts are usually confounded with those of other interventions and changes, rendering the impact pathways very unclear. Consequently no attempts were made to relate GCP activities with issues such as poverty alleviation and capacity development.

Other areas that were not fully addressed during this review:

- Who is using GCP products, how are they being used and what is the client feedback on their utility? Have the products been demand driven or supply driven ("this product surely must be useful ...")? The Review Team has suggested in several areas of this report that case studies be used to help document the answer to these questions.
- While the RIs appear to be making reasonable progress on drought tolerance research in target crops, it is unclear to the Review Team how well these projects are currently integrated into the mainline improvement programmes in the NARS or within collaborating CGIAR Centres. There is a risk that these may be isolated from the mainstream of target crop improvement and "wither on the vine" when funds are exhausted or interest moves elsewhere.
- The Review Team noted in several areas a lack of field efficacy data. The bottom line for all of GCP's research products will be how much they contribute to stability and magnitude of grain yields in farmers' fields, and what rates of genetic gain have been obtained and at what cost. It will be those data that convince variety release committees and policy makers that GCP products can make a difference to the welfare of resource-poor farm families.
- Targets were not set for communications activities (social media for example) by GCP, but this is a relatively minor issue.
- The Review Team notes however that field-based yield data on the efficacy of AltSB and ZmMATE genes is rarely found in GCP reports, even though this is the ultimate measure of effectiveness.
- The Review Team did not have the resources or mandate to undertake a detailed assessment of financial management at GCP, its Host Agent, or the various projects funded by GCP (and undertaken by a variety of partners, each with its own financial- and risk management system).
- The Review Team's mandate and resources permit a detailed assessment of various possibilities for funding and sustaining IBP after 2014. Furthermore, the IPAC is chaired by the GCP Legal Advisor and has four additional members. It was formed by the EB to advise it on strategic IP matters and specific IP issues. The Review Team was unable to access minutes from IPAC meetings and assumes that it is relatively inactive and meets on an as-needed basis.
- The Executive Board is advised by an external, independent, five-member Intellectual Property Advisory Committee (IPAC) of senior IP experts drawn from the private sector, ARIs, NARS, and CSOs. The Review Team had neither the resources nor the mandate to examine how effectively the Amended Consortium Agreement's IP provisions have been followed by Consortium Members and GCP-funded projects.

1.4. The Generation Challenge Programme

The GCP is one of five CPs introduced after the 2001 CGIAR reforms to foster a programmatic approach to research, bring in new partners, and improve research quality in the CGIAR. The GCP focuses on 'promoting the use of genetic diversity and modern plant science for crop improvement in developing countries'. The challenge for agricultural research is to understand better the science that underlies useful traits such as drought tolerance in order for plant breeders, particularly those in NARS, to be able to develop better adapted crop varieties for dissemination to farmers living in harsh environments. Such environments are home to some of the world's most disadvantaged farmers whose often marginal conditions are likely to become even more precarious in the face of climate change. Since its inception in 2004, GCP has been an independently governed, multi-partner programme, with a pre-set 10-year life span.

During its first five years (Phase I, 2004–2008) GCP covered 18 CGIAR mandate crops, and concentrated on exploration and discovery of crop diversity through genomic research and molecular breeding. Then, in Phase II (2009–2014), as recommended by the 2008 External Programme and Management Review (EPMR), GCP focused more narrowly on nine priority crops addressed through five research themes.

The 2008 EPMR also led to a major governance reform, replacing the Programme Steering Committee (PSC) with an independent Executive Board (EB) and a CC in Phase II. This sought to enhance the Programme's independence from GCP consortium members, whose representatives now serve on the CC in a scientific advisory capacity to the EB and GCP Management.

From its inception GCP has anticipated its closure in December 2014 after a 10+ year life. In 2010 planning for an orderly end to the Programme began with the production of the Transition Strategy 2011–2013, against the backdrop of CGIAR Reforms and the formation of the CRPs. This plan laid out the GCP Workplan for that period and the integration of GCP activities within the CRPs. Its purpose was to ensure that the RIs were embedded in their appropriate CRPs and integrated into their log frames. The document noted that the GCP was well positioned to draw 'cross-cutting lessons to inform molecular breeding in varied circumstances' for the CRPs. The main theme however, was the Integrated Breeding Platform (IBP). It noted that the IBP was under development as a 'one stop shop providing access to modern tools, applications and services for integrated breeding' and was expected to function as a legacy product well beyond the life of the GCP. It identified 14 user cases drawn from the RIs where MB was being applied using the tools of the IBP, and these would play a key role in the future development of the IBP.

1.5. Overview of GCP during Phase II

The GCP utilises a 'research consortium' approach, linking several CGIAR Centres and numerous other major partners, under the theme of 'unlocking genetic resources for the resource-poor'. Such an approach pools individual strengths and capacities such that the consortium is able to undertake work that would not be possible for individual organizations. Non-CGIAR partners, such as ARIs, NARS, academia, regional and national research programmes, and private firms, receive a substantial portion of GCP funds. The Programme operates globally from its headquarters at

CIMMYT (in Mexico), the CGIAR Centre that serves as the 'host agent' for GCP and provides the legal framework for its operation.

The numbers of partners involved in 2012 totalled 239 (Table 1.1) with about a half (48%) from the NARS – congruent with the mandate of the GCP. Partners from the private sector are few (3%), a deficiency that will have to be addressed in IBP Phase 2 if it is to have paying clientele and greater impact.

Table 1.1: Numbers and type of partners involved in GCP projects in 2010
(2010 is the last year for which complete information is available)

Type	**Number**	***Percent***	**Comment**
CG Centres and CRPs	18	*8*	
NARS in developing countries	72	*30*	Includes many Universities
NARS in emerging economies	53	*22*	
Developed countries	38	*16*	Mainly universities
Consortium members	18	*7*	
R4D public sector institutions	24	*11*	Example: NGOs
Private sector	7	*3*	SMEs and multinationals
Service providers	8	*3*	
Total	**238**	***100***	

Source: GCP (http://www.generationcp.org/network/collaborators)

The GCP Mission is to use advanced genomics science and plant genetic diversity to generate information that can be used to address complex bottlenecks that affect agricultural production of some of the world's most needy people. GCP's vision of the future is 'one where plant breeders have the tools to breed crops for marginal environments with greater efficiency and accuracy for the benefit of the resource-poor farmers and their families.' Such tools can only be developed based on research that generates information on traits that can be deployed in crop varieties that are better adapted to environmentally stressed conditions. In seeking to fulfil its mission and its vision GCP has attempted to leverage skills and expertise from many sources to become a multinational, multi-sector and multidisciplinary collaboration in the plant sciences (GCP Director, pers. comm.). From its inception GCP has focused primarily, but not exclusively, on developing drought tolerant crops for marginal, drought-prone areas, especially in sub-Saharan Africa and South Asia.

In Phase II GCP re-focused its research programme to cover only nine crops (cassava, legumes (beans, groundnuts, cowpeas, chickpeas), maize, rice, sorghum and wheat). The four legume crops form the target species of a large special project, Tropical Legumes 1 (TL1), now in its second four-year phase. The crops (plus legumes as one group) are organized as six crop- and region-specific Research Initiatives (RIs), with a seventh, Comparative Genomics, focusing on exploiting genetic similarities among three cereal crops, namely rice, maize and sorghum. The RIs focus on promoting

the use of modern, integrated breeding approaches using conventional and molecular breeding methods to improve each crop through a series of specific projects undertaken in more than 30 countries. These projects are largely commissioned, but do include some competitive projects. Each of the nine crops and the Comparative Genomics RI are led by a PI and monitored and mentored by a Product Delivery Coordinator (PDC) who works 90% of his time in his home institution while devoting 10% of his time to his task as a PDC. The PDCs report to GCP's Product Delivery Leader. The narrowing of focus from Phase I to Phase II represented an attempt to concentrate research efforts on a representative range of the most import crops, including those where it was considered that greatest progress could be made.

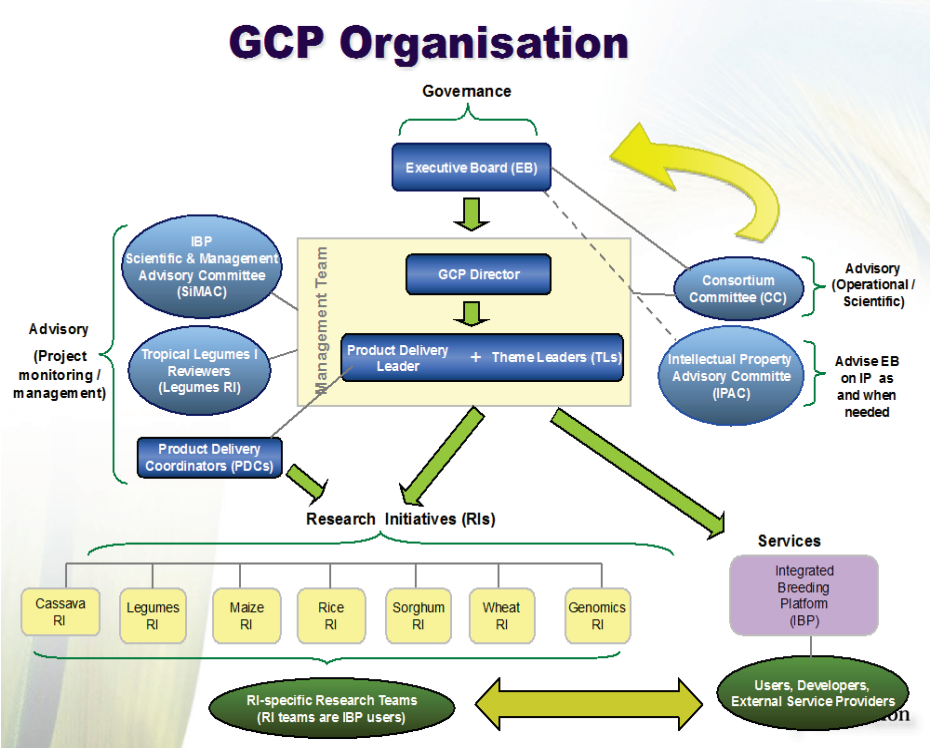
The RIs form a matrix with five themes: Genomics; Integrated Breeding; Bioinformatics (the Integrated Breeding Platform; IBP); Capacity Building; and Product Delivery. For much of Phase II each of these five themes has been led by a full-time GCP staff member, and these and the Director have formed the Management Team of GCP. The RIs have several components in common: phenotypic characterisation of a diverse set of germplasm resources, molecular breeding, data management, capacity building and appropriate product delivery plans.

The annual budget of the GCP has averaged around $15 million. There has been a progressive shift in the proportion of the budget managed by NARS, and in 2013 this reached 42%, while 50% of GCP's projects are now led by PIs from NARS. At the same time, the focus of the GCP's research agenda has moved from discovery and characterization of genetic variation to product delivery to crop breeders. Ultimately farmers are set to benefit through being able to grow better adapted crop varieties. The emphasis on capacity building has steadily increased throughout the period of the Programme, both in terms of trained manpower, and in research infrastructure.

Linking the themes of research, capacity building and product delivery has been the IBP, a special project. The IBP includes practical tools for conventional breeding, molecular, genomics and informatics technology and links to high-throughput laboratory services, along with capacity-building components. It seeks to generate knowledge and technology to plan the efficient management of breeding programmes and their subsequent execution, through a series of inter-connected software modules, supported by training in their use. The IBP is beginning to provide data management and analytical tools that accelerate crop breeding. It is currently advised by an external Scientific and Management Advisory Committee (SiMAC), and will be the leading legacy product of GCP of potential benefit to most partners engaged in modern crop improvement programmes.

GCP's organization, as of November 2013, is depicted in Figure 1.1.

Figure 1.1: GCP Organization (November 2013)



A key feature of the GCP has been its partnerships (see Sections 3.5, 4.6) with the NARS, ARIs, several CGIAR Centres, and large multinational seed companies as well as private small and medium enterprises (SMEs). In the period 2008–2010 an average of 214 entities partnered with GCP each year in executing Programme goals. With the development over the past three years of the CGIAR's Research Programmes (CRPs) based on crop or farming system themes, the CRPs are emerging as the organisations to which much of the GCP legacy in crop improvement will be passed as it concludes many of its crop improvement projects in 2014.

1.6. About this Report

The key criteria of relevance, effectiveness, efficiency, science quality, impact and sustainability, as in the IEA evaluation standards, form the main assessment chapters of the report with the GCP performance regarding governance and management being addressed separately. The review was structured around major activities in genetics, crop improvement, capacity building and planning for the future placing in-depth treatment of these activities in a single location within these chapters, and references to them within the other chapters.

Each chapter begins with an introduction that describes the approach for addressing the topics in that chapter. Governance and management are considered in one integrated chapter covering institutional effectiveness and efficiency. Final chapters of the report address overall assessment and lessons learned, some of which may be relevant to CRPs.

2. RELEVANCE

2.1. Introduction

This chapter focuses on the relevance of the GCP – the extent to which stated objectives and activities of the GCP address the needs identified when the Programme was designed, and as they evolved over its life. Areas considered in depth constitute the major pillars of the GCP – molecular breeding technologies in the context of modern plant breeding, the role of comparative genomics, and the importance of capacity building. Critical mass, programme coherence and the GCP's comparative advantage are also considered. The transition plan, that aims to ensure that the gains obtained by the GCP are fully utilized as a legacy for the future, is also reviewed.

2.2. Relevance of the GCP mandate

Traditional plant breeding is invariably slow and therefore molecular breeding offers a potential means to accelerate the breeding processes and produce adapted germplasm that tolerates the effects of stresses experienced in harsh environments and which are exacerbated by climate change. The private seed sector is less likely to invest in research for low production environments and the responsibility is therefore left to public organisations such as the CGIAR and GCP.

The research programme of the GCP is a key part of the ongoing quest to develop higher yielding and more stable crop varieties needed to meet the food and feed needs of the growing global population, especially in less developed countries. Production of crop staples by 2050, especially rice, wheat and maize, will need to increase by 70%, and around 75% of this will come from increased yields per unit area (Fischer et al., 2014). Although gains in yield also result from improved crop management practices, GCP's mandate was to focus only on improving the genetic basis of the crop to provide improved yield and yield stability, particularly in stressed environments, through the efficient utilization of new and existing sources of genetic variation.

2.3. Genetics and Molecular Breeding

In order for molecular breeding (MB) to deliver gains in the rate of genetic improvement, there are several core necessities. Firstly, lab-based molecular information must be available to the breeder at the time and in the form needed to make critical breeding decisions. Secondly, phenotyping must be conducted accurately and in an environment that represents the target for the variety. This is becoming increasingly important for breeding schemes such as marker-assisted recurrent selection (MARS) and genomic selection (GS) where the genotype-phenotype associations established during one crop season are used to make selections for 2-3 subsequent cycles without further phenotyping. If those associations were established from a poorly conducted trial or in an atypical environment, it could cause genetic drift in the breeding population and lessen its performance in the target environment. Many phenotyping sites in developing countries are on non-uniform soils, are inadequately supplied with basic field equipment such as irrigation, cold rooms, perimeter fencing and tillage equipment, and are inadequately staffed. A workforce trained in using MB technologies is

essential. These necessities are often in short supply in developing countries, thereby limiting or preventing the use of such proven means of increasing/accelerating genetic gain.

2.4. Genomics and Comparative Genomics

Genomics and comparative genomics have been important pillars of GCP's research agenda. Applied genomics primarily involves using DNA sequencing, RNA sequencing and gene expression tools to discover and catalogue genes and annotate their functions, correlate gene expression differences with environmental conditions, and discover/apply molecular markers and construct high resolution physical maps in the studies of genome structure, diversity and trait genetics. Essentially all of these activities play an enabling role for applied molecular breeding (MB), a core activity of GCP.

Of GCP's nine focus crops, rice, maize, sorghum, and to a lesser extent wheat, lend themselves well to comparative genomic approaches. Legume genomes are currently being sequenced with active GCP participation, enabling comparative genomics approaches among them as well. In the first stage of the GCP, additional monocot crops were studied, including pearl millet. Significant effort was devoted to developing genomic resources for pearl millet, mainly EST sequences, SNP markers, and low-resolution genetic maps.

Comparative genomics approaches can be especially appropriate in the early stages of discovery, when genes positively identified in one species may allow identification of functional analogs in another species. This was the case in 2003 when the GCP was launched, and it has been very successful in using this approach in the discovery of genes for aluminium tolerance and phosphorous utilisation efficiency in rice, maize and sorghum, both important traits in GCP's target regions. However, the mechanisms of Al tolerance and P use efficiency differ among species. Therefore, in addition to comparative genomic approaches, *de novo* QTL mapping, fine mapping and positional cloning approaches are highly relevant (e.g., for sorghum and rice Al tolerance). Genomic resources and informative markers are adequate for each of the Phase II crops, and the use of comparative genomics will focus on translation of the work on well characterized and validated genes into their orthologs in other species. This also implies that some other applications of reduced relevance, such as the creation of genetic maps, may diminish.

The greatest gains in comparative genomics within GCP have not been for drought-related traits but rather for traits associated with Al tolerance and P uptake efficiency. The Review Team notes that this reflects the complexity of drought research and supports GCP's decision to pursue opportunities with other highly relevant and economically important traits. This in no way distracts from the relevance of the drought tolerance work.

GCP has generated an array of useful tools for breeders and geneticists seeking to understand the architecture of specific traits and efficient ways to transfer them to target lines and varieties. The identification and characterization of the reference sets was consistent with the mandate of GCP to unlock genetic diversity and a very relevant activity. The GCP has deployed numerous genetics and genomics tools and products generated, although the degree of user demand needs to be gauged before making elaborate plans for the maintenance and storage of each product.

The Review Team concludes that the GCP science has been relevant, strategic and needed. Following the improved focus on key crops in Phase II, it is likely to benefit a large number of molecular breeders who are developing varieties directly useful for farmers and/or providing more and cheaper food for urban consumers.

2.5. GCP: a Thematic Programme

The GCP differs from other programmes in the CGIAR in that it works across crops and CGIAR Centres on common themes of MB and genetic diversity, demonstrating the usefulness of common MB approaches across a range of crops. At the time of its conception, the CGIAR crop centres had invested in MB techniques, but none could claim a critical mass of staff or resources in MB enjoyed by the larger private seed companies, and to a less extent northern university campuses. In the GCP, critical mass was aimed at through partnerships and planned outsourcing. The IBP is a logical outcome of the need to exploit and summarise the benefits of the critical mass offered by partners, especially in the ARIs, for the benefit of NARS and SMEs. The IBP represents a set of tools, analyses and services that, when complete, will provide the means by which NARS scientists, often working under difficult circumstances, can access modern plant breeding techniques (see Annex 7).

2.6. Evolution of the GCP Research Portfolio

In Phase I (2004–2008) GCP activities were organized into five Sub-programmes (SPs), each led by a 50% time Sub-programme Leader (SPL). In Phase II (2009 onwards), the Management Team comprised the Director and five Theme Leaders (TLs). The themes are structured in a matrix of seven Research Initiatives (RIs), which are essentially crop based or focused on comparative genomics. The evolution of GCP from Phase I to Phase II is shown in Table 2.1 indicating specific elements within the Phase II Themes.

Table 2.1: Relationship between Sub-programmes of Phase I and Themes of Phase II
(Activities are grouped by rows)

Sub-programmes of Phase I (2004)	Research Themes of Phase II (2008)	Elements of Themes in Phase II
1. Genetic diversity of global genetic resources	(None; ongoing diversity research was moved into Themes 1 & 2)	(Complete phenotyping of reference sets)
2. Comparative Genomics for Gene Discovery	1. Comparative and Applied Genomics	Research Initiative involving rice, sorghum and maize for POC of comparative genomics
3. Gene Transfer and Crop Improvement	2. Integrated Crop Breeding	Six crop-based RIs for nine crops developed as POCs of integrated molecular breeding
4. Genetic Resources, Genomic and Crop Information systems	3. Crop Information Systems	The Integrated Breeding Platform (IBP) Phase 1
5. Capacity Building	4. Capacity Building	Training, Communities of Practice, and improved phenotyping facilities in NARS
	5. Product Delivery	Product delivery plans developed, and on-line product catalogue; PDCs appointed.

The GCP research portfolio began as an attempt to characterise genetic variation and diversity in relatively few crops. However, it quickly evolved to address most CGIAR mandate crops when more CGIAR centres joined the Consortium as they realised the potential GCP offered for generating genetic information on relatively minor crops (e.g. finger and foxtail millets). The major trait chosen for proof of concept was drought tolerance, a key trait across target crops, especially for Africa. Drought tolerance is a difficult trait to improve – its genetics are complex, the selection environments are often low yielding and variable, there is a high level of G x E interaction, heritability is often low, susceptibility varies with growth stage of the crop, and sources of tolerance are often associated with low yields in unstressed environments. The Review Team supports the GCP decision to maintain this focus, while taking advantage of opportunities to improve germplasm in terms of other relevant traits.

Following the EPMR in 2008, the number of crops addressed was reduced from 18 to nine, with a much sharper focus on product delivery and geographies for impact. While this change was welcomed by the majority of stakeholders, there were downsides to it. Most discontinued crops were relatively minor in importance and were once again orphaned. For some survey respondents

(Annex 10) the increased focus on major crops and their delivery decreased the emphasis on pre-breeding (considered a strength of the GCP) and placed GCP in competition with the main CGIAR crop programmes. The Review Team's view however, is that the downsides are easily outweighed by the sharper focus on crop and product in Phase II, resulting in a clearer proof of concept of the value of MB in improving drought tolerance in the strategically important staple crops and generally increasing the relevance of the GCP.

During Phase I, the GCP lacked a coherent research programme and functioned as a rather loosely-related portfolio of activities across 18 crops. As the GCP has evolved over time it has moved from a discovery mode in Phase I to a product creation and delivery mode in Phase II, which has greatly enhanced its coherence and relevance. The emergence of a crop focus in product development makes it easier to transfer unfinished research to the appropriate CRPs. The Review Team backs the GCP Management Team (MT) in its choices of RIs, the engagement of partners in the process, and the manner in which research priorities within crop were established. The Review Team also has no doubts that drought tolerance is needed in all target crops to ensure stability of production in those agricultural production areas that are destined to be most severely affected by climate change. Similarly all trends point to a looming shortage of phosphorus and acidification of soils from weathering, N fertilization and acid rain. The trait focus of the GCP is extremely relevant and necessary. In the stakeholder survey (Annex 10), 94.1% of the respondents agreed or strongly agreed that the GCP has evolved in a way that has ensured its relevance.

The priority crops in Phase II are grown extensively in poor areas of South Asia and sub-Saharan Africa. The analysis of the coincidence of poverty and drought by Hyman et al. (2008) shows the importance of rice. It is followed by maize, sorghum, wheat, millet, chickpeas, beans, groundnuts, cassava and cowpeas, in order of importance. The allocation of Phase II research funds follows this general pattern of priorities, in declining order: rice, sorghum, wheat, cowpeas, beans, chickpeas, groundnut, maize and cassava. Surprisingly, millets were not funded in Phase II, but there are several species of millet to consider. Maize appears to be underfunded, but has alternative suppliers from the private sector. Investments in cowpea appear higher than is justified by this analysis, but perhaps reflect opportunities for improvement in this relatively neglected crop.

As noted in GCP's Medium-Term Plan 2011–2013, in the early years of the Programme, only about 25% of the research budget was allocated to NARS, as compared to a projected allocation of 42% in 2013. This change is congruent with the CGIAR goal of enabling the research capabilities of NARS – including directing research. The budgetary allocation to CGIAR Centres has remained at about 30–40% over time.

2.7. Impact Pathways - Capacity Building

GCP products are largely genetic and genomic resources and data management tools for plant breeders, rather than improved varieties per se. Pathways to impact in resource-poor farmers' fields therefore are via motivated plant breeders who are trained in data management, statistics and analysis. In design and from the outset, capacity building was a central aim of GCP, focused specifically on NARS and 'consortium scientists' (CGP, 2004 – MTR). This included a survey of needs, generic training and project-specific training.

The main aim of the GCP capacity building programme was to enhance the application of MB, genomics and information technology in developing countries by bridging human resource and infrastructure gaps (GCP 2012). Both gaps are large: national research programmes have few scientists, and they are often poorly supported and motivated. Sub-objectives were to build the technical capacity to implement research and to facilitate a flow of research products to intermediate and end users. The means to achieve these aims were wide ranging, including development of training platforms, formal courses, making opportunities for scientific interaction, mentorship, Communities of Practice (CoPs), supplying open access training materials and purpose-specific support services like help-desks. The refocusing of capacity building on end products and NARS for Phase II was appropriate. The Review Team concludes that capacity building is central to achieving the main project goals, and therefore remains a highly relevant activity.

Accurate and high throughput phenotyping is an essential capability in MB. Field phenotyping facilities in national programmes are often insecure, non-uniform with infrastructure that is inadequate for the conduct of drought experiments. Especially relevant were the investments in irrigation systems, field levelling, fencing, tillage equipment and drainage in sub-Saharan Africa, since these had an immediate effect on the quality of the field trials. These physical improvements were complemented by training of station personnel in their use and the conduct of high quality field trials – a much needed investment. GCP considers that the development of CoPs, focused mainly around RIs or the IBP, is an important means of mentoring staff and transferring technology. The Review Team encourages the continued support of the CoPs.

2.8. Transitioning as GCP Sunsets

The transition process was discussed at several fora at the 2013 GRM, in an effort to engage all GCP collaborators in the process. The PDCs and RI members separately developed plans to complete on-going research and to list unfinished activities. The final processes of transition are being overseen by a Closure Working Group that began meeting November 2013. This group comprises the DDG-Corporate Services of CIMMYT, the Director of GCP, two members of the EB, the legal counsel for CIMMYT and GCP, and the GCP Knowledge Manager. It will oversee the orderly closure of the GCP administration and its transfer to CIMMYT, recommend budgets for the transition period, and the termination of outstanding projects by 31 December, 2014 unless an extension is approved through supplementary grants to CRPs. The Task Force has approved a staff 'retention bonus' plan, a strategy to communicate the transition process, and has recommended to the EB an extension of the term of the Director of GCP to December 2015.

The GCP has produced nine white papers that provide a comprehensive assessment of accomplishments and work remaining to be completed in the major research and service areas supported by GCP. The papers however give limited guidance on the relative importance of the different products and activities, e.g., genomic resources vs. cloned genes vs. informative markers; or trained staff vs. genetic products – something the Review Team **suggests** that GCP undertake during 2014.

2.9. Overview of Relevance of GCP—Then and Now

In 2003, the record of the CGIAR centres in deploying MB was relatively poor. Laboratory and field activities were often uncoordinated and molecular information generated from the laboratories frequently arrived after critical selection decisions had been made. Field scientists were often unaware how to use marker data. The CGIAR crop Centres attempted to 'go it alone', were responsible for largely uncharacterised germplasm collections, but had their own molecular laboratories that were relatively poorly resourced. Most NARS practised conventional breeding and had very limited or no access to MB technologies that were expensive and rapidly changing. There was need for a critical mass of funds, innovative partnerships among all stakeholders, and a systematic approach to MB. GCP was formed to address all of these constraints, and met an immediate need. The across-centre and crop-modality of the Programme, with heavy emphasis on partnerships from ARI to NARS, training and the enabling of NARS, ensured buy-in at all levels. This has resulted in a high level of enthusiasm (the 'GCP spirit') for this style of collaborative research.

Survey data (Annex 10) bear this out – 95% of stakeholder survey's 159 respondents agreed that GCP's promotion of the use of genetic diversity and MB had added value to the CGIAR, and 94% agreed that GCP's objectives had remained relevant over its 10 year life because management had been flexible in adjusting methodologies to changes in the science.

The Review Team concludes the following:

- The original mission of GCP of unlocking genetic diversity held in germplasm collections ultimately for the benefit of resource poor farmers continues to be highly relevant, as is the choice of drought tolerance as the main trait for improvement.
- The Review Team endorses the changes in GCP's research focus resulting in the seven trait-crop combinations (RIs). This improved focus has significantly increased the relevance of the GCP's research programme in addressing global needs in poverty alleviation and food security.
- The use of MB methods, integrated fully with conventional breeding, is relevant and essential, and is fully justified by ongoing GCP results. The key focus should be however on increasing and sustaining the rate of genetic gain for target crops.
- Investments in bioinformatics, phenotyping facilities and data analysis are relevant and essential if the benefits of MB in specific locations and across time and location are to be fully realised. GCP-sponsored MB methods and bioinformatics tools are likely to be fully embraced by line breeders in almost all crops.
- Still important but somewhat less relevant has been the development of some genetic stocks and genomic resources. MAGIC and TILLING lines are also relevant to the sustained increase in genetic gain. GCP-developed genetic and genomic resources are likely to remain relevant to crop improvement needs for much of the next decade.
- Comparative genomics has diminished in importance as GCP-supported research has resulted in an increase in genomic resources of each of the major crops. Exceptions may be the continued use of orthologs of candidate genes such as AltSB and PSTOL1 to provide tolerance to Al and P uptake efficiency in other crops. There is a need for continued field testing of these candidates under realistic field conditions.

- The IBP is the single largest legacy product of the GCP and plays a crucial role in maintaining the momentum of MB that targets product development and increased rates of genetic gain. The IBP is highly relevant to GCP's mission and will remain even more so to the collective mission of the crop CRPs over the next decade.

Given the less than optimal circumstances prevailing in the CGIAR in 2002 the decade-long investment in the GCP has been very relevant and generated synergy across the CGIAR Centres and partners. It has demonstrated how molecular breeding can be effectively conducted in mainstream crop improvement programmes. It has also shown that with outsourcing of genotyping services MAS can be undertaken in real time while increasing rates of genetic gain and facilitating the introgression of key traits with little or no linkage drag.

The RIs that were launched in 2010 as part of Phase II have continued to demonstrate these advantages and will do so beyond 2014. Thus GCP's research has remained highly relevant throughout its lifetime, and the Review Team is confident that the RIs and the IBP will continue to be so for the next five or more years in the Post-GCP period. The continued relevance of this research and the value it delivers will depend on whether the transition to new funding sources and management is carried out effectively during the 2014–2015 period.

3. QUALITY OF SCIENCE

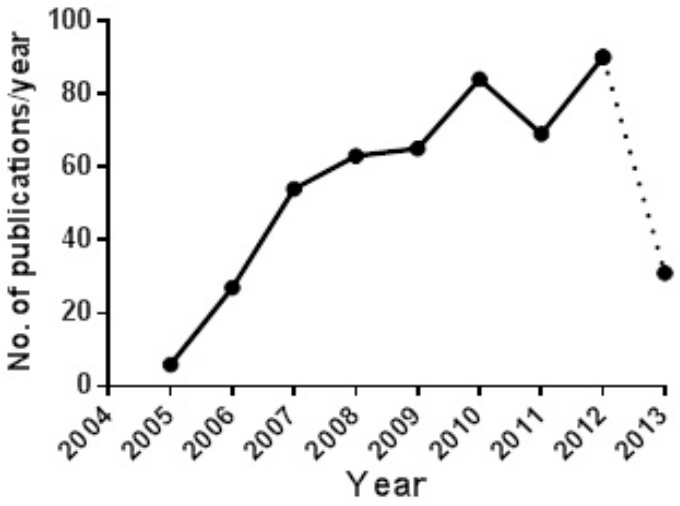
3.1. Introduction

Science quality in GCP can be assessed on the basis of the rigour of its science and the quality of its outputs. The impact of the scientific papers can be assessed through citation analyses. Another consideration is whether the skill set in GCP and its partners is adequate to meet its research goals. How well have GCP and its partners maintained science quality so that value continues to be imparted into the future, is a third criterion. The Review Team briefly considered each of these. Literature cited in this section is in Annex 6.

3.2. Science Quality and Enhancement of Molecular Breeding

Scientific rigour can be assessed by asking if the science meets international standards. The Review Team considered the large numbers of scientific papers as indicating scientific rigour in GCP. In the period 2005 through September 2013 the number of papers totalled 489, and papers continue to emerge (e.g., Varshney et al., 2013; Hamidou et al., 2014). This is a remarkable record, helped by the fact that ARI partners are part of a publishing culture, and despite the fact that much of the research programme of GCP has been dedicated to methodology development rather than variety development per se. The distribution of published papers over time is shown in Fig. 3.1.

Figure 3.1: Distribution of peer-reviewed papers (2005–2013)



Source: GCP. Note that 2013 data are incomplete.

For detailed analysis, the Review Team selected 29 peer-reviewed papers from among the ~500 available and evaluated their relevance to GCP goals, quality and citation record.

Papers were chosen in areas Review Team members felt competent to review (mainly genomics and comparative genomics, but also target setting and phenotyping) and spanned most of GCP's publishing life. The Review Team's assessment of the selected publications is presented in detail in Annex 6. The average citation frequency of these papers was 45 (range 0-236, SD = 55). The work on Al tolerance and P utilization resulted in a large number of well-regarded and well-cited papers in high impact journals. Another set of important papers reports genomic sequencing of legume species. Perhaps surprisingly, some important and high quality papers are not cited as widely as expected, reflecting the modest size of the scientific community working on traits of relevance in tropical regions.

The Review Team noted that papers covered the following areas:

- Germplasm resources, including molecular characterization, tools for understanding and developing germplasm collections
- Genome science, including genome sequencing and comparative genomics. Pigeon pea and chickpea draft genomes are the most visible examples
- Molecular marker discovery (SSR, DaRT, and, more recently, SNPs)
- QTL mapping of traits, including fine mapping
- Gene discovery, most prominently for Al tolerance, P utilization. The best example is an outstanding set of papers from L. Kochian and collaborators
- Development of computational tools for plant genetics and breeding, and bioinformatics
- Phenotyping techniques and field trial results
- Trait physiology
- Genetic modification

The distribution of papers by research themes (Table 3.1) shows that almost 80% of papers addressed genomics, genetic resources, informative markers or cloned genes. Phenotyping papers were much slower in coming out – 74% were published after 2010, reflecting the relatively slow realization by the GCP of the importance of phenotyping.

Table 3.1. Distribution of peer-review papers around research themes

Research theme	Number	Percent
Genomics	159	32.5
Genetic resources	78	16.0
Informative markers	74	15.1
Molecular breeding	58	11.9
Informatics	42	8.6
Gene cloning	15	3.1
Phenotyping	23	4.7
Other	40	8.2
Total	489	100.00

Source: GCP

In some cases, the publications have outlined ground-breaking and foundational research. There are as yet relatively few papers representing successful introgression of traits of interest into agriculturally relevant germplasm. Nonetheless, the Review Team rates the science quality demonstrated in publications as high. The publication output of GCP may yet prove to be its most substantial contribution to science. This output will have an impact for years to come. However, the GCP has not used publication as a metric of its impact. The Review Team **strongly suggests** that GCP collect information on the citation record and impact factors of its publications and include this information in its record of achievement.

Around 90% of papers were published in international journals and 10% in journals with regional or national coverage, implying very wide distribution of information among the scientific community. The GCP has ensured accessibility by publishing papers in open access formats in 43% of the cases, and therefore they can be downloaded from the GCP website at no cost.

A full analysis of the types of journals used in publication was not possible, but a number were in high impact journals (Table 3.2).

Table 3.2. Selected GCP publications (2005-13) and their impact factors

Journal	Articles published	Impact factor
Nature	10	38.6
Nature Genetics	2	35.2
Nature Biotechnology	4	32.4
PNAS	4	9.7
Plant Physiology	13	7.1
Field Crops Research	18	2.5
Crop Science	18	1.6

There has been a recent surge in papers published on phenotyping, a number of them from GCP's well-regarded book (Monneveux and Ribaut, 2011). Most describe the measurement of an array of traits putatively associated with drought tolerance.

Specific activities, such as the IBP and work on reference sets are discussed in detail elsewhere in the report. Based on its overall analysis of the quality of science in the GCP, the Review Team concludes that the science quality underpinning the IBP and its analytical tools is of international standards. The quality of science underlying the establishment of reference sets is also considered high. Approaches used in reference set research have directly assisted the science of mini-core collections, and led to a number of other similar studies in association mapping.

3.3. Enabling and maintaining quality of science

The Review Team assessed also the measures in place for enabling high quality science. The GCP has been successful in accessing the skill sets needed to meet its research mandate in genomics. Stakeholders (Annex 10) almost all agree that GCP has raised scientific standards (95%) and improved science quality (97%). It has been less successful in doing so in crop breeding *per se* and this may have slowed the development of the IBP. A second area of concern has been the slow development of field phenotyping skills. Phase I was characterized by a number of relatively low quality evaluations of germplasm reference sets, and it was not until 2010 during Phase II that the deficiencies of NARS phenotyping sites were addressed by GCP.

For maintenance of science quality there appear to have been no internally commissioned external reviews conducted on specific topics during Phase I & II. The Review Team endorses this means of evaluating specific areas of the research programme for strategic purposes and assuring quality of science. The Review Team notes that these could have had a useful role in helping shape the activities surrounding the reference set studies, the GCP phenotyping investments, the role of socioeconomics in GCP goal setting and product mix, and in the direction and conduct of the IBP. Although the GCP has been the subject of a number of general reviews (EPMR, 2008; EC reviews

2008 and on several other occasions) these rarely considered specific technical topics in depth. Donors have conducted reviews of Projects such as TL1 and IBP, but focused more on specific issues associated with the execution of these projects. The CRPs can benefit from this experience, and the Review Team **suggests** that GCP in its final year commission two external reviews that focus in areas that can now be recognized as keys to its long-term success. These could be of GCP's investments in equipping and enabling phenotyping at sites in Africa, and an evaluation of the use of newly identified genetic variation in breeding programmes. Both would be of continuing interest to the CRPs.

The Review Team finds only limited evidence that GCP has invested in the development of research skills of individual GCP staff members. The Review Team recognizes that sabbatical leaves are unlikely in a Challenge Programme, but targeted study leaves are certainly a possibility. GCP staff have participated in professional meetings on a regular basis where they have presented on behalf of the Programme; and the annual or biennial GCP research meetings (e.g., GRM, 2013) have played a role in updating GCP staff skills and enhancing the quality of science thereby. However, there has been little formal involvement with the seminar programme of CIMMYT, and the Review Team saw no specific plan for staff development offered to Sub-programme Leaders or Theme Leaders. When staff are dispersed geographically and often working alone, it is important that their skills are maintained.

In summary, the Review Team finds the quality of the science output from GCP staff and collaborators to be high, although further measures could have been taken by GCP to maintain those standards and to upgrade GCP staff skills.

4. RESULTS AND EFFECTIVENESS

4.1. Introduction

This chapter examines programme achievements in Phase I and Phase II; phenotyping and infrastructure; balancing research initiatives vs. research themes; management of research; monitoring and evaluation; partnerships with ARIs, NARS and the private sector; and responsiveness to external reviews in 2008.

4.2. Programme Achievements in Phase I

A number of important achievements were realized during Phase I. Reference sets were established in 21 target crops. Varshney et al. (2010) define a reference set as "a set of genetic stocks that are representative of the genetic resources of the crop, and are used by the scientific community as a reference for an integrated characterization of its biological diversity". Diversity was assessed using passport data and a set of up to 50 neutral DaRT or SSR markers to narrow collections to reference sets of approximately 300 landraces and some elite lines or varieties. Large-scale genotyping on these sets was mostly completed, and the development of a phenotyping network began, usually using testing sites at NARS' stations or at CGIAR locations. Both genotyping and phenotyping of reference sets were challenging. By 2008 the decision was taken to develop a phenotyping manual for the main GCP crops, though disappointingly it was not completed until 2011.

The reference sets have been used in a number of studies *per se* or as reference entries in other studies, or as sources of abiotic and biotic stress resistance. They have therefore fulfilled much of their early purpose. The approach to characterizing the variation in germplasm collections using reference sets is robust, and effectiveness is very satisfactory. For the first time minor crops were put on the same level as the major crops in the identification of new sources of genetic information. The Reference Set studies laid a foundation for the rest of the GCP (genotyping, phenotyping, tool development) and for other projects using new sources of genetic variation (e.g., the B&MGF supported projects DTMA, WEMA and IMAS). The need for uniform standards in measuring traits led to the development and publication of a clear set of ontologies (Sreshtha et al., 2012) and ultimately to the development of the IBP. Software was developed to take into account population structure during association mapping studies. The communities of practice that developed around reference sets generated social capital that contributed importantly to an extension of GCP activities.

The chickpea reference set has been particularly useful (Varshney et al., 2010). Here the 300 lines capture around 90% of the genetic variation and show a clear hotspot – a 30 cM region that accounts for 58% of the variation for drought tolerance, a region confirmed from MAGIC line analysis also.

New low cost markers and marker technologies were developed, along with associated MB and genomics resources, including marker sets, genetic maps, etc. Mutant collections were generated (rice, potato, bean). DArT markers, which are well suited for diversity studies, were developed for cassava, coconut, *Musa* species, pearl millet, potato, sweet potato, yam, chickpea, groundnut and

pigeon pea. This provided sufficient markers to conduct meaningful genetic studies for each priority GCP target crop, and the so-called 'orphan' crops as well. These resources include SSR marker sets associated with all germplasm reference sets, thereby allowing a user to assess the diversity of local collections.

Gene discovery/identification of stress tolerance genes in landraces and wild relatives of crop species (usually genebank accessions) made significant progress. Examples include biotic and abiotic stress tolerances for chickpea (Singh et al., 2008) and improved groundnut varieties incorporating drought tolerance, rosette and rust resistance (Alves et al., 2008; Fonceka et al., 2009). Candidate genes associated with drought tolerance were also identified, and comparative genomics confirmed the utility of Alt_{SB} and *Pup1* and their homologs, genes that increase tolerance to acid soil or efficiency of P uptake in more than one species.

Specific projects targeted the physiological and genetic basis of drought tolerance in many crops, leading to protocols for use in specialized testing environments for drought tolerance evaluation. The need to define standard trait ontologies and identify and develop suitable testing environments for drought research was recognised. These developments generated a large flow of molecular and trait-based data. New bioinformatics tools were made available to all partners, though not as an integrated package. Support services in design and analyses of data were developed. GCP project data were lodged in the GCP Central Registry.

GCP communications were well established during Phase I. The GCP website was recognized as an important source of information on MB. Public awareness materials were generated and the GCP e-newsletter launched. At the same time the GCP was developing a reputation for high quality science – by the end of 2008 150 articles had been published in peer-review journals. Competitive grant applications were evaluated by an external review team, and internal peer review was offered via the MT and the Research Advisory Panel.

There were, however, questions emerging about the focus and outcomes of the GCP. Although an excellent start had been made in establishing partnerships and tapping into the diversity of many CGIAR mandate crops, the programme was perceived as opportunity driven, operating in a discovery mode, and not oriented towards end products and specific crops. By 2007 GCP lacked a coherent research programme and functioned as a rather loosely related portfolio of activities. The EPMR and EC Reviews of 2008 catalysed reforms that halved the number of crops addressed, and provided a clear product focus. The unwieldy PSC was replaced with the much smaller EB whose members were chosen for their skills and experience in research administration as well as their familiarity with the science of molecular breeding.

4.3. Programme Achievements in Phase II

Achievements in Phase II have occurred against a backdrop of enabling MB, empowering NARS, and an increased focus on the ultimate deliverable of improved crop cultivars available to farmers. GCP also reduced its emphasis on research themes and increased its emphasis on crops through the RIs. Other aspects remain unchanged from Phase I – e.g., the formation of and dependence on partnerships; generation of high quality scientific publications; and the strategic role played by training of research staff. A key change was the coalescing of information management, data analysis and MB procedures around the IBP.

Information on the key achievements of GCP Phase II is summarized here:

Molecular Breeding

While molecular breeding in GCP has accelerated genetic progress for a number of traits affected by a single or several genes, its usefulness in increasing drought tolerance has been less spectacular. This does not surprise the Review Team, since drought tolerance is a complex trait with relatively low heritability, affected by many genes whose expression is often strongly influenced by the environment. It is not likely to be 'fixed' by incorporating a few strong QTLs, except in rare cases such as that reported for rice (Swamy et al., 2013). The Review Team **suggests** that the more recently developed GS approaches that rely on accumulated effects of many small, unidentified QTLs may be more generally successful as an MB strategy for improving drought tolerance.

Extensive genomic resources are rapidly becoming available for many crops, and GCP has contributed significantly to this change. Their contribution of genomic information and resources, especially in Phase I among the minor crops that were subsequently discontinued in Phase II (i.e., bananas and plantains; barley; coconuts; lentils; finger, foxtail and pearl millets; pigeon peas; potatoes; sweet potatoes and yam) has been a significant accomplishment.

Development of SSR molecular markers has been undertaken for all mandate crops (plus pigeon pea). SNP markers have also been generated for all mandate crops (plus pigeon pea and soybean). A subset of SNP markers, mainly ranging between 1100 and 2100 per crop, were converted to KASP (Kompetitive Allele Specific PCR) assays for use by genotyping service provider LGC Genomics / KBioSciences. KASP markers offer the advantage of high throughput genotyping in a cost-effective manner with low error rate (Semagn et al., 2013). Development has kept pace with technology in GCP, with markers advancing from SSRs to SNPs. There are several reference sets where SSR information should be updated to SNPs, and the Review Team **strongly suggests** that this be done, since the phenotyping costs have already been met on these sets. Informative SNPs have been converted to the KASP markers to allow users to employ the most economical approach for genotyping and MAS.

Currently, marker sets and other genomic resources to enable MB are available for all nine Phase II target crops. Informative markers are available for specific traits: drought tolerance for each of the nine key crop species of Phase II and for pigeon pea and soybean; aluminium toxicity tolerance for maize and sorghum; salt tolerance for rice; low P tolerance for rice; disease resistance genes for

maize, rice, and cassava; Striga resistance for cowpea; and male sterility genes for rice (to facilitate hybridization). Genomic tools and data have been used effectively to develop molecular markers and to translate them into practical assays for all target species for applied breeding use.

In general NAM, BCNAM, and TILLING populations were generated in 1-2 crops, while MAGIC populations were generated in about half of the target species. Synthetics were developed in groundnut, and CSSLs in rice. RILs associated with QTL identification were developed in almost all crops, though NILs associated with validating QTL effects were less plentiful. Large effect QTLs for drought tolerance were identified in rice, and a QTL 'hotspot' region discovered in chickpea. Physical maps were assembled for cassava and chickpea, and supported the development of the first-ever draft genome sequence map for a *kabuli* chickpea variety, as well as a similar draft sequence for pigeon pea -- both developed through a large collaborative effort with participation of the GCP. Other genomic resources include BAC libraries and transcriptome data.

The following genes were cloned: Alt_{SB}, the gene underlying the major QTL for Al tolerance in sorghum; *ZmMATE1*, an orthologous gene of Alt_{SB}, underlying a major QTL for Al tolerance in maize; and *PSTOL1,* the gene underlying the major QTL for P-uptake efficiency in rice, *Pup1*. Gene discovery for these relevant traits with relatively simple genetics has been very effective, and comparative genomics tools were used effectively to translate discoveries into related species.

Information management in MB: A portfolio of tools has been developed, most of which have been assembled into the IBP. Other modules look more to future potential technological applications in breeding. An information management infrastructure has been developed for databasing information produced through breeder projects and accessing centralized crop databases. Beyond the user level, data can be shared at the organizational level and the public level. Anticipating a considerable growth in data volume with widespread adoption of the IBP, iPlant has been solicited to partner in information management and will also offer its cloud computing capability to IBP users. Databases have been established in Europe on servers operated by Amazon.com, close to the geographic centre of projected usage of the IBP. The Review Team notes that the IBP appears to be a highly effective suite of linked algorithms and procedures.

Product development using MB: Through 2012, eleven improved varieties developed using GCP's MB technologies have been released in regions across the developing world, demonstrating that the efforts of GCP are in fact culminating in better seeds for resource-poor farmers. The improved varieties feature drought tolerance in rice (Africa) and common beans (South America, Central America, Africa); salt tolerance in rice (Asia); low P tolerance in rice (Asia); disease resistance in cassava (Africa), rice (Asia), and maize (Africa, Asia); and high-yield hybrid rice (Asia). Two high-yielding, short-statured maize hybrids incorporating resistances to Grey Leaf Spot and Maize Streak Virus have been released in Kenya by KARI.

In summary, the MB programme in GCP has been effective in creating and documenting an array of products. Were these products supply driven or demand driven? The Review Team's assessment is that both played a part in design and execution. The survey of stakeholders (Annex 10) indicates 98% agreement with the statement that 'since 2004 GCP has generated significant output/products in support of genomic research and molecular plant breeding'.

How widely these products are being used is unknown, and is beyond the capacity of this review to formally assess. Usage and impact of genetic and genomic resources should be addressed in the Post-GCP Impact Assessment that the Review Team **suggests** be scheduled for 2016-17.

Capacity building

Capacity building has involved mainly training but GCP has also contributed to institutional capacity development in developing research infrastructure and phenotyping capacity.

Training has occurred at several levels in GCP, making measurement and assessment of quality challenging. A rather limited needs assessment workshop was carried out early in the Programme's life (p. 9 Martin and Jacobsen, 2004). Some training has been 'stand alone', such as the Integrated Breeding Multi-Year Course (IB-MYC). Individual developing country crop breeders are benefiting from the IB-MYC, now in the second of its three years, which is offered to 180 participants mainly from NARS and SMEs in Asia, sub-Saharan Africa and Latin America. Other training events have occurred within projects and grants. GCP has counted its training events (74 identified by this review) and its post-graduate grantees. Through July 2012 a total of 74 PhD and 27 MS students had been, or were being supported to some extent by GCP during their studies. Of these, 55% were fully supported by GCP.

The Review Team is generally satisfied that GCP has been training the right people – though there is some indication that the level of trainees attending the IB-MYC may not have always been appropriate (e.g., technicians rather than breeders). Important training and capacity building links and relationships have been formed with key centres of learning (e.g., Cornell, Iowa State, Hohenheim and Wageningen Universities).

In Phase II there was a greatly increased emphasis on capacity building at the level of NARS, reflecting the general shift of the project towards products, impact and sustainability. In some cases this was aligned with provision of key equipment (e.g., for phenotyping), provision of access to services and development of communities of practice. One way of measuring increased inclusion of developing country scientists is their increased leadership of projects as the programme has evolved, and this has increased from around 25% in 2008 to more than 50% in 2013.

Training in Phase I was, to some extent, generic, responding to a set of perceived needs rather than directed at practices undertaken by field scientists. The linkage of training with specific projects and grants in Phase II resulted in 'training by doing' with immediate uses within that project, e.g. the IB-MYC where participants are directly involved in the conduct of MB in their home institutions, and use their own data as inputs to IBP during the course. The Review Team considers that this practical slant to the training packages was more successful in Phase II than Phase I. Numbers in the IB-MYC course appear large, but it is axiomatic that turnover of staff is higher than the ability of a project to replace those staff, and, with funding, the course could be easily repeated in an updated form.

Rapid technology changes, such as those occurring in MB, can mean that training quickly becomes out-dated. The model of developing concentric levels of capacity, with higher levels able to adapt more readily to technology change and lower levels focusing on tried and true technologies crucial

to product delivery seems appropriate, provided impact pathways are clearly understood. Building capacity to deploy MB is being done largely through the IB-MYC, designed to build competencies to use the IBP – even though it was not a fully functional product. The IB-MYC, the CoPs and the help desks established in Phase II will have a continued role in training and mentoring in CRPs and IBP Phase 2.

Training appears to have been appreciated by project partners and individuals from NARS when interviewed. The stakeholder survey (Annex 10) noted that the 'GCP training programme can help researchers in developing countries learn new tools for improving their research activities'. There was a high level of agreement (95%) among stakeholders that GCP helped staff in partner institutions raise scientific standards through training and professional development. Some delivery and mentoring methods such as the CoPs were particularly appreciated as these gave voice and access to a key group of NARS breeders that are otherwise isolated from their peers.

Formal measurement of performance of capacity building is difficult and expensive to disaggregate from the overall impact of the GCP – beneficiaries have to be followed and their application of the learning quantified. Informal measures depend in part on records of specific training events conducted by GCP, but these are not complete. This is partly due to some training being within the context of specific projects that may not have involved GCP staff directly. Indicators for measuring impact of capacity building were set in the MTP log frame up to 2010, but are missing from the 2012 Annual Report. However, without indicators of quality or impact these log frame items are unquantifiable. For example in Output 7 (MTP, 2009), establishing MB in Africa is a capacity building goal, with well-trained breeders as the outcome, and finally, increased capacity of the NARS as the impact. Although GCP has lists of participants available, some training reports have not been filed. It is difficult therefore to assess the value of the training except through interviews of participants. A standard survey administered at the beginning and end of the course, or use of self-assessment tools should be a mandatory part of training courses. Individual training participants seem to have greatly valued the training, but on the whole the monitoring of the training activities has been inadequate. Evidence from the Stakeholders' survey (Annex 10) shows that 97% of respondents agreed that GCP has enabled scientists from country programmes to participate in developing new tools and methodologies for breeding, and that they had benefited from training and professional development.

Some training data are disaggregated by gender, though far from all. The 2012 Annual Report captures the number of female beneficiaries for the IBP-MYC (33% in East Asia; 14% in West and Central Africa), likely reflecting the poor representation of women in the scientist population as a whole. The Programme has tried to promote female attendance, but GCP could have sponsored some women-scientist-specific activities to increase participation, e.g., a women-only CoP.

An important component of capacity building has been development of research infrastructure. Total projected expenditure on infrastructure by GCP to the end of 2013 was $4.7 million. Of this around $2.2 million were spent in Phase I, mainly for laboratory equipment. In Phase II, expenditures ($2.5 million) were mainly on field facilities. Of the $4.7 million total, 56% was spent in the field and 44% on lab equipment. The largest proportion (60%) was spent in Africa, 21% in Latin America (mainly Brazil), Asia accounted for 21% and the Middle East 5%.

During 2010–2013, significant investments ($2.4 million) were made by GCP in improving phenotyping at 22 sites in seven countries in sub-Saharan Africa: Kenya [7], Tanzania [1], Mali [4], Burkina Faso [2], Niger [1], Ghana [3], Nigeria [3], Ethiopia [1]). All but one were managed by NARS. Equipment needs and field layout were assessed by an experienced consultant agricultural engineer and the NARS. Purchases were mainly irrigation systems, fencing, land levellers, rainout shelters, and electronic weather stations. Areas developed to a suitable standard for large-scale field phenotyping ranged from 2–12 ha per site.

It quickly became apparent that the skill package of station managers was limiting, so two training courses each of two weeks duration, were conducted in Africa in 2010 for a total of 50 station managers and field technicians. This must be considered a timely and important component of capacity building by GCP. The 2011 publication of detailed guides on phenotyping for drought tolerance in GCP target crops (Monneveux and Ribaut, 2011) in print and on line was an important milestone. Courses based on this book are in demand, and individual book chapters have been published in journals. Distribution of around 200 electronic tablets to collaborators (mainly IB-MYC participants) to enable same-day uploading of data recorded in the field has been well received and will reduce error rates.

In summary, a needs assessment of training in MB should be made before the project ends to ensure that capacity building successes and short-falls are highlighted in the transition to CRPs. Furthermore, all GCP training courses should have been accompanied by an assessment of their effectiveness – either a 'before and after' skills assessment or a self-administered evaluation of changed skill levels. Facilities on NARS experiment stations have improved and follow-up training courses have been run, though questions remain around the ability of NARS to maintain these facilities in the long term.

Communications and publications

Communications from GCP were handled in-house by a Communications Unit which is responsible for delivering all publications, websites, marketing and public relations as well as facilitating internal and external communications (GCP, 2006). Communications gathered more momentum during Phase II, and in the Review Team's view were especially effective. For example in the years 2009-2013 (to date) a total of 339 articles were published in peer-review journals, and several were in high impact journals. GCP's use of varied communications methods has been impressive. The key tool used was the GCP website (www.generationcp.org), which has maintained a separate identity from the host, CIMMYT, and has provided a clear 'brand' for its product. In 2012 the website was revamped, and web traffic for July-August increased to 3,852 visitors from 2,808 in July-August 2011. Significantly, over the same time period the number of pages viewed per visit increased from 1.7 to 4.7 and the duration of the visit from 1.1 to 5.5 minutes, with a sharp increase in returning visitors (GCP White paper on communications and knowledge sharing, 2012). The website is professional, easy to navigate and comprehensive. It is rich with material and deep in terms of its levels of data and different applications. It includes a full list of GCP publications and journal articles, many of them directly downloadable. Also listed is the full product catalogue including genetic and genomic resources.

A feature of GCP publications and the website has been the colourful illustrations of African and Mexican farming scenes and an upbeat tone, creating optimism while reminding readers of GCP's mandate. In 2012, GCP entered social media, and launched Facebook, Twitter and LinkedIn pages, while maintaining a presence on Flickr, YouTube, Slideshare and similar sites. The Review Team was unable to assess the effectiveness of the social media as a communications mode.

The experiment with having the IBP accessible via a web portal as a 'shop window' for disseminating technology (https://www.integratedbreeding.net/) has also been successful. The IBP website has over 500 registered members.

Overall, the GCP maintains a high standard of communications and excellent global image. The Review Team regards the communications and publications strategies of GCP as highly effective, setting a standard in quality that CRPs could seek to emulate. However the impact of those strategies has yet to be assessed formally.

Product delivery

As noted in Section 2.5, Phase II research is rather loosely divided into five themes, each led by a full-time subject matter expert. The first four themes loosely correspond to the Sub-programmes adopted in Phase I. Theme 5, Product Delivery, is new to Phase II and focuses on identifying a product. It inventories products and monitors project delivery plans that outline pathways required to get products to intended users (mainly crop breeders) along with information on how they are best used. The product plan targets capacity building to strengthen weak links in this chain so that products flow smoothly through to users. Promotion and dissemination forms part of this strategy, though it is unclear what (if any) market research has been undertaken in support of this strategy. The strategy is embodied in an on-line delivery plan kit completed by project staff that also considers IP issues, and identifies the users of each product.

Products fall into the categories of germplasm, genomic resources, genes for target traits, informative markers, protocols, informatics tools, learning resources, datasets and publications, in three categories based on potential impact. The on-line product catalogue, currently containing 284 items, highlights the product focus of GCP, and is possibly unique in the CGIAR. The Product Delivery Leader is responsible for the catalogue and for overseeing all projects developed by the seven RIs.

In Phase II, the organization of GCP's research programme has focused much more strongly on crops in specific geographies through the seven research initiatives (RIs) encompassing the nine target crops. The Review Team's further observations and assessment on each RI are provided in Chapter 8.

A decreased focus on themes and an increased focus on crops in Phase II has prepared the GCP well for transition to the CRPs, since most research activities within each RI have obvious homes in their respective CRP. Among the themes, Crop Informatics (Theme 3) will pursue its own identity as a cross-cutting set of activities under the IBP and be available to all CRPs. The Review Team has some concerns about Theme 5, Product Delivery. It is unclear from the catalogue and the GCP website

which are the key products (excluding the IBP) that GCP wants to ensure will add maximum value in the immediate post-GCP period.

R1. The Review Team recommends that during 2014 GCP select 20 or so products with highest potential impact and develop a market and promotion strategy that strongly emphasizes their value and utility to targeted users.

4.4. Management of Research

One of the main responsibilities of the CC is the provision of high-level advice on research in GCP. A review of the recent CC meeting minutes shows that research issues are rarely discussed in depth, implying that the CC has not played a major role in shaping the research agenda of the GCP (some CC members have been active in the Transition Task Force as well as GCP's sub-programmes and research projects). More detailed discussions of research policy issues are evident in the minutes of EB meetings (in which the CC Chair also participates as observer). The EB has met more regularly than the CC, and therefore has remained in closer touch with GCP research issues. The involvement of CC and EB members in GCP's general research meetings have ensured that the main governance bodies are exposed to current research results and issues. For much of Phase II research has been managed on a day-to-day basis by the Management Team (MT), comprising the GCP Director and the five Theme Leaders. The MT is a small team, so each of its members inevitably has diverse responsibilities and undertakes a variety of functions.

The Review Team is concerned about the workloads carried by each of the current MT members – but especially the Director and the Product Delivery Leader. This is exacerbated by the fact that staff are dispersed geographically, and finding common time zones for tele- or video-conferencing is challenging. In 2013 a total of 45 Projects in MB and genomics were underway, and the PIs leading these require oversight since only one is led by a GCP staff member; and some projects will extend beyond 2014. Handovers to CRPs will need to be managed, and the development of new proposals for IBP Phase 2 and possibly Tropical Legumes 3 will take significant resources. At times this may be more than the PDCs and the remaining Theme Leaders can manage without loss of quality. Twenty projects are listed under IBP for 2013 also, but 50% of these are supervised by staff currently part of GCP-IBP.

R2. The importance of IBP is such that the Review Team recommends that early in 2014 GCP appoint a senior staff member who understands the plant breeding process, the CGIAR and the private sector, and also has software development and commercial skills to guide and manage the launch of final versions of IBP, oversee the development of hubs, and help finalize the workplan of IBP Phase 2. This will free some of the Director's resources for oversight and management of the wide range of important closure-related activities that will need to be undertaken by GCP in 2014.

Monitoring and Evaluation

Although the founding logic and relevance of the GCP was sound, the original proposal (CIMMYT, 2003) did not contain a logical framework. The logical framework introduced in 2004 has been amended, notably during Phase II, and provides some basis for monitoring and evaluation at the

Programme level. However baseline studies and counterfactuals were not established early in the life of the GCP.

Since its inception, the GCP has faced challenging M&E problems. The technologies being developed were mainly for breeders, and farmer benefit occurred well beyond the implementation period. M&E systems focused on development of recognizable 'products', defined as an output of research deployed by 'users' for the next stage of research leading toward a final output. In Phase II, individual projects included a matrix of verifiable milestones against which progress could be judged, but this did not extend to the programme itself. The development of the product catalogue has allowed some monitoring of progress through the workflow management system. This is a management tool that was a reasonable solution to the complex M&E challenges of GCP, but it falls short of the comprehensive M&E system that ideally might have been developed for the GCP.

A large but unknown number of projects in Phase II have met their milestones. A notable exception has been the IBP, which in its first two years consistently missed its development deadlines (and sometimes not met the anticipated product specifications), though performance has been much improved in this respect since June 2012. GCP attempted to manage IBP development through a combination of logical frameworks and the workflow management system but failed to monitor progress against the requirements of field breeders at appropriate stages. In other cases, targets set at theme and project level were sometimes not quantified (e.g., 'a database, genes and crops to be decided'), the intended users tend to be vague (e.g., 'GCP scientists'), outcomes un-quantified (e.g., 'enhanced access') and impact un-measurable (e.g. 'enhanced knowledge'). As already noted, capacity building has been reported as numbers, but quality and impact have not been assessed. For these reasons, the Review Team concludes that the M&E tools adopted have been useful for planning, but have not been completely successful in managing delivery and preventing delays – in short, that GCP's M&E systems at the programme level are somewhat unsatisfactory.

What could have been done in M&E? What can still be done?

Ideally, a baseline against which progress can be gauged is preferred, based on a careful assessment of the degree to which MB was currently being used routinely at the outset among Consortium members, NARS and SMEs. Such a baseline however would have had only limited value after a decade in which the technologies used in MB have changed dramatically. A second means of showing progress from MB could have been to establish counterfactuals – where conventional breeding with and without the intervention of MB was conducted over sufficient time to demonstrate the enhanced rates of genetic gain in NARS-led breeding systems. These types of comparisons were not deliberately designed in GCP, and the programme instead assumed that MB would routinely provide a proven increase in breeding efficiency. In fact, it is has been well demonstrated that MB delivers improved rates of gain when it is properly executed, but for this to occur the availability of genotypic and phenotypic data must be synchronized in time – something that a number of public sector breeding programmes have struggled to accomplish. This sort of information could possibly still be unearthed within currently available datasets of GCP Projects, even when not explicitly included in their original goals. For example, results from the Maize RI indicate that yield increases from one cycle of phenotypic selection plus one of genotypic selection

increased yield under flowering drought stress by 50% over that from two cycles of phenotypic selection.

The lack of a baseline, possibly due in part to lack of access to an M&E specialist in the early stages of the Programme, has made *ex-post* impact assessment by conventional means virtually impossible. The question 'what difference has GCP made to rates of genetic gain in target crops and in skill levels of partners' cannot now be formally answered, though some guidance can be obtained by comparing rates of gain in mature breeding programmes before and after the inception of MB. M&E could have been an element of the GCP's overall experimental approach, bringing to the forefront of project deliverables the exceptional challenge of measuring impact from MB advances. In the absence of an effective baseline dataset, the GCP could have developed parallel case studies, established counterfactual hypotheses, and built sets of change theories that could have been tested. Just as GCP has responded quickly to the moving technology background, the Programme might have adopted new emerging M&E norms being tested elsewhere in the CGIAR. For example, some Centres were experimenting with theory of change models (see for example CPWF, 2013 and ISPC, 2012).

What measurement of impact can still be salvaged from the data available at GCP? As noted earlier, the Review Team suggests that an independent adoption and impact study be carried out in 2016/17. This evaluation should indicate varieties released, genomic resources used, genetic gains and methods adopted compared to some form of counterfactual devised by the evaluators. In the absence of a counterfactual, the study will simply indicate the degree of adoption of technologies and not their impact. However, the Review Team considers such an assessment to be essential since it would help assure the CRPs that the technologies developed and promoted by GCP had measurable positive impacts and were worthwhile employing in updated forms by CRP breeders.

There are several ways to demonstrate impact and impact pathways around longitudinal case studies focused on breeders and, in a few cases, farmers. These studies could be started by GCP in 2015 in consultation with the Standing Panel on Impact Assessment, and a comprehensive impact assessment study competed in 2016/2017. Areas that could be valuable to follow-up *ex-post* include:

- Procedures and technologies, that when adopted have future impact; how far has adoption spread, and are adopters attesting to their worth?
- Policy reform that could deliver impacts beyond the Programme lifespan, e.g., free movement of germplasm from/to China, India and Brazil.
- Publications that are influencing the direction of future science.
- Have research leaders used capacity building provided by GCP to make changes that affect the achievement of GCP's goals?
- Assets provided by GCP resulted in impact outside of GCP, e.g., use of improved laboratory equipment in Brazil or improved field irrigation and drainage systems to select improved varieties not included in the 14 user case studies or the RIs.

Within GCP there might be islands of excellence with profound future impact. Examples would be draft DNA sequences of target crops, cloned genes and homologs, and the IBP. The existence of a vibrant MB research community for less important crops is itself a measure of the effectiveness of GCP. A case study of the key elements driving success and benefits arising from a few CoPs vs. the

costs (fiscal and opportunity) could be valuable for guiding future investments in establishing CoPs as an important vehicle for technology transfer and mentoring. The Review Team therefore **strongly suggests** that in 2014 GCP seek assistance to conduct several case studies of successful and less-successful stories where potential impact is large, and draw lessons from each. Both could yield valuable lessons regarding possible pathways (or dead-ends to be avoided) in seeking to maximize impact. Given the scale and scope of GCP, a modest investment in testing these approaches is still warranted.

Conclusions on M&E:

Professional project management today demands that M&E systems provide simple but accurate tools to assess progress towards goals and the ratio of resource use to output. In GCP M&E have not been quite satisfactorily conducted. Lessons emerging from the GCP experience for other programmes include:

- Appropriately utilizing the services of an M&E specialist at the start of the programme.
- Establish early in the programme's life a simple baseline based on a questionnaire quantifying the current use by target beneficiaries (in this case crop breeders) of technologies under development – even in cases where the use was virtually non-existent or very limited.
- Establish logical frameworks to monitor progress with care and use them to manage the project and report on progress.
- Invest in a tool that allows research managers to regularly assess progress against milestones without imposing a substantial data collection load on scientists, and then use the tool to manage effectively the rate of progress and the use of resources (including reconsideration of further disbursements when milestones were not met or were delayed).
- Ensure that changes resulting from capacity building investments are assessed. In most training courses this will be a self-assessment of additional skills acquired. In the case of post-graduates, a survey of their publication record from thesis research and current placement would suffice.
- Use case studies to illustrate impact. For example, several case studies documenting the benefits of infrastructural improvements on experiment stations could also provide an indication of outcomes from investments.

4.5. Consortium and Partnership Modalities

A by-line theme for GCP in Phase II is 'partnerships in modern crop breeding for food security'. The success of GCP's partnership approach had already been established by the end of Phase I and was recognised by the 2008 EPMR. The Review Team concludes that inter-institutional partnerships among scientists have continued to play a critically important role in Phase II. Today the dynamic network of partners in GCP and its projects is well recognized by the research community. GCP has played an important role in attracting leading scientists in the field of molecular biology and MB, and this has made GCP much more than a simple funding body. The development of the IBP, the main product of GCP Phase II, is a good example. For the IBP, the partnership has involved many CGIAR centres, universities and national programmes in both developing and developed countries; and the

software design and development has been shaped by client-feedback from 14 'user-cases' covering eight crops (maize, rice, sorghum, wheat, beans, chickpea, cowpea and cassava) across 32 countries in Africa and Asia. Its development over the past four years demonstrates that significant results can be achieved through concerted action by diverse partners working towards a common goal.

Examples of excellent partnerships are the collaboration among EMBRAPA, Brazil, Cornell University and Moi University to develop Al–tolerant maize based on Alt_{SB}; among University of Sydney, CAAS, China, and IARI, India to develop drought-tolerant wheat and a network of uniform phenotyping sites; and among QAAFI/DEEDI Australia, ICRISAT, and African countries in sharing staygreen sorghum lines (see Section 1.2 for list of principal partners).The Review Team notes from its extensive discussion also that collaboration and trust have been effective in lifting the scientific standards of the poorer performing members of the partnership.

Data sharing is an area needing improvement. The 2012 'Mapping the Future' stakeholders survey undertaken by GCP indicated that willingness to share data among groups was not universal: only 40% of the 710 respondents felt that data should be freely shared, and 44% preferred to share only among collaborators; others felt that only metadata should be shared. In order that the CRPs set to receive components of GCP's legacy can maintain, strengthen and expand partnerships, there has to be a change in attitudes such that there is greater consideration given to providing and sharing information and data among partners.

Non-Consortium institutions may sometimes feel 'left out of the club', and excluded from the benefits of GCP. The Review Team regards this as a minor price to pay for the close and effective sense of *esprit de corps* that characterizes GCP and motivates the majority of its staff. There are alternatives; the CoPs are a further expression of partnership and are open to all. The relatively few scientists in any single crop CoP (23-46) perhaps reflects the challenges of maintaining partnerships when a flow of funds does not provide direct motivation. Other alternatives are GCP's social networking sites on Facebook and Twitter that are rapidly increasing in popularity and accessibility.

The GCP's self-evaluation of the impact of partnerships in its white paper series places partnerships among the highest of all GCP activities. The 2012 survey of stakeholders mentioned above ranked the importance of partnerships third, after research facilitation and capacity building but ahead of research data management. In the current review's stakeholder survey the GCP was perceived to have been effective and efficient in its partnership approach. It scores well for the effectiveness of its partnerships, its equal treatment of all partners, its proper attribution to others for their contributions, and its communication with partners (Annex 10). One comment noted was: 'GCP helped … researchers from the CGIAR and NARS to establish efficient collaborative networks. Without GCP… CGIAR centres would still work alone.'

In summary, the development of effective and synergistic research partnerships has been at the heart of GCP's research strategy throughout its 10-year history. The Review Team regards the partnership model of GCP, based on equality and respect of NARS, as exemplary, and acknowledges GCP Management on maintaining this standard. Undoubtedly it is fuelled in part by a flow of funds that allow partners to work together, but the Review Team believes that a number of these research partnerships will persist beyond the life of the GCP and may play a critical role in the testing and

adoption of the IBP. The Review Team **suggests** that the more productive partnerships established by GCP be identified and linked to appropriate crop CRPs.

4.6. Responsiveness to External Reviews

The GCP has been independently reviewed six times in 10 years, not counting the current review. There has been one major external review (EPMR, 2008) and five reviews of the EC-funded components (EC, 2004, 2007, 2008, 2010 and 2011). For a stand-alone Programme of this scale, this is not a surprising number of reviews.

GCP Management has taken a positive approach to all these reviews. Since the EPMR made its recommendations in 2008, the progress towards implementing the accepted recommendations of that review has been reviewed internally on two occasions (GCP MTR in 2009 and 2010).

Overall, there has been a high level of compliance with recommendations from the two significant reviews conducted in 2008 at the end of Phase I. Their resulting actions have changed the nature of GCP's research agenda substantially and focused research towards products and product delivery during Phase II. The adequacy of M&E at programme level has not been fully addressed, but it is difficult to address retrospectively.

5. EFFICIENCY

5.1. Introduction

This chapter addresses efficiency, or how well the Programme generated outputs from the level of inputs used. Topics receiving special attention are: the research programme structure, organisational matrix, project selection procedures, the dispersed nature of the programme, and the management of physical information and knowledge resources, with examples from reference sets of germplasm and capacity building in terms of trained scientific staff.

5.2. Research Programme Structure

In the transition from Phase I to Phase II, the GCP re-focused its programme considerably. There were significant increases in expenditures on all legumes (bean +233%; groundnuts +35%; cowpeas +37%; chickpeas +264%), reflecting the impact of the special project Tropical Legumes 1 (2007–2014) that injected around $2 million annually into the GCP budget, specifically for upstream genomics and MB research on these four crops (TL1 Phase 2 proposal). Other changes in the transition to Phase II were slight declines in research expenditures on rice (-14%), maize (-20%) and cassava (-3%), but significant increases for sorghum (+175%) and wheat (+35%). Overall, rice received more than double the research expenditures compared with any other crop, and accounts for almost a quarter of total research expenditure during the life of GCP. Wheat was a distant second followed by sorghum, cowpeas and maize.

As noted earlier, the GCP structure changed in moving to Phase II. The Review Team finds the changes introduced in Phase II have created a more logical structure around which research within GCP has been organised, and provided the opportunity to appoint as Theme Leaders full-time staff with technical expertise in those areas. To increase the focus on product delivery, the Themes (especially Themes 1 to 3) have remained in the 'background' of research organisation, with the seven RIs in the fore as research drivers and the core 'management unit'. As noted in Section 3.5, the workloads on Theme Leaders 3 (bioinformatics) and 5 (Product Delivery) have increased markedly, especially since the recent departure of the Theme 3 Leader and Director of Research. Strong leadership is needed for the IBP, and for the interface between Product Delivery and the CRPs to whom these products must be passed.

The GCP's partnership approach has become increasingly successful in Phase II (see survey results in Annex 10). The Review Team considers that the formation of partnerships has had a major effect on research efficiency, based on the following:

- Scientific standards have been raised and scientific skills transferred to partners through mentoring.
- The context in which research for development must succeed has become clearer to scientists from ARIs.

- The impact pathway from discovery to product delivery is usually linked directly to the experience of the partners in most projects.

Offsetting the benefits of the GCP partnership model have been the transaction costs associated with diverse partnerships and its dispersed staffing model. The transaction costs of partnerships can be significant. Again, the GCP-instilled culture of using regular teleconferencing and prompt replies to emails has reduced transaction costs substantially.

5.3. Budget Management

Budget management at project level has combined incentives with accountability. Normal procedures have been to adopt a total project budget during acceptance of the proposal. The GCP Financial Officer then establishes accounting procedures with her counterpart in the recipient institution. Payments in advance are made in accord with the first year budget. Second and subsequent annual payments are made when research and financial reports have been lodged in the Project Management database and accepted by GCP management. Budget adjustment during the project needs GCP approval, and GCP can stop payments half way through the second year if justifications from the first year are incomplete. GCP can withhold 20% of the budget until the project final report has been received and data are lodged in a public database. Accounting procedures among partners are very variable – the CGIAR centres provide quick, accurate information, while ARIs are accurate but slow, and NARS vary greatly in both speed and accuracy.

Project reporting online uses CROPSTER, a proprietary software package that includes the Workflow Management System, and is best described as clunky but safe with limited search capability. PIs upload reports within a firewalled section of the reporting structure. Technical reports are compared with project milestones in the project proposal and if they align the next round of payments is made. No-cost extensions can be approved by GCP as needed.

Resource allocation is well thought out, and flexible enough to recognise research opportunities as they are identified. Examples of these would be the aluminium, low P and salt tolerance research that provides the basis of the Comparative Genomics RI, and disease resistance that is incorporated into what are ostensibly drought tolerance studies in the wheat and cassava RIs. Budget management is quite adequate. The GCP's accounting procedures are appropriate given the diversity of administrative procedures among partners. However, some improvements in efficiency may have been realised if more flexible project management software had been used to enhance the ability of management to search across the entire project portfolio.

5.4. Project Selection and Coordination

Projects in GCP have been competitive, commissioned or special. The process of selection of competitive bid projects is considered by the Review Team to be rigorous. In brief, there were three calls for pre-proposals 2004–2008. Research proposals submitted were carefully reviewed by an independent external Review Team appointed by the Director, usually with input from the PAC Chair. Over the life of GCP, a total of 36 competitive grants have been funded at a cost of around

$5 million per year, and the last of these was completed in 2012. Commissioned projects have been designed to fill gaps in the research portfolio. They have been selected by the MT with input from the RAP, and presented to the EB for approval. It is unclear if proposals were externally reviewed. All research projects in the RIs are commissioned, and expenditures on them average around $7 million per year. Special projects are fewer and are established by a donor to undertake a specific piece of work – examples are IBP and TL1, both funded by the B&MGF.

Competitive grants have delivered projects with a high standard of research when compared with commissioned research projects (according to Review Team's publication analysis, Annex 6). Although the process of selection of competitive grants is rigorous it can result in a portfolio of projects that appear unrelated. Commissioned research projects have normally been assigned to recognised experts in the field. Nonetheless in some cases commissioned research has been viewed by busy scientists as doing GCP 'a favour', and adherence to timelines and product specifications has been quite variable.

The Review Team is concerned that the process of identifying commissioned research projects seems not to have been sufficiently rigorous. The process of deciding priority research areas has rested with the GCP MT, with some guidance from the EB. The preparation of the research project full proposal has been undertaken by delegated members of the GCP MT or by leaders of the RIs with input from other stakeholders (e.g., see the 2010 white papers developed as background to the RIs), but it is not clear if these were peer-reviewed in preparation or during execution.

The development of special project proposals has been done by the GCP MT with stakeholder input, with the donor deciding the level of independent external review needed. Special projects usually have their own external advisory groups, and the IBP has the 14-person SiMAC that provides occasional guidance.

Based on the GCP experience the Review Team **strongly suggests** that IBP Phase 2 and CRPs allocate at least 20% of their research budgets to competitive research grants, and that they institute a transparent system of external review of project proposals for these and for commissioned research proposals.

5.5. Management of Physical, Information, and Knowledge Resources

On the discovery side of genomics, efficiency is not easy to measure because the degree of difficulty of discovery projects varies. Straightforward measures, such as number of genes discovered per dollar spent, or per employee equivalent, or per unit elapsed time are not particularly meaningful, and cannot be directly compared among projects. Such numbers are, in any case, not available. Subjectively, GCP has been very efficient in use of genomic resources. This has been especially the case in the area of identification of genetic markers, evaluation of germplasm diversity, in some cases *de novo* genome sequencing (in selected legumes), and in broadening the geography of the use of molecular markers. Because of rapid developments in science, some methodologies used early in the Programme would not be chosen today, but the outcomes usually can be translated for

use by new tools. In short, the research methods used in genomics, comparative genomics, and MB are considered by the Review Team to have been efficient and effective, given the state of knowledge at the time they were employed.

In general, the Review Team regards the implementation of the IBP as a very important step in increasing the efficiency of molecular breeding, especially among national research programmes and SMEs. This will be the major contribution of the GCP to breeding efficiency, though proof of concept studies specifically aimed at measuring efficiency in terms of genetic gain per unit time, per dollar or per research worker have still to be assessed.

The efficiency of the process that governs IBP development is less impressive. There have been a number of challenges encountered during the development of the IBP, many lessons learned, and the project has lagged well behind its initial release deadlines. Thus, while relevance of the IBP remains very high, the efficiency with which the project is executed was lower than expected. The resultant delays meant that some of its principal supporters, such as the key CGIAR Centres ICRISAT, CIMMYT and IRRI have pursued alternative software solutions to information management in MB. However, for smaller institutions and for the NARS the IBP facilitates conventional breeding and additionally offers breeders the opportunity to use modern genomics-based technologies proven to enhance rates of genetic gain. Although large seed companies generally have customized IT systems to support their breeding pipeline, many smaller sized companies and public sector breeding programmes do not. The RIs have provided the opportunity to demonstrate proof of concept of molecular breeding to NARS using the IBP. Thus, it is the view of the Review Team that the IBP is a unique product and an important enabling tool for NARS and SME breeders whose access to a complete suite of enabling tools is restricted.

For the remainder of this section we consider two areas where efficiency could be questioned and improved.

Evaluation and utilization of reference sets of germplasm:

Reference sets represent a group of genotypes that are highly suitable for association mapping or direct screening of germplasm for pre-breeding. There have been challenges. Field studies and analyses have been completed in relatively few of the species (perhaps 5 of the 15 started). This low success rate reflected the attempt by GCP to have the studies conducted by members of the research communities. Strengths and limitations of community-based genomic research have been clearly shown. The lack of uniformity in genotyping **suggests** that a single laboratory should have been used for genotyping components. The development of a robust ontology that defines traits and their measurement is an important step in enforcing standard procedures. Progress was slowed by varying protocols and a relatively high error rate in genotyping and phenotyping. Complexity of drought tolerance and variable field conditions resulted in few new findings in drought tolerance arising from reference set studies. The situation improved somewhat in Phase II with better managed stress drought screens. The cassava reference set has been expanded during Phase II (ref. 2012 Annual Report) and genotyped with SNPs, since the initial sample of germplasm was considered too narrow to represent traits of interest properly. The accomplishments related to the work on reference sets are discussed in Chapter 4.

The Review Team rates the effectiveness of reference set studies as **satisfactory**, in part because useful alleles for traits other than drought have been identified (Chapter 4). For the first time in some minor crops, reference sets have provided much-needed information on genetic variation for disease resistance and quality traits.

However, the efficiency of the reference set study series has been **less than satisfactory**, and perhaps only one third of them have reached a satisfactory level of completion. The approach taken appears to have been 'learning by doing' in early attempts at both genotyping and phenotyping, and there were some notable failures. Researchers should have been aware before evaluations started of the challenges of narrow adaptation and the large variation in maturity among diverse entries. The GCP should also have been aware of the limitations in phenotyping capacity by NARS partners prior to these projects. The lack of uniform quality in the standards of partners' marker labs within the CGIAR centres and other ARIs was both surprising and disappointing, but could have been evaluated before the start of the reference set studies.

The Review Team endorses the approach GCP has taken with reference sets, **strongly suggests** that in the future community-based efforts in evaluating genetic variation be carefully managed by a few well equipped laboratories and field facilities, backed by clear protocols and ontologies endorsed by the crop community.

Capacity Building:

In this discussion, capacity building is confined to training activities undertaken by GCP directly or through its projects. GCP has spent about 12% (or around $20 million) of its total lifetime budget on CB, with expenditures running at around $2 million per year in Phase II. The largest single item in the current CB budget is the IB-MYC that has an annual cost of about $1 million. The pattern of CB activities over time is shown in Table 5.1

Table 5.1: Total and average value of capacity building commissioned projects

Year	Total value of commissioned projects (US$)	Average value of commissioned projects (US$)
2005	2,534,372	93,866
2006	1,117,054	139,632
2007	1,557,145	111,225
2008	2,797,057	155,392
2009	861,434	71,786
2010	152,836	30,567*
2011*	5,000,000	2,500,000*
2012	365,984	121,995*
Total	**14,385,882**	

Source: GCP; * the averages in column 3 are estimates, since latest figures were not available from GCP; the 2011 figures include activities planned for 2012-13 as well.

Initially there were relatively large numbers of medium sized CB projects, but in Phase II the value of CB commissioned projects declined until 2010 when a new strategy of fewer but larger CB activities was funded, e.g., the IB-MYC that got underway in 2012. There is some evidence also that GCP has successfully leveraged capacity building through association with its partners (e.g., commercial seed companies). There has been a high investment premium in training for GCP for several reasons since much of the training material developed by GCP has been done from scratch or with individuals and small groups.

Some capacity building has been less successful than expected, something that GCP acknowledges (GCP 2012, White Paper). GCP-funded genotyping and fingerprinting services were not taken up, and free conversion of data into the IBP Workflow System has not been widely used. It is apparent that not all home institutions in the partner developing countries had parallel training or research policies supporting uptake of the new CB methodologies.

Record keeping of CB in GCP has not kept up with staff changes, and there is some uncertainty surrounding numbers of graduates supported, their deployment in NARS institutions and even their gender. In total, GCP has supported (or is supporting) 74 PhD and 27 MS students. Almost all these are associated with individual RIs and are well distributed geographically. Roughly 70% of these students were from Least Developed Countries. The 35 grants awarded to students from non-LDCs can only be justified as a means of ensuring that key research was completed. Data for expenditure on CB are not particularly revealing, since GCP has subsumed much of its costs into individual project budgets. Since 2005 there have been 89 commissioned CB projects and this number has steadily declined over the project period.

The Review Team supports the investments in field phenotyping capacity building by NARS ('better late than never'), notes that this has generated a strong sense of self-confidence among the NARS, but has concerns about the maintenance of these investments by national programmes. The Review Team **strongly suggests** that GCP (and the CRPs) examine the cost effectiveness of such investments at specific NARS sites vs. investments in the regional testing networks managed collaboratively by the CGIAR centres and the NARS in sub-Saharan Africa. There seems little justification for investments in several relatively small and inadequately resourced NARS test sites in the same agroecology but in different countries vs. investments in a strategically placed regional testing network of higher quality. As the NARS gain in strength and resourcing over time, it will become cost-effective to invest resources in specific NARS testing sites, but only if the national testing locations remain representative of large target areas and are of a high standard. The possibility must also be explored of combining public regional test networks with those run by private seed companies to extend the numbers of test sites and improve the standard of the trials conducted.

The scale of investment in researchers of the future is impressive, though no information on current placement of those graduating scientists is available. The Review Team **strongly suggests** that a more elaborate CB measurement and recording system is merited, given the scale and scope of the Programme.

How could the efficiency of capacity building activities be increased? This theme is taken up again in Section 9.2. Efficiency could be increased by linking with other training activities in the CGIAR,

continuing the current focus (in Phase II) on 'learning by doing' rather than running generic courses, reducing travel costs by boosting e-learning and supporting regional rather than global workshops, strengthening CoPs so they play a training role, and improving self-evaluation techniques to identify what worked and what did not.

Communication:

The Review Team considered whether the communication output could have been delivered in a more efficient way. On balance, there might have been cost savings from using external communications facilities (e.g., those of CIMMYT), but the benefits of a unique identity and brand for GCP and IBP outweigh the overall costs by a considerable margin. GCP has not set itself targets for communications, so the Review Team is unable to judge whether GCP's communications effort has achieved it aims. Some products such as journal articles and book chapters may have substantial impact beyond 2014, as will CoPs, and could be usefully measured *ex-post* by conducting case studies focused on reconstructed generic impact pathways. The Review Team **strongly suggests** that the GCP Communication Team select some specific publications and communications tools (e.g., the phenotyping guide book, Monneveux and Ribaut, 2011; the cassava CoP) as potential case studies for impact assessment.

The vast majority of intra-programme communications in GCP has been done via email, and more recently using Skype, or through CoPs. The Programme has maintained a culture of email responsiveness, a characteristic noted by stakeholders, and this has likely improved the efficiency of partner engagement. Annual or biennial General Research Meetings have played an important part in internal communications. These were held annually in Phase I but biennially in Phase II because of cost (GRM Lisbon cost an estimated $400,000). These meetings have been indispensable in sharing information, strengthening partnerships, planning, brainstorming and generating the collegiate GCP spirit. Stakeholders consider the Annual Research Meetings have been a key element in GCP's success, and the Review Team agrees.

Under the IBP, nine crop CoPs and two professional networks on data management and genomics have been created, each with a chat room. Six of these have proven vibrant and successful, especially that of cassava – it is likely that this CoP has created a platform for dialogue in cassava breeding globally. Persuading some institutions, particularly NARS, to actively participate in communication at the level of individual scientists remains a problem. Scientists need the confidence that communication spaces are 'safe', and for this mediation and leadership are essential, particularly where the CoP is a learning tool.

5.6. Management of Staff and Teams, and Development of the GCP Spirit

The Review Team was impressed by the culture of optimism and openness among GCP staff, especially at this juncture close to the sunset of the Programme when some staff are departing to other jobs. There is a strong sense of collective pride in what GCP has accomplished, especially in its role of empowering and enabling NARS to use CB. The geographically dispersed nature of GCP staff

represents a challenge with possible lessons for CRPs. GCP staff suggest that it is not a major issue, but there are challenges in establishing meeting times when staff are globally distributed. Having staff located where their research is being undertaken, however, is essential and the PDCs generally use this to advantage.

A negative intangible, however, is some loss of peer pressure for performance among the Theme Leaders, and the sense of team work and idea generation that arise when staff meet regularly and informally 'around the coffee pot'. For some Theme Leaders the distance management of PIs was frustrating. Partnerships can be equally difficult to manage, and for some staff the management of the process became disconnected from the ultimate goals of GCP. The annual or biennial General Research Meeting helps link research staff and build a sense of common purpose and trust, and is indispensable in this dispersed staffing model. GCP has also fostered a climate of email responsiveness, and regular teleconferences, so communications among staff, PDCs and PIs is known to be good, internet connections permitting. The Review Team concludes from its extensive discussion with GCP staff that dispersed staffing reduced efficiency when SPLs were part-time employees, but that it has had little effect on research efficiency in Phase II. The judicious use of videoconferencing through Skype and GoToMeeting-facilitated staff meetings has greatly improved the sense of teamwork.

6. IMPACT AND SUSTAINABILITY

6.1. Introduction

The major themes of this chapter are the impacts of GCP-led research activities on beneficiaries, and the maintenance and utilization of the legacy of the GCP's research and capacity building products. The impact of GCP will be felt by beneficiaries for a decade to come as varieties developed using GCP's analysis tools and selection methods are released and taken up by farmers. Under the topic of sustainability we address the question of how to ensure that the accomplishments and products of GCP continue to deliver value, and how research in key areas (especially the IBP) can be maintained or even expanded. Assessment of the impact of MB and genomics/ comparative genomics requires understanding of the extent to which resources and techniques developed have been used in breeding and are leading to the development of new varieties. Assessments of impact in the field are relatively few in GCP reports because considerable time is needed for varietal development and adoption.

Topics receiving special attention in this chapter are: impact of genetic products but especially the IBP, and their maintenance; impact of capacity building; role and adequacy of communications; and the sustainability of existing GCP products including the future of the IBP. Intellectual property management that affects the sustainability of GCP benefits is addressed in Chapter 7.

6.2. Outcomes and Potential Impact

GCP has inspired and facilitated crop-focused partnerships involving CGIAR centres (germplasm; know-how), ARIs (cutting edge expertise; education skills), and NARS (phenotyping; knowledge of local market needs; hands-on efforts to develop improved cultivars). As such, GCP has been a prime agent of change, using foundational genetic principles and applications of modern technology coupled with education and training to solve key issues in food production. Information contributing to an expanded knowledge base in the genetics/plant breeding community has been a hallmark of the GCP and a distinguishing outcome.

Ultimately, the impact of the GCP will be demonstrated by the number and performance of improved crop cultivars available to and grown by farmers that have resulted from GCP efforts in enhancing the efficiency and effectiveness of breeding. Although 11 improved varieties (cassava (6), maize (2), rice (2) and bean (1)) have already been released through GCP efforts, many more will appear over time, and the overall impact will be difficult to track. The proposed impact assessment in 2016/17 would be timely and useful, and should focus on adoption of released varieties as well as varietal release *per se*.

In addition, other resources have been produced through the GCP that can fuel further efforts and create impact beyond GCP's lifetime. These include:

- Informative markers for drought tolerance, aluminium toxicity tolerance, salt tolerance, low P tolerance, disease resistance genes, Striga resistance, and male sterility, with crop- specific molecular marker sets for >10 crops.
- Equipped and enabled testing sites in 22 locations in sub-Saharan Africa and several sites in South Asia, plus protocols for evaluation of drought tolerance in several crops including rice, wheat, maize, sorghum, chickpea, pigeon pea, cowpea, groundnut, bean, and cassava, pearl millet, sweet potato and banana.
- Scientific publications related mainly to MB and its implementation.
- e-Learning modules, especially those related to aspects which factor into decision making in the practice of MB.

Many of the outputs of the GCP across its 10 year lifetime are posted as a unique collection on the current GCP website. However, these would be more accessible and have greater impact if query tools were available to facilitate searches of various kinds. Moreover, it is not clear what plans are in place for this website collection beyond 2014. More than 40% of the journal manuscripts have been published as open-access articles; a complete collection of these could be posted to a website for easy access over the next five years. Furthermore, post-2014 stewardship of this important resource needs to be assigned, perhaps to a CGIAR centre.

R3. The Review Team recommends that to maximize the impact of GCP publications and products the website collection of published documents developed from GCP-sponsored molecular breeding research (2005–2014) is maintained on a CGIAR-sponsored website along with a means to query this collection.

More measurable impacts involve adoption rate and use of the IBP (see below) and its associated tools and services. Measurable impacts should also arise from the development and dynamics of crop-based CoPs, and from demand for the various products delivered through the Research Themes, including genetic resources, genomic resources, markers for target trait genes, crop-specific marker sets, protocol and learning materials. Estimation of impacts from these will likely wait until the impact assessment proposed by the Review Team in 2016/2017 has completed its work.

<u>The Integrated Breeding Platform (IBP)</u>

The primary goal of the IBP is to improve the efficiency of NARS' plant breeding programmes, especially those involving MB, through 'a one-stop shop' that provides breeder support for a full range of MB activities. A detailed description of the IBP and its development is given in Annex 7. This section focuses on the IBP as a conduit for outcomes from GCP research.

The IBP has served as the fundamental vehicle to meld research with education to provide the tools needed to produce improved cultivars, and is the prime focus of this section. The development of the IBP represents a bold initiative to put MB applications and IT support in the hands of breeders everywhere, regardless of professional affiliation or country infrastructure resources.

As noted earlier, the advantage of using MB approaches such as molecular markers to achieve breeding targets has been clearly established. For example, Knapp (1998) showed that theoretically

MAS can increase efficiency up to 17-fold, while Eathington et al. (2007) demonstrated >2-fold increase in genetic gain from MARS breeding schemes practised in maize, soybean and sunflower. The advantage is greatest in dealing with traits that have a low heritability, such as drought tolerance. Because MB is facilitated by the IBP, there is significant potential for impact with the IBP provided NARS and SME breeders have access to uniform field screening facilities in locations representative of targeted market regions. Current usage statistics to July 2013 are encouraging: 1300 total registered IBP users across the nine target crops; 11,726 visitors to the IBP Portal website, 23% from India; and 138 downloads of the IBP software from the iPlant site.

Nonetheless, the IBP has had little impact yet on outcomes in farmers' fields. *Ex-ante* studies to assess the potential net economic benefit of the IBP applied to wheat, sorghum, cassava, and rice improvement in specific countries have highlighted a range of possible gains due to IBP deployment. Projected increases in economic benefit to the agricultural sector vs. phenotypic selection for most crops were substantial, largely because MAS shortened the production time. At the high end was wheat in China, with a potential incremental net present value over conventional selection of $1.18 billion; at the low end is rice in Burkina Faso, with an estimated $5.8 million benefit gain. Also the use of the IBP mitigated the risk of failure and increased the probabilities of research success: for rice, 9%; for sorghum 25%; for wheat 5.5 – 15%; for cassava, 6-16%. Plant breeding is often referred to as 'a numbers game'; improving the probabilities of success by as much as 25% is an important advantage.

Part of the anticipated impact of the IBP relates to future uses of the crop-specific databases that will be populated with phenotypic and genotypic data by IBP users. Such data could be the basis for future meta-analyses that fuel gene discovery and understanding of gene function and G x E interactions. Genotypic data, particularly fingerprinting profiles of lines, coupled with phenotypic performance data of the lines in various environments, are particularly useful. As the genotyping technologies advance, sequence information on individual lines is also being obtained.

Although the original vision was for fully shared data made publically available, this is not a requirement for access to IBP. As more users from the private sector become engaged, sharing of data is likely to diminish – and in fact confidentiality of data is critically important if private sector clients are to be attracted. Although this is a departure from the original vision, this trend does not reduce the impact of the IBP *per se*, but does curtail additional value that might otherwise have been extracted from full data sharing. CRP users are expected to continue with data sharing; NARS users will also likely share data for the most part.

Demand is being created among NARS clients. The IB-MYC training is expected to generate a cadre of trained and committed IBP users, but it is too soon to use this group to assess the effectiveness of the initiative. The Review Team is satisfied through its discussions with stakeholders that the IBP has already modestly increased the use of molecular breeding in NARS and in the CGIAR, especially among lower profile crops such as chickpea.

In summary, increasing rates of adoption of MB are expected with releases of the improved IBP since this tool is a primary facilitator. Issues of IP related to the IBP are discussed in Chapter 7.

6.3. Impacts of Capacity Building and Communications

Capacity building : Trained and empowered research staff will be responsible for most of the impacts from genetics and genomics provided that lack of equipment, domestic policy issues, resource short-falls and the demands of other donors do not restrict their ability to conduct MB research. Without GCP capacity building, especially in Phase II, the ability of breeders in national programmes to utilize research products would have been limited to a few advanced breeding programmes. Impact on future national and regional breeding programmes is also resulting from the high proportion of postgraduate degree students from developing countries – provided they have been placed in adequately supported positions in national research programmes.

R4. The Review Team recommends that GCP allocate funds from its reserves to ensure that PhD and MS theses in process at the end 2014 are completed, and request that the appropriate CRPs assume responsibility for oversight of those that continue beyond that date.

In order to assess the impact of training adequately, including post-graduate training, the Review Team **suggests** that a follow up survey of those trained under GCP be conducted to determine their current placement and level of support, and the resulting information be shared with respective CRPs. Needs assessment of what would be most strategic and cost-effective kind of training is also pertinent to IBP Phase 2 also since it plans to create hubs which would host support staff providing training and everyday help to molecular breeders.

Communications and websites: The GCP has used a number of communication means for enhancing the influence and impact of its activities. Scientific papers were discussed in Chapter 3. Non-scientific media: GCP's profile in the non-scientific media is unexceptional. GCP has issued only 22 press releases during its lifetime, with the annual number of releases ranging from 1 to 7. GCP has chosen not to attempt to educate the general public on issues related to biotechnology such as genetic modification but to concentrate on highlighting its technical contributions to supporting traditional crop breeding. This profile, plus its stated position on genetically modified crops ('the GCP will not … support any projects aimed at the development of transgenic varieties'; GCP, 2005) have largely avoided adverse press reaction.

Social media: GCP's communication methods are evolving. A serious push into social media started in 2012 with the aim of driving traffic to the GCP website and blogs. The range of communications tools is impressive. GCP has used film (http://www.youtube.com/user/GCProgramme), which has 18 subscribers, and Facebook (since 2012 – see https://www.facebook.com/GCProgramme?fref=ts), which currently has 599 'likes'. GCP's Twitter account has nearly 2,000 followers. GCP has also developed podcasts (http://gcprogramme.podomatic.com/) on a range of subjects. More recently the Programme has used LinkedIn groups as a way to encourage a more professional level of interaction between scientists, and this now has the potential to take over some of the roles of the CoPs.

Webpage: The GCP webpage has played a key role in communicating with the outside world. Significant programme events have been actively broadcast on the news update section of the

webpage on a regular basis. The number of news items and updates on GCP's website since 2007 has averaged 36 per year.

6.4. Sustainability of GCP Products

The GCP has developed a large number of genetic resources (see Chapter 4). Looking forward, the major issue is sustainable maintenance of these valuable resources and their continued use, and this requires a source of continued funding. Some of the genetic resources are components of the IBP, e.g., genetic maps that show the ordering of markers across the genome, informative markers linked to crop-specific databases, and LGC Genomics KASP markers available through linkages to LGC, who owns these markers. Access to these KASP markers should be maintained by the IBP. Genome sequences and maps are mainly maintained in public databases, and stability and sustainability of these databases has generally been high. The series of white papers by GCP in 2012–2013 reviewing the status of its main products is useful, but lacks consideration of the private sector in the future deployment of GCP products. The GCP product catalogue currently lists 284 products but it should be updated through 2014 with the latest information on products. Provided it is systematically updated the catalogue will continue to be a valuable resource and an important legacy product for the next few years.

Storage, dissemination and regeneration of genomic resources: This is a major consideration when GCP sunsets. Genomic resources from minor crops developed in Phase I have already been subsumed in CRPs, stored in genebanks or discarded. In the case of the reference sets, it is preferred to have them remain as individual accessions in their appropriate genebank, since if they are designated as standalone 'reference sets' then they will attract an additional storage charge. Their sustainability depends on their continued availability, and this is most likely when entries are stored as accessions in CGIAR genebanks. Other items, such as CSSLs, mapping populations, RILs, MARS and MAGIC lines, and finished inbred lines must be maintained under good storage or regularly regenerated to retain their utility. These resources were mainly developed from CGIAR germplasm, so the CRPs stand to benefit substantially from them in their routine breeding programmes.

R5. The Review Team recommends that GCP begin discussions immediately with the crop-specific CRPs to take ownership of the most valuable of these as genetic resources for improvement of their mandated crops, and that these discussions be brought to a satisfactory close before the GCP sunsets in December 2014.

The genomic resources associated with the genes *SbMATE*, *ZmMATE*, *PSTOL1* and the QTLs Alt_{SB} and *Pup1* are of considerable value globally. Although EMBRAPA and Cornell are conducting active research on these, GCP needs to ensure that these remain in the public arena and are easily available after the GCP sunset.

BAC libraries are a special case. Their maintenance as arrays of clones is expensive and dissemination problematic. These libraries could also be maintained as DNA pools. Once good physical/contig maps and high quality genome sequences are developed, the maintenance of the BAC resources may no longer be needed. Cloned genes can usually be recovered by PCR once good quality sequences are

available – although whenever possible, maintenance of physical clones by the laboratory involved is advisable.

Maintenance of 'soft' genetic resources: Bioinformatic-type data, such as DNA and RNA sequences with annotation, and physical and genetic maps, should be deposited in appropriate data banks. Well-established databases such as GenBank could be used, as well as collaboration with iPlant. Trait maps/ QTLs and lists of informative markers for breeding should be maintained in IBP, and the Review Team **suggests** that the IBP Phase 2 proposal include a small component specifically for that purpose.

Archiving of marker information for breeding poses some specific challenges, since it is desirable to identify not only the marker and the desirable/undesirable allele, but also to catalogue the germplasm known to contain desirable alleles. The Review Team **strongly suggests** that pedigree information associated with genetic and genomic resources be retained and appropriately encoded in the databases. However, there is no uniform way to do this for haplotypes, so it may be best to store high marker density genotypes to be integrated into haplotypes as needed.

Maintenance of social capital**:** Considerable emphasis has been placed on the role of crop-specific CoPs to carry forward the momentum generated by the GCP and help ensure the impact of its deliverables. However, it is not clear that this is a realistic expectation. For sustainability, the current cassava and rice CoPs, though successful, are not the best model for the future: funded with more than $200,000 per year, these are more like research projects rather than low cost CoPs as defined and envisioned within IBP.

GCP plans to provide minimal support to CoPs to facilitate meetings, website development, etc. Communities of this sort often rely on the leadership and charisma of a few motivated individuals, and without incentives and funding it is not clear that desired effects (e.g. mentoring, promotion of IBP and MB) can continue. Maintenance of GCP's crop-specific CB projects and infrastructure investment will be most effective where GCP is able to nurture and fund the CoPs through IBP Phase 2. Therefore, the Review Team **suggests** that IBP Phase 2 provide a small amount of funding to foster the CoPs and to encourage leadership within each. The CoPs are structured around crops which fit well with the 14 user case studies that are being evaluated with the IBP, and may be the appropriate vehicle for capturing the metrics associated with IBP impact. As noted previously, some of the functions of the CoPs are gradually being taken over by social media (Facebook; LinkedIn; Twitter) grouped around specific crops, but this process will also require leadership and incentives.

The Review Team **strongly suggests** that during 2014 GCP ensures that the management of the existing CoPs is firmly embedded in the structure of the IBP; and if that is not possible because of donor priorities, the CoPs should be linked to their appropriate CRPs along with a modest incentive package for the facilitators of each. Peer-to-peer support, mentorship and helpdesks started by IBP Phase 1 should also be continued under IBP Phase 2 funding where possible.

Capacity building: There is a rich legacy of training materials that have been developed to support CB, and the Review Team **suggests** that these be shared systematically with training programmes in the leading CRPs.

Communications: The information accessible through the GCP website delivers considerable value. The website is well organized and easily navigable. As previously noted, it needs 'immortalizing' for at least the next five years. Support should be sought from the CGIAR to maintain the GCP website in its present layout and updated to December 2014, with improved searchability, especially of publications. This cost, probably less than $50,000 in total, will leverage the total investments in GCP, expected to be around $180 M at closure.

In summary, the Review Team concludes that most of the funds needed to complete existing research activities (estimated by GCP, in its 'Transition Overview Paper' of March 2013, as $0.70 million – $1.3 million in total; being updated) should come from either the IBP Phase 2 as it continues on with the RIs, or from the respective CRPs. The Team considers that it would be unrealistic to expect financial support for ongoing research activities, storage and maintenance of genomic resources from other sources.

R6. The Review Team recommends that on-going costs associated with the maintenance of the GCP website and updating on-line of publication lists and the product catalogue be budgeted through 2018 as part of the GCP sunset financial strategy.

6.5. Continuing the Integrated Breeding Platform

Of GCP's products, the IBP has the greatest potential for sustained impact and is GCP's major legacy product. The IBP has already influenced the way in which molecular breeding is practised in the CRPs and in the NARS' crop improvement programmes. Delays in the development of the IBP in its first phase have in turn delayed its impact.

A second phase of the IBP looks likely, and increasing rates of adoption of MB are expected with releases of the fully-functional version of the IBP. Phase 2 marks a change from development to deployment. To be fully effective, the IBP needs a 5-10 year horizon with stable funding, so it is critically important that it finds a suitable long-term home, possibly in a cross-cutting CRP. In the meantime, likely donor support for around 50% of its projected 5-year cost will provide a critically important funding bridge. This will permit the IBP to complete its development, establish support hubs in key regions and explore means by which it could generate income to continue its development as a cutting-edge breeding and information management tool.

The IBP is 'conceived as a vehicle for the dissemination of knowledge and technology' and has the potential to deliver significantly more impact than any other GCP product. The following sections are based on presentations and discussions with GCP staff and stakeholders, on a number of visioning documents that have been shared with the Review Team, and from responses to the 2013 stakeholder survey (Annex 10). Additional details on the future of the IBP appear in Annex 7.

Phase 2 of the IBP: Current status: A concept note has been developed by GCP (Concept Note Integrated Breeding Platform: Phase 2, October 2013) and submitted to B&MGF for funding. Towards the end of IBP Phase 1 major improvements in the efficiency of system development occurred – outsourced software development, Chado database schema, a structured way of gathering user requirements, engaging VSNi to partner in commercialization of IBP, and more

realistic targets for software and rollout plans. The new features planned for software development in Phase 2 relate mainly to pedigree management and nursery or trial creation, additional experimental designs and improved database architecture. However, the main software focus in 2014 will be on ensuring system robustness and improved user interface so it better meets the needs of field breeders. While ARI collaborators will develop algorithms for new software tools, Efficio will be responsible for inserting them smoothly into the existing system. The concept note calls for the launch of the first fully functional production version in June 2014, and the full proposal for IBP Phase 2 is under development.

Phase 2 marks a change from development to deployment. The proposal lists 'must haves' that include improvements of the IB workflow system and in promotion and awareness to create demand. The main development is in support services – for breeding support and capacity building and social networking, including CoPs. Capacity building is central to improved competence and confidence in using the IBP. Genotyping services will be continued from Phase 1, and eventually software and genotyping support will be offered for GBS and genomic selection. Plans call for a much greater effort in promotion and awareness, especially among SME seed companies. The latter are major targets for commercialization in a 'go to market' strategy that is proposed as a means of sustaining development of the IBP into the future to ensure it remains 'cutting edge'. The proposed model of commercialization involves three tiers – full price licences (SMEs); half price (CGIAR Centres; universities) and free (NARS from developing countries).

A key component of IBP Phase 2 is the concept of regional hubs housing support teams. Plans call for five in sub-Saharan Africa, four in Asia, and three in Latin America. The ideal staffing profile at each hub calls for expertise in breeding, capacity building and technical support, initially offered through a single scientist located at the hub.

There are a series of unresolved issues related to the future sustainability of the IBP. Of special concern are its maintenance as a cutting edge tool, the need to find a host for the IBP, its deployment through regional hubs, and the need for an updated and well-research business plan. The Review Team's further observations on these and related aspects are summarized in Annex 7.

Risks: As noted in the IBP Phase 2 Concept Note (p. 11), risks mainly relate to sustainability – an inability to generate, deliver, maintain and update a unique product over the next 5-10 years. This will directly affect adoption, especially by those key sectors, the SME seed companies and the CRPs. As the GCP looks beyond its closure date in 2014, it would be appropriate to structure the IBP as a tightly managed project. The Review Team considers placement of the IBP within a cross-cutting CRP as an option that should be vigorously pursued. This will allow pursuit of broader goals that could provide the length of life, flexibility and stable financial support that it needs to attract clients, maintain its cutting edge technologies and meet its goals. Sustained CGIAR funding for at least 50% of the total operating costs would hopefully be provided. A further risk lies in the 'future-proofing' of the IBP – especially in its bioinformatics ability and cutting edge analysis tools that are at stake going into the future. However, even if the IBP functions at 100% efficiency, this is not a guarantee that the platform will be adopted – inertia related to learning software and converting data to new formats may be sufficient to depress adoption rates. Finally, if data are not shared freely among

cooperating institutions and entered into common databases, this will result in reductions in the benefits arising from MB and in impacts from the IBP.

Transition plan: As a starting point, the IBP Phase 2 proposal must include a post-GCP transition plan. Input to the plan was solicited from key stakeholders at the IBP Phase 2 Brainstorming Meeting in October 2013 at Lisbon, and further development of this plan is encouraged. Analysis suggests that the transition plan should include elements addressing the process of leveraging CRPs to engage CGIAR users**,** promotion, marketing and income generation by IBP; and sustained linkages to genetic resources such as genetic maps, marker catalogues, databases, genotyping services such as LGC Genomics, and technical and breeding support. The Review Team considers it crucial that the momentum of IBP development be accelerated in the 6-month period from the review date until Phase 2 is launched. The present IBP manager is also the Director of GCP, who will have many additional tasks during the sunset period of GCP. The Review Team **strongly suggests** that when funding looks assured every effort should be made to hire a fulltime IBP project manager whose responsibilities are solely to ensure that IBP meets its development and performance deadlines.

R7. The Review Team recommends the funding of Phase 2 of the Integrated Breeding Platform.

6.6. Donor Co-financing and Visibility

Five donors provided 95% of the GCP budget, the EC (34%), B&MGF (21%), DFID (19%), World Bank (11%) and the CGIAR (10%). GCP acknowledges its donors, partners and contributors through its website. GCP has created a strong brand making it difficult to recognise individual donors easily, but future activities might try to find a way to raise the visibility of individual donors without weakening the brand image or sending mixed messages on the Programme's independence from donor influence. The EC evaluates its investment periodically. B&MGF has also conducted external reviews of its special projects, as well as tracking closely the implementation of each project. Other donors have relied on CGIAR reviews to evaluate their investments, despite the potential risk of weakening the visible link with a specific donor. There is however good donor collaboration that reduces duplication of evaluations.

7. GOVERNANCE AND MANAGEMENT

7.1. Introduction

Here the Review Team addresses the performance of the governance arrangements of the GCP, primarily the Consortium Agreement, the functioning of the Executive Board and Consortium Committee, and the oversight provided by these bodies. It also assesses the effectiveness and efficiency of fiduciary and administrative services, including the functioning of the Host Agent Agreement with CIMMYT. Management of financial and human resources, the effectiveness of the Management Team, development of the 'GCP spirit', the GCP's embrace of diversity, and its consideration of gender issues, are discussed. The future governance options of the IBP Phase 2 are considered as well, from both the long- and short-term perspectives, and the chapter concludes with an evaluation of GCP's intellectual property management and governance and risk management. Supplementary information finances can be found in Annex 8.

7.2. Effectiveness of Governance Arrangements

The Consortium Agreement. The GCP is undertaken through a Consortium comprised of 18 Consortium Members (including 9 CGIAR Centres and 9 reputed ARIs, Universities, and NARS institutions) and 4 Provisional Members. The original Consortium Agreement came into effect on 10 August 2004, and the Amended Consortium Agreement on 15 July 2009. In the Review Team's view, the Amended Agreement is comprehensive and clearly written. It provides useful details of such matters as the Consortium's basic understandings, objectives, and covenants; the term and possible termination of the Agreement; and various aspects of GCP's governance and management.

The Executive Board. GCP's governance arrangement has worked well in Phase II, due largely to the exceptional calibre, diverse expertise, and broad international experience of EB members and (successive) Chairs, and the highly professional manner in which the EB has conducted its business. The agenda for the bi-annual EB meetings (at least once per year in person) covers relevant topics; the background documentation is well prepared; and research and financial issues are discussed in depth in parallel sessions (as Board sub-committees), and then in plenary. The EB has diligently addressed hard and complex issues ranging from research to governance, and has nimbly responded to programme needs as they arise. Discussions are reportedly open and thorough (the Review Team did not have the opportunity to observe this directly). The minutes of EB meetings are comprehensive and clear, and follow-up of decisions between meetings (by the EB Chair) and at the next EB meeting, is systematic.

In establishing a small EB, the GCP has also ensured the appointment of capable and independent Board members. It has sought diversity of gender, research programme experience, and regional background. For directing and managing GCP's research programme, strategic decision making and oversight are the sole prerogative of the EB, which also has established policies for IP, data sharing, resource management (covering HR and finance), partnerships etc. Both the EB and the CC have responsibility for providing independent scientific advice on research; and the Amended Host

Agency agreement has provided a reasonable balance between the roles assigned to GCP and CIMMYT.

The governance and management survey conducted for this external review (Annex 11) shows that almost all 40 respondents agreed or strongly agreed that the EB performed its functions effectively. Its relationships with the CC and GCP Management have been reasonably effective as well. The Review Team concurs with this assessment. The EB is perceived by survey respondents and the Review Team to have done best in overseeing financial management, guiding the preparation of strategic, medium-term and transition plans, and providing strategic guidance to GCP Management. It has supported GCP operations and monitored potential conflicts of interest reasonably well; but has done less well in establishing programme-level performance criteria, monitoring risks, and providing guidance on IP matters to the CC and GCP Management.

Supplementing these positive survey data, interviews conducted by Review Team members reinforce the conclusion that in general, relationships among EB members, and with the Host Agent representatives, CC Chair and members, and GCP Director are cordial and supportive, based on mutual respect and common purpose. Hence, no major changes in the composition, functions, and processes of the EB are anticipated by its members — and none are suggested by the Review Team — before GCP's closure .

The Consortium Committee. As per the Amended Agreement, the role and membership of the CC are important. According to the governance and management survey (Annex 11), in Phase II the composition of the CC has not led to conflicts of interest; and the CC is perceived to have performed its functions reasonably effectively (though not as well as the EB). Its interactions with the EB have been good. But in providing scientific advice to the EB and GCP Director, participating in the annual/general research meetings, and communicating with Consortium Members, the CC received somewhat lower ratings, with about 20% of 40 respondents indicating some level of dissatisfaction with the CC's performance of its main functions.

Supplementing these survey results, the Review Team had the opportunity to attend the 2013 GRM meeting in Lisbon. Most CC members were active participants at this GRM; and many have led, advised, or served as team members in various GCP-funded projects, some since GCP's inception in 2004. Their contributions have often been vital to the development and delivery of many of GCP's products. At the GRM, their interest in scientific matters was impressive, as was the openness and informality of discussions, though participation of various members was rather uneven.

Oversight of GCP termination by GCP's governance bodies. In October 2013 the GCP Consortium Termination Agreement was being circulated to Consortium Members for endorsement. Its clause 6.1 stated that '… surplus Challenge Programme Funds will be directed to charitable and scientific research activities in accordance with the decision of the GCP Management Team in consultation with the Consortium Committee and the Executive Board.' This clause, delegating the Executive Board's strategic decision-making function and financial oversight authority to the GCP Management Team, was clearly inappropriate. It was also inconsistent with the Amended Consortium Agreement of 2009.

Subsequent to these discussions, the Review Team has been informed that the Transition Taskforce, now re-named the 'IBP Phase 2 Governance Taskforce', would be responsible for 'developing the governance and management strategy' for the IBP; and that its recommendations would be submitted to the EB and CC for approval. Clauses 2.2 and 2.4 of the revised (draft) Consortium Termination Agreement of December 2013 appropriately acknowledge the full authority of the EB for guiding and overseeing the 'orderly termination' of the GCP, including decisions regarding its termination date; and its clause 6.2 states that decisions of the EB (and not the CC) would determine the use of funds and other assets of GCP.

However, some inconsistencies in this Agreement still need to be addressed, e.g., clause 2.3 states that the CC has the authority to decide the 'final termination date'; and it does not recognize the role and responsibility of the EB in this important decision, which seems to be contrary to clause 2.2 of the draft Agreement. Nevertheless, the various revisions being made in the Consortium Termination Agreement demonstrate the willingness of GCP governance bodies and Management to make changes in their approach and documentation, when needed.

In 2014, the GCP Executive Board is expected to make or oversee important decisions regarding the orderly closure and/or future sustainability of current GCP activities. These decisions include: (a) the future of IBP Phase 2; (b) the possible reassignment in CIMMYT or termination of GCP staff, as per their employment contracts and CIMMYT's HR policies; (c) the disposition of intellectual property, as per relevant Agreements with various partners; and (d) the transfer of GCP's knowledge-based and physical assets, to CIMMYT and others. Some of these issues are also being considered by the recently established Closure Working Group.

Other ongoing programme-related issues relate to: (a) making suitable arrangements for sustaining GCP research activities through CRPs and other potential partners; (b) advance-programming of CGIAR/donor funds or GCP reserves beyond the expected life span of GCP; (c) decisions regarding the use of GCP funds or reserves for potential commercial benefits for private companies, rather than production of international public goods; and (d) assessment of public-private partnerships for further developing the IBP and delivering this CGIAR-funded product and related services to interested NARS, SMEs, ARIs, and other partners on a subsidized, cost-recovery, or fee-for-service basis.

Two other key issues for the EB in 2014 would be: (a) ensuring that the terms of reference, composition, and functioning of the Closure Working Group and the IBP Phase 2 Governance Taskforce are consistent with various Agreements governing the GCP; and (b) ensuring that IP and other aspects covered by the various Consortium-related Agreements and the Amended Host Agent Agreement are addressed appropriately.

The Review Team notes also that GCP's various Agreements clearly specify the respective roles and functions of the Executive Board, Consortium Committee, and GCP Management. These Agreements stipulate that the EB has final decision-making authority and full oversight responsibility for GCP strategy, policy and operations; the CC is primarily a scientific advisory body; and GCP Management is directly accountable for programme implementation solely to the EB.

In view of the recent instances of apparent misunderstandings of the respective responsibilities and decision-making authority of the EB, CC, and GCP Management, the Review Team stresses the need to ensure a clear and necessary line of demarcation between the policy and oversight functions of the EB, the advisory role of the CC, and the implementation responsibilities of GCP Management. The various Taskforces and Working Groups could be useful for discussing issues, developing options, and making recommendations to GCP's governing bodies, but the independent oversight by the Executive Board (in consultation with the CC for some aspects of governance) needs to be maintained, and the EB must retain final decision-making authority over all aspects of GCP as it moves toward closure.

To facilitate this, the Review Team **strongly suggests** that in 2014 the GCP Executive Board, Consortium Committee, and Management redouble their efforts to govern and manage GCP activities fully in accordance with the Amended Consortium Agreement of 2009, the Amended Host Agent Agreement of 2009, and the finalized Consortium Termination Agreement.

7.3. Effectiveness and Efficiency of Fiduciary and Administrative Services

The Host Agent Agreement. The GCP, as an 'unincorporated consortium' of research institutions bound together by the Consortium Agreement of 2003, has no independent legal status of its own. Since 2004, it has relied on CIMMYT, a CGIAR Centre as well as a GCP Consortium Member, as its Host Agent. Their relationship is governed by the Host Agent Agreement of 1 January 2007, amended on 1 October 2009, which defines the respective rights and obligations of GCP and CIMMYT. According to this Agreement, CIMMYT is the 'legal representative' through which GCP acts; and as the Host Agent, it assumes fiduciary responsibility for the administration of GCP.

The Review Team is satisfied that the Host Agent Agreement has adequately served its intended purpose, and could continue to do so till GCP ends. As the formal framework guiding the relationship between GCP and its Host Agent, it has enabled the two parties to navigate their potentially complicated relationship satisfactorily, with relative ease and cooperation. The Agreement's amendment in 2009 — to take into account the experience of the previous five years, as well as the governance reforms introduced by the GCP Consortium and Programme Steering Committee (PSC) in 2008 — was facilitated by the competent legal counsel available to both parties, and the pragmatic approach adopted by CIMMYT and GCP Management and their respective Boards.

CIMMYT as GCP's Host Agent. Results of the governance and management survey indicate that interactions between GCP's governance bodies and the Host Agent have been reasonably good, and their relationship has contributed to GCP's effectiveness (Annex 11). Many of the above (and other) provisions of the Amended Host Agent Agreement have been utilized — and have proven beneficial to both parties.

Matters relating to fiscal management have been addressed in a spirit of cooperation. The provision that the CIMMYT Board could formally approve the temporary provision of its own funds to GCP to tide over the shortfall, were unexpected cash flow problems to occur, has served as a 'safety net' —

which, fortunately, has not had to be used, since GCP has prudently managed its expenditures to ensure adequate reserves throughout.

At the strategic level, the main mechanism for facilitating mutual understanding has been the regular participation of the CIMMYT Director General in GCP Executive Board deliberations as an observer. This has been supplemented by periodic but ad-hoc consultation between GCP and CIMMYT staff on such operational matters such as financial and project-reporting procedures and formats, accuracy and completeness of periodic financial reports, and external and internal audits of GCP finances. Matters as the possible use of GCP reserves for sustaining its activities beyond 2014 and the specific clauses of the Consortium Termination Agreement that have implications for the Host Agent, still need to be discussed.

CIMMYT Management, based on its experience as Host Agent over the past decade, specifically expressed its concern to the Review Team that its fiduciary responsibilities seem insufficiently matched with its authority to adequately address in advance various GCP decisions with potentially-significant financial-, donor- or IP-related implications, and with potential pending or contingent liabilities for CIMMYT as the legal representative of GCP.

To address such issues explicitly and in detail, closer collaboration between GCP and CIMMYT would be beneficial to both parties. The Closure Working Group could facilitate regular consultation and action by senior GCP and CIMMYT staff (e.g. the Director of GCP, and the Finance and HE Directors and legal staff of CIMMYT).

The Review Team stresses the importance of this cooperation, and **strongly suggests** that GCP and CIMMYT (as Host Agent), guided by their respective governance bodies, intensify their Director-level collaborative planning and resolution of all current and potential Host Agent-related issues pertaining to GCP and its orderly closure in December 2014.

7.4. Effectiveness and Efficiency of Resource Use

Financial management. Since 2004, GCP has received about US$167 million from thirteen donors (Annex 8). Of this amount, about $157 million (over 94%) was collectively provided by just five donors: the EC roughly $57 million (34%); the B&MGF $34 million (21%); DFID $32 million (19%); the World Bank $18 million (11%); and the CGIAR $17 million (10%). These donors have been fairly consistent in their level of funding for GCP, though there was a big jump in EC funding in 2007 and 2009 and a notable gap in 2008. Some other donors, such as SIDA, SDC, and Pioneer have been consistent as well, though their contributions were much smaller.

GCP has managed its finances well, with expenditures below that year's income for all except two years during the period 2003-2010, and (as expected) gradually increasing expenditures in recent years to utilize accumulated reserves before the programme comes to an end. It has maintained a healthy cumulative reserve throughout, which has helped cushion occasional fluctuations in the timeliness of donor contributions during any particular year (Annex 8). A conservative investment policy, jointly determined by the EB and GCP Management, has kept the investment risks low. Prudent programme- and administrative decisions by GCP Management, effectively overseen by the

EB, have kept total research at roughly 86% and research management at about 4% of total expenditures (Annex 8).

Indirect costs, for financial and administrative support provided by CIMMYT, have been in accordance with the Amended Host Agent Agreement, and have totalled about US$7.9 million for the 12-year period. The formula used for determining these costs has been 18% of direct costs, 15% on B&MGF-funded projects, and 4% on pass-through funds administered by CIMMYT. Expenditures on the two governance bodies (PSC/CC and EB) have been reasonable as well, respectively totalling US$0.26 million and US$0.49 million for the 12 years (Annex 8). The annual financial statements for CIMMYT, which include a report by its independent external auditors and a special supplemental schedule for the GCP, as well as the audits of the GCP risk management system undertaken by the CGIAR's Internal Audit Unit in 2007 and 2010, have not noted any adverse comments regarding financial management of GCP funds.

The Review Team did not have the resources or mandate to undertake a detailed assessment of financial management at GCP, its Host Agent, or the various projects funded by GCP (and undertaken by a variety of partners, each with its own financial- and risk management system). However, in light of: (a) the satisfactory annual financial reports of the Host Agent responsible for fiduciary management of GCP activities; (b) the reports of financial experts who have been responsible for the external and internal audits of CIMMYT and GCP; and (c) the results of the governance and management survey that indicate a high level of satisfaction with GCP's financial management, budget approval process and expenditure control, the GCP's EB and Management, as well as CIMMYT's corporate, financial and administrative management of the financial resources provided to GCP has been prudent.

Human resources management. In November 2013, GCP had 22 staff members, 19 of whom were based at GCP headquarters at CIMMYT (in Mexico). CIMMYT has provided all the required human resource services; has broadly adhered to the provisions of the Amended Host Agent Agreement regarding the employment and service conditions of GCP staff; and has followed the applicable human resources policies and guidelines of CIMMYT, as well as relevant Mexican laws applicable to Mexican nationals employed by CIMMYT on behalf of GCP.

CIMMYT HR policies and Mexican laws are also expected to be followed for determining severance payments from GCP reserve fund to Mexican nationals who might be terminated when the programme ends. For reducing the risk of losing essential staff prior to programme closure, GCP and CIMMYT have agreed upon a graduated retention-bonus scheme that rewards the continued employment of motivated and productive IRS staff (and possibly NRS as well) until GCP closure. The Review Team considers these various measures reasonable and prudent, and in accordance with the Amended Host Agent Agreement.

Management Team effectiveness. The overall results of the stakeholder survey and the governance and management survey are generally very positive (Annex 11); and the GCP Management Team receives high scores for most functions, including financial management, strategic- and medium-term planning, work planning and budgeting, proposing policies to the EB for project selection, compliance with CGIAR's administrative and other requirements, and public awareness and

communications activities. It also scores highly on ensuring science quality, compliance with conflict of interest policies of partner institutions, and risk management. The areas in which it does not score as well are receiving and documenting information related to IP, project management, and proposing monitoring, evaluation, and impact assessment policies for Board consideration and implementing approved policies.

Since 2005 the GCP Director has guided and managed the MT through most of GCP Phase I, the programme and organizational reforms of 2008, the renewed focus on products and partnerships in Phase II, and the current transition towards anticipated closure of the programme in a very competent manner. The Director and other members of the MT have worked with partners in a large number of institutions, both within the CGIAR and outside it, and have succeeded in generating a shared 'GCP spirit' of partnership and collaboration that has come to signify GCP's 'consortium governance' approach.

In addition, the MT has ensured diversity of partnerships and researchers, and has effectively used a combination of full- and part-time staff in leadership positions. It has worked with staff and consultants located at GCP headquarters as well as at partner institutions; and it has made good use of resources available in developing as well as developed country institutions, including the private sector, universities, and ARIs, as noted in previous Chapters.

Development of the GCP spirit. In the Review Team's view, the GCP Director, staff, and their scientific partners are clearly devoted to the goals of the Programme. Together, they have achieved much, as noted elsewhere in this report; and they have developed a commendable level of mutual respect and partnership. A spirit of collegiality and learning was palpable at the GRM in Lisbon. This is borne out by the stakeholder survey undertaken for this external review (Annex 10). The Review Team understands from GRM participants that this 'GCP spirit' and the GRM's focus on scientific discourse rather than project plans and budgets is what they will miss most when the Programme closes; and it is this collaborative spirit and science-orientation that they hope can be replicated in the CRPs and other programmes through which GCP activities could be sustained.

The GCP Management has successfully introduced a 'new' process-oriented, participative, partnership approach from its inception in 2004. It has sought to develop a science-focused spirit of collegiality and collaboration among disparate partners and researchers; and after the inevitable difficulties of the initial start-up phase, it has maintained and even intensified this approach to managing the programme and delivering its outputs.

Embracing diversity of internal partners. GCP's partnership approach, that seeks to optimize synergies from a diversity of external partners, is also reflected in the way GCP has organized itself internally. This is apparent from the way it has constituted its governance and management bodies, appointed its internal management team, and selected its product delivery coordinators (PDCs) for GCP-funded research projects. The selection of PDCs is primarily based on their suitability for the position; but the diversity of their institutional affiliation is notable Tables 7.1 and 7.2). This embrace of internal diversity, which has presumably contributed to the effectiveness of external partnerships and the collaboration have become major features of the 'GCP approach'.

Table 7.1: Institutional affiliations of GCP governance and management bodies (2010)

Institutional Affiliation	**Consortium Committee** (CC)	**Executive Board** (EB)	**IPAC** (of the EB)	**SiMAC** (of the IBP)	**User Cmte.** (of the IBP)
CGIAR Center	9	-	-	1	5
ARI (Institute)	4	2	1	-	1
ARI (University)	1	3	1	1	2
NARS (Institutes, Univs., and Regional Assoc.)	4	1	1	1	1
Private Sector	-	1	2	9	1
GCP (ex-officio)		-	-	1	1
Total	**18**	**7**	**5**	**13**	**11**

Table 7.2: Institutional affiliations of GCP research leaders and coordinators (2010)

Institutional Affiliation	**Sub-Program Leaders** (SPLs)	**Product Delivery Coordinators** (PDCs)	**PDCs** (as % of total PDCs)	**Principal Investigators** (PIs) (project leaders)	**PIs** (as % of total PIs)
CGIAR Center	1	1	14%	30	29%
ARI (Institute)	1	2	29%	13	13%
ARI (University)	1	3	43%	17	17%
NARS (Institutes, Univs., and Regional Assoc.)	-	1	14%	29	28%
Private Sector	-	-	-	5	5%
GCP (ex-officio)	3	-	-	8	8%
Total	**6**	**7**	**100%**	**102**	**100%**

***Gender*.** The consideration of the role of women in smallholder agriculture is a challenge for a programme like GCP. Many of the technologies are several complicated steps and some years from uptake, so assessing likely impact pathways is already difficult without looking at specific sub-sets of beneficiaries.

Gender representation among researchers, grant winners and investigators reflects the (inadequate) proportion of women in science as a whole, especially in developing countries. Only 16% of PIs in Phase II of GCP were women (21 of 128). The picture is little better for participants in the IBP-MYC where only 21% of students were women. There was an opportunity to collect information on gender of those receiving training and post-graduate support, which was not taken. Future research efforts on this scale should actively seek to redress this imbalance to encouraging more women to lead and apply for grants, seeking individuals to champion the cause of women in science and designing opportunities for women scientists to share their experiences as an example to future generations.

GCP has begun to demonstrate that useful impact hypotheses can be constructed for upstream research, even to the point of suggesting areas with a greater likelihood of gender effects. The Review Team therefore **strongly suggests** that the design of future projects similar to the GCP systematically include issues like gender equality as a key criterion in design and activity selection.

7.5. Future Governance of IBP Phase 2

The IBP is a work-in-progress. The Review Team's views on the technical aspects of the IBP are given elsewhere in this report (including Annex 7). It is clear that further developing and effectively delivering the IBP will take a few years and the GCP needs to consider various funding and governance options that would enable potential clients to maximize their benefits from the IBP.

The Review Team's mandate and resources did not permit a detailed assessment of various possibilities for funding and sustaining IBP after 2014. The Review Team is concerned that the GCP seems not to have intensively pursued some longer-term strategic possibilities for IBP, and has instead focused on more immediate needs. As result, at the EB meeting in November 2013, the emphasis was on the 5-year project proposal for IBP Phase 2 and on the criteria for selecting a host agent. The possibility of integrating the IBP with one of the CRPs (soon preparing their 2nd phase research proposals) in due course did not appear to have been sufficiently addressed at the meeting. Some thoughts on possible governance of IBP Phase 2 are presented in Annex 7 for further consideration by GCP's EB and Management.

R8. The Review Team recommends that in early 2014 the GCP Executive Board and Management assess both long- and short-term options for governance and hosting of IBP Phase 2, prepare business plans for these options, and in consultation with interested parties (the CC, IBP partners, other stakeholders, the Consortium Board, and various potential donors) pro-actively pursue a suitable long-term option (such as a new cross-cutting CRP), while also deciding on (possibly-short term) governance arrangements for IBP Phase 2 that would take effect immediately upon GCP closure.

7.6. Management of Intellectual Property Rights

The basis for intellectual property (IP) management in the GCP is outlined in the Amended Consortium Agreement (2009). Background IP associated with the providers of any product is honoured, though Consortium members have a royalty-free licence to use background IP for GCP activities other than commercialization.

The protection of products generated within the GCP by individual Consortium members has been largely covered by the Humanitarian License clause whereby each Consortium member agrees not to assert IP rights and grants royalty-free licenses of GCP IP 'to persons throughout the world' solely for subsistence use. Agreements clearly state that the resource poor of the world are the intended beneficiaries. GCP has the right to take out IP protection on its own products where such protection is judged necessary in order to keep a GCP product as an international public good accessible by its intended beneficiaries. The Review Team notes there is a patent on the Al tolerance gene *SbMATE* (Kochian et al., Patent No.: (45): US 7,582,809 B2 Sep. 1, 2009 (54)) assigned to USDA and EMBRAPA), but is unaware of others cases where this has occurred. As an additional step in public disclosure of its discoveries, the GCP is committed to publishing all non-confidential data in public databases and making all germplasm generated by GCP funds freely available subject to provisions of Material Transfer Agreements compliant with FAO treaties.

Annual reports of possible GCP IP have been required by collaborating institutions, and these are considered by the EB after advice from the IP Advisory Committee (IPAC). The IPAC is chaired by the GCP Legal Advisor and has four additional members. It was formed by the EB to advise it on strategic IP matters and specific IP issues. The Review Team was unable to access minutes from IPAC meetings and assumes that it is relatively inactive and meets on an as-needed basis. In addition there is an IP Help desk on the IBP portal that receives 15-22 visitors per month. Since there has been no protected IP generated by GCP's work to date, there has been no call on the services of IPAC.

There are current IP questions facing the GCP. The largest of these are restrictions imposed by India, China and in some cases Brazil on the free exchange of GCP-generated germplasm – a general issue that must be faced by the CRPs also. A further issue may be the IP rights of private seed companies not party to the CC agreement where they have added value to the product by subjecting them to proprietary procedures during their development. Further IP questions may arise if private sector providers contribute software during the development of the IBP. IP issues that may affect users of the IBP have been anticipated by provision of an IP and policy module that offers support on IP rights and freedom to operate in the use of biotech products and procedures. Finally, as GCP closes, its IP policy provides that the entity that develops the intellectual asset is entitled to IP rights on that asset. Furthermore, IP protection under GCP's humanitarian provision does not apply to discoveries made on GCP germplasm after GCP ends. However, if these situations do not arise, any IP rights on GCP products will pass to CIMMYT as GCP's designated agent unless Consortium members agree to pass the IP rights to a successor organisation or programme such as a CRP.

The IP Advisory Committee. The Executive Board is advised by an external, independent, 5-member Intellectual Property Advisory Committee (IPAC) of senior IP experts drawn from the private sector, ARIs, NARS, and CSOs. The Review Team had neither the resources nor the mandate to examine how effectively the Amended Consortium Agreement's IP provisions have been followed by Consortium Members and GCP-funded projects. However, the governance and management survey shows that over 30% of respondents are dissatisfied with the EB's level of guidance on IP-related matters (Annex 11).

With GCP's anticipated closure in December 2014 (or perhaps December 2015), and to avoid inadvertent omissions in dealing with potentially far-reaching IP matters relating to current activities and the future sustainability of GCP products (including the IBP), the Review Team believes it would be appropriate for the EB and GCP Management to give high priority to IP-related issues in the next two years as GCP draws to a close. Some of these issues might relate to maintaining IP protection in order to ensure that specific products remain in the public arena, accessible by all. For this, advice from IP experts on the IPAC could be very useful, as discussed in Section 5.5.

R9. Review Team recommends that the EB request its IP Advisory Committee to regularly provide specific advice on IP-related risks and potential liabilities as GCP moves toward closure in December 2014, and that the EB systematically discuss these in 2014 and suitably advise GCP Management.

7.7. GCP and Risk Management

GCP has taken its risks seriously. There have been two external audits of GCPs' internal risk management system (IAU, 2007 and 2010), and risks have been regularly reviewed by the EB with evidence of follow-up. The ambition, scale, scope and complexity of science associated with GCP mean that there were many potential risks that the Programme might not achieve its aims. The Review Team considers the risk audit process as appropriately comprehensive, and notes that it has been subjected to regular review – important in such a large and complex Programme. However that despite these risks, none of the GCP log frame formats discuss risks and assumptions. Some risks that could de-rail a time-bound stand-alone programme such as the GCP have been well managed. Notably, staff motivation, turnover and skill erosion have been addressed by management, and the level of risk has actually declined during programme implementation. The risk of early departure of key GCP staff as the programme draws to an end has been mitigated by an active retention policy linked to bonuses.

The nature of risks changed between 2007 and 2010. The most recent audit identified 49 'major' risks. Of these, there were 14 where the risk associated with at least one variable was considered 'high'. For example, since 2010, the EB and the Transition Taskforce have pro-actively sought to mitigate risks of non-sustainability or non-uptake of GCP products and impact following transfer of activities to relevant CRPs, e.g., adoption of IBP services. Another risk, although downgraded in 2010, was the inability to evaluate GCP long-term achievements.

In the closing years of the programme, a systematic effort to address outstanding risks can be seen; for example the creation of a Taskforce on IBP governance and the Closure Working Group. Indeed, this independent external review, sought by the GCP (its EB and MT, in consultation with the CC) is in itself an effort to identify and manage Programme risks during the limited time remaining before programme closure in 2014.

R10. The Review Team recommends that GCP give high priority to 'Risk management' on the agenda of the EB and MT as they respectively oversee and manage Programme closure and the transition of GCP activities to the CRPs and IBP Phase 2 governance bodies

8. OVERALL ACHIEVEMENTS AND PERFORMANCE

8.1. Introduction

Here the Review Team considers the overall assessment of GCP performance in Phases I and II, evaluating first the outcomes of Sub-programmes and themes from both phases and then the outcomes of the crop RIs developed in Phase II. Our assessment is based on Review Team findings drawn from its review of GCP documents, reports of previous reviews, interviews and surveys of stakeholders, and GCP staff's own assessment of programme performance. Our intention is to provide a high level overview rather than repeat specific information presented in Chapters 2-7. A summary of the Review Team's overall assessment of the GCP's performance is presented in Annex 9.

In generating its achievements, GCP was confronted with the challenge of working with the diverse approaches and institutional cultures of partners that had come together to address a common problem. It sought to generate a coherent research programme rather than simply finance a portfolio of interesting but disparate research. Partnerships were fostered that spanned the whole spectrum of stakeholder institutions and their cultures, from ARIs to African and Asian NARS. These partnerships remain one of the key accomplishments of the GCP. Partnerships at the project level have been the glue that has held the GCP research programme together, even during periods when turnover of staff in GCP could have led to significant discontinuities. A number of these partnerships will continue as a significant GCP legacy into the future, improving both scientific standards and research relevance across the board.

A major challenge that both united and frustrated some partners was the choice of drought tolerance as the trait for which GCP sought to establish 'proof of concept' of the practical value of comparative genomics. While undoubtedly of paramount importance, the trait has a long history of being difficult to improve, and gains in true tolerance using conventional means have been modest in most crops. Fortunately GCP showed commendable flexibility in its approach, and was able to take advantage of opportunities to improve other traits, disease resistance and tolerance to acidic and low P soils, status to make some impressive discoveries and genetic gains. A willingness to modify selection methodologies to include genomic selection within the context of schemes such as MARS will be an important step in improving drought tolerance using marker-assisted selection (MAS). The wider use of this approach is underway, and it has already been adopted in crops such as maize. The Review Team believes that this will prove to be the most successful of MAS methods for drought tolerance tested to date.

The organization of GCP has been largely virtual, with a small headquarters staff coordinating and managing research activities among organizations that differed widely in their degree of expertise, structure and even accountability. Good communications within the GCP at all levels have been crucial to its success. Capacity building has resulted in a trained cadre of research staff in collaborating national programmes, and has resulted in improved field phenotyping facilities at a number of African sites and better understanding of MAS applications and their implementation.

Key challenges emerging have related to freedom of information and germplasm exchange and, except for a few notable instances, GCP has been remarkably successful in both of these areas.

A key change between Phase I and II was a shift away from competitive funding of projects. It allowed GCP to make more progress in specific areas but at a cost in research efficiency and governance. This is an important lesson for CRPs which are tending to follow the grant model at a time when donors would like to see competition for research funds. The Review Team **strongly suggests** that a significant proportion of the research funds (at least 20%) should be available for competitive bidding.

After Phase I, governance of GCP transitioned from a relatively ineffective PSC that was constrained by its large size and inherent conflict of interests to a smaller and more focused EB. A move at the same time from a part-time Management Team to a full-time team of theme managers increased the effectiveness of research management. Accountability and efficiency have also been increased by the concomitant change in emphasis in the Programme from discovery to product delivery, and the appointment of a Product Delivery Manager. He has been well supported by ten part-time Product Delivery Coordinators with improvement expertise in specific crops, and by the development of a product catalogue. The GCP scientific community was overwhelmingly in agreement with this change in orientation. This is despite the narrowing of the number of crops addressed from 18 to 9.

In the process of undertaking the GCP, some challenges have developed and remain. During Phase I the attempt to conduct complex field-based research documenting genetic variability and associating it with markers in more than 20 crops in the reference set studies was only partly successful because of errors, staff turnover, lack of uniform protocols, inadequate phenotyping, and inaccurate genotyping. Much was learned about the needs for outsourcing of genotyping, protocols, phenotyping facilities and phenotyping skills. The second major challenge has been the ten year life of GCP, meaning that instead of building on the successes of Phase II, the EB and GCP Management have had to focus on an orderly ending to the Programme and to develop plans to transfer genetic, and genomic information, partnership and capacity building assets to successors, mainly the CRPs.

A third challenge has been the development of the IBP, the major legacy product of the GCP, and plans for its sustained operation, adoption and maintenance for at least five years after GCP closure. The proviso however is that investments continue to be made in keeping the tools available to breeders through ongoing version updates that reflect applications of proven value. For example, future capabilities would be expected to include data management capabilities to handle the volumes of data arising from remote sensing and genomic selection or other data intensive applications of phenotyping and marker-assisted selection. The development process of the IBP has highlighted weaknesses in the design and management of complex information management systems that aid product-oriented molecular breeding in an array of crops. It has also shown a clear need for product specifications, the limitations of software development by collaboration, and the clear need for end user involvement at all stages of software development. These and the development of reliable indicators of success could have prevented some of the loss of credibility that has accompanied premature rollouts of this important product. Phase 2 of the IBP is necessary, and is looking increasingly likely, but many decisions regarding hosting, support hub locations, and

capacity development remain, and some of these would show results only in the post GCP period. In light of IBP's potential for generating a continuing stream of significant benefits, the Review Team **strongly supports** the full development and deployment of a robust and well-tested version of this strategically important product in 2014.

8.2. Achievements of the Sub-programmes and Themes

In the following assessment, the Review Team considers Sub-programme 1 as a separate entity since it existed only in Phase I (Table 2.1). The other Sub-programmes are considered across Phases I and II.

Sub-programme 1(SP1): Genetic diversity of global genetic resources

During Phase I, GCP established reference sets of germplasm for 21 crops, and these 300 or so entries were considered to represent 80-90% of the genetic variation in each of the species. These were phenotyped reasonably extensively for disease and also for drought tolerance. Phenotyping was of variable quality, adaptation was improved when entries were divided into maturity groups, and genotyping in some cases had to be repeated through a single laboratory. Effectiveness was therefore less than anticipated. A number of QTL associated with disease and/or drought tolerance were identified and several QTL located in rice appear to have large effects on yield under drought. No genes associated with drought tolerance have been identified through these studies, though several putative identifications have been made. Current availability of seed of some entries and some field datasets may be in doubt, and future storage and use of reference sets in some crops is uncertain.

However, these studies have led to a considerable increase in interest in genetic resources, minicore collections and association mapping within the sets themselves. The EPMR (2008) considered that SP1 was an essential component of the GCP research programme, but did not elaborate in detail on the products *per se*. With the benefit of an additional 5 years of research on the reference sets, the Review Team expresses some disappointment at the lack of tagged genes and other genetic information on drought tolerance emerging from SP1. Some of the issues that led to slow progress and repeated attempts to genotype and phenotype the reference sets should have been anticipated and their effects mitigated. However, as noted by the EPMR (2008), this degree of documentation of genetic diversity linked to annotated markers would not have occurred without the GCP's commitment to working with diverse genotypes that by definition are poorly adapted and often low yielding. Achievement is therefore rated as **satisfactory**.

Research Theme 1: Comparative and Applied Genomics

The most significant accomplishments under this Theme and its predecessor SP2 have been:

- Genetic stocks: Development of breeding resources that contain new combinations of genes in a structured architecture that provides markers that can be used to transfer traits of interest. The MAGIC, NAM and TILLING lines fall this category, as do sets of RILs, synthetics and CSSLs. These breeding resources will deliver added value over the next 5 years.
- Genomic resources: Development of sets of informative SSR, DArT and SNP markers have provided a means for the efficient manipulation of drought adaptive traits. Marker sets are

gradually being converted to SNP platforms and thence to the KASP platform of LGC Genomics. Linkage maps now exist for all Phase I crops, and physical maps for several. Draft genomes for chickpea and pigeon pea have been produced. These are significant accomplishments.

- Informative markers: Comparative studies in rice, wheat and maize have identified common QTL and informative markers for drought tolerance (e.g. for kernel set) and disease, but can only be used in a predictive sense for breeding when established in individual crops. Linked markers for the QTLs containing *ZmMATE1* (Al tolerance maize), Alt_{SB}, (Al tolerance, sorghum), *Saltol* (salt tolerance; rice), *Pup1*(low P tolerance, rice) have been verified. Linked markers to a QTL hotspot in chickpea have been used to transfer heat and drought tolerance via changed rooting characteristics. Other markers have been identified for disease resistances, Striga tolerance, and sterility.
- Cloned genes: Alt_{SB}, *ZmMATE1*, the ortholog of Alt_{SB}, and *Pup1* genes have all been cloned, and precise and reliable gene-linked markers have been identified.

The Review Team found these accomplishments impressive and rated them as **highly satisfactory**, but noted that there is little published information on the quality of the markers or their efficacy in the field.

Research Theme 2: Integrated crop breeding

The main goal has been to demonstrate how MB can be integrated into existing crop improvement programmes in developing countries, and this has been successfully accomplished in all RIs. It forms the heart of the IBP, and the MARS breeding scheme has been commonly used in a number of crops.

It has resulted in some early successes – e.g., combining South American and African cassava to improve cooking quality and disease resistance in Nigeria; the development of four CMD and CBSD resistant cassava varieties for Tanzania; four upland rice varieties tolerant of low P released in Indonesia, and the low P tolerance trait introgressed into IR64 and IR74; blast resistance transferred to upland rice for India; drought tolerant beans released in Nicaragua; and six hybrids identified with improved grey leaf spot resistance for Kenya.

The GCP focused integrated plant breeding resources on quite difficult problems. The Review Team believes that integrated breeding has increased the efficiency of backcrossing, for example, sharply reducing the linkage drag associated with transfer of unwanted DNA. It is anticipated that many more products like these will be delivered over the next 5 years. It rates the accomplishments under this theme as **highly satisfactory**.

Research Theme 3: Crop Information Systems

In Phase I the focus was on development of informatics tools, a LIMS system, a central registry for data, a database for markers and a breeding simulation tool. In Phase II the IBP was developed to link these pieces together to facilitate a logical flow of information in a typical breeding programme. The system comprises the crop information system for breeding programmes, and has developed electronic data recording systems for direct uploads, complete with bar coding capability. Modules

were developed that managed pedigrees in crosses, developed field books and labels, and managed and analysed field data both within and across environments. Genotypic data received special attention, so that it could be combined to generate a selection index summarizing all data for a specific genotype. The system has enabled the efficient utilization of genotypic and phenotypic information during selection, though it can be used with phenotypic data alone – offering flexibility to breeders.

Phase 2 of the IBP is in preparation and represents an opportunity to correct a number of the problems encountered in Phase 1, discussed earlier. It is clear that some aspects of software development is best left to the professionals, and that GCP staff instead need to focus on writing product specifications and building capacity to use the product when it is fully functional and ready for its launch. The Review Team considers the IBP to be a very important product, yet the progress made by GCP in its development and launch has been somewhat disappointing. Given the expectations involved, and the challenges of developing a package of procedures by a diverse group of scientists, the achievements in Crop Information Systems are rated as **satisfactory**. The strategic importance of the IBP and its potential for impact are high, and the GCP has been bold in creating the vision of an integrated work platform for molecular breeding and taking the necessary steps to implement it. There are clearly important lessons to be learned from GCP's experience with the IBP for those who aspire to assemble similar software packages in the future.

Research Theme 4: Capacity Building

Capacity building has focused mainly on training of NARS, the supply of support services, the improvement of field phenotyping facilities, partnerships and communities of practice. The series of activities, all essential to the sustained impact of the GCP and the achievements have been discussed in detail in earlier Chapters.

The key accomplishments include significant training resources, training events and supervision of degree students. Training has changed from being generic in nature in Phase I to capacity building directly linked to skills needed in a specific project in Phase II. Trained staff are a key legacy and 'training by doing' (the IB-MYC is the largest of such endeavours) has increased impact during Phase II. The provision of services, a growing emphasis in GCP, has been excellent, and include Genotyping Support Service, Phenotyping and Protocols service and IP and Policy service. The GCP has invested significantly in improving phenotyping (22 sites in seven countries in sub-Saharan Africa) although this started late. Training of experiment station managers has already had impact on trial quality. These truly strategic investments should have been made perhaps five years earlier.

Capacity has also been built through partnerships a very strong feature of the GCP. Six functional CoPs focused around specific crops are one example of partnerships that have progressed to exchanges of ideas and mentoring. However, other CoPs have foundered because of lack of dynamic leadership or of a common theme uniting scientists, and it is unclear how well any of these will function without continuing cash injections. Good communications, both internal (responsiveness of GCP staff, GRM) and external (e.g. remarkable publication record, well organized websites), have been a characteristic of the GCP.

The Review Team notes that despite the lack of quantitative measures of effectiveness in capacity building and some questions around its efficiency, it has been widely appreciated by stakeholders, and rates it as **satisfactory to highly satisfactory**. Ensuring access to the GCP website after the programme terminates is an important issue, since significant parts of GCP's information legacy and institutional history are contained on the site.

Research Theme 5: Product Delivery

This cuts across the other themes, in an attempt to ensure that research products have maximum impact and target client groups are properly served. It has developed a product delivery plan for core projects and products, and each plan is monitored by one or more PDCs who report to the Product Development Manager. A key component is the development, maintenance and updating of the on-line searchable product catalogue, currently containing 254 listed items along with a description of the product and its uses and access information. The development of a business plan for the IBP is a further responsibility under this Theme. Product orientation in Phase II was highly appropriate although most products will not be used directly by resource-poor farmers, but mainly by plant breeders and geneticists. The GCP's definition of a product is perhaps too broad, and a careful prioritization of the contents of the product catalogue would help identify the top 20 items that merit special attention. Nonetheless, the Review Team rates the accomplishments in Product Delivery as **satisfactory to highly satisfactory.**

Overall assessments of achievements of Research Themes

Progress towards the overall goal of unlocking genetic diversity and providing the molecular tools to exploit it without introducing unwanted genetic variation has been **highly satisfactory**. The impact of this new variability on crop productivity and stability has yet to be fully assessed, and the noted defects in M&E will make this task difficult. An excellent start has been made – progress that would not have been possible in most crops without the GCP.

8.3. Achievements of the Crop Research Initiatives

Research Initiative 1: Cassava

This RI has expanded its initial reference set to include more variation from Africa and South America, and is currently evaluating it in a series of contrasting environments. A marker set of 1740 SNPs converted to the KASP platform and associated with this reference set is now available. Predictive markers for CMD resistance for Africa are also available and informative markers for drought tolerance in Latin America have been identified. A MARS breeding programme for drought tolerance is currently underway. One CMD-resistant variety has been released in Nigeria, and four with CMD and brown streak resistance released in Tanzania. These achievements are substantial and **highly satisfactory**. The African leadership has strength and it is encouraged to ensure that the varieties get into the hands of farmers. A greater degree of involvement of IITA in this RI may be required if it is to have broad impact in Africa.

Research Initiative 2: Legumes (beans, groundnut, cowpeas and chickpeas)

Beans: A validated reference set representing the IITA and CIAT gene bank diversity has been developed, accompanied by a validated SSR kit. A DArT marker array is also available, as are 1497 KASPar SNP markers for trait tagging. Informative markers linked to storage insect resistance and virus resistance have been identified, and drought tolerant lines selected. A drought tolerant variety, INTA Fuerte Sequía, has been released in Nicaragua.

Groundnuts: A germplasm reference set has been developed based on ICRISAT's genebank accessions, and groundnut amphiploid synthetics and CSSLs are available as breeding resources. The first genetic map has been developed, and informative SSR, SNP and DArT markers are available for breeding. Molecular breeding activities have yet to be developed, and progress in MB of groundnuts appears to be lagging behind that of other crops.

Cowpeas: A validated reference set based on collections held in the IITA genebank has been developed. MAGIC populations will provide useful new combinations for breeders, and RILs suited to studies of abiotic and biotic stress resistances have been developed. A total of 1122 KASPar SNP markers and a physical map are available for breeding. Markers have been identified for Fusarium resistance, heat tolerance and Striga resistance. A MARS breeding programme for drought tolerance is being managed in West Africa.

Chickpeas: A validated reference set and a MAGIC intercrossing population have been developed. A total of 2068 SNP markers converted to the KASPar platform are available for genotyping. Markers linked to the 'QTL hotspot' are available for improving root-related traits, and have been used to introgress these traits into shallow rooting and drought susceptible lines. The first draft genome has been published, and a MARS breeding programme for drought tolerance has been established.

Considerable progress has been made in legumes, supported by the TL1 Project. An additional outcome has been the publishing of the first draft genome of pigeon pea. These crops are often considered minor, so these genetic and genomic resources would not have been developed in this time frame without the intervention of GCP. Breeding programmes in each are now well positioned to use MB routinely in crop improvement. The Review Team acknowledges these very significant achievements, knowing that there are few alternative suppliers of this type of genetic information, and none that could have generated these products at this stage of crop improvement. Progress is rated as **highly satisfactory** in bean, cowpea and chickpea, and **satisfactory** in groundnut.

Research Initiative 3: Maize

A validated maize germplasm reference set (plus SSR markers) representing CIMMYT's Gene Bank diversity has been phenotyped, and QTLs for drought tolerance and leaf blight resistance identified and validated from sets of RILs. A total of 1250 SNPs have been converted to the KASPar platform. QTL maps for maize diseases (GLS, northern and southern leaf blight) have been generated and SNP markers for downy mildew resistance identified. Grey Leaf Spot and MSV resistant hybrids have been developed in Kenya. No evidence was provided to indicate how these genomic and genetic resources were currently being utilized by large African breeding programmes such as those

operated by CIMMYT or the private sector. A MARS breeding scheme for drought tolerance in maize using sources of tolerance from Africa is underway in Asia, and is being converted to a genomic selection scheme since the trait in controlled by a number of small-effect QTL. National programmes and CIMMYT value this programme highly. The Review Team notes the importance of evaluations of genomic selection, and rates progress as **satisfactory**.

Research Initiative 4: Rice

A reference set has been identified representing the diversity in IRRI's genebank and has been phenotyped. MAGIC populations have been generated in both *indica* and *japonica* gene pools, while CSSLs involving African rice are available to increase drought tolerance in Asian gene pools. NAM populations have also been established in Africa and at CIAT to increase cross-species diversity, and 2015 strategic SNPs have been converted to the KASP platform for use in selection. A series of informative markers have been identified – for *Saltol*, for bacterial blight resistance and for sterility systems related to hybrid generation. A MARS breeding programme is underway for drought tolerance in West Africa. A drought tolerant rice hybrid has been released in China, a salt tolerant variety in Myanmar and four varieties with increased P uptake efficiency (*Pup1*) in Indonesia. Advanced lines carrying blast resistance for upland areas and *Saltol* for Bangladesh have been generated. The Review Team regards these as **highly satisfactory** outcomes from GCP-supported molecular breeding.

Research Initiative 5: Sorghum

A validated germplasm reference set and an SSR marker kit have been identified and the reference set genotyped. A MAGIC population has been established, and a NAM population developed to introduce stress tolerant alleles into elite germplasm. RILs for Al tolerance have been created and male sterile elite lines of Mali sorghum generated to facilitate hybrid production. Among genomic resources are 1503 SNPs converted to KASPar markers. Gene specific markers for Alt_{SB} have been made available, and elite breeding lines carrying this gene have are being field tested. A MARS breeding programme for drought tolerance has been established in West Africa. The Review Team finds these outcomes **highly satisfactory** in a crop that has been too often overlooked in recent years.

Research Initiative 6: Wheat

A validated germplasm reference set representing diversity in bread wheat in the CIMMYT genebank, and a second set representing emmer wheats have been identified and phenotyping is continuing. Synthetic wheats (*T. dococcum /Ae. tauschii*) have been formed and RILs for drought traits have been generated from these crosses. A total of 2714 SNP KASPar strategic markers is available to breeders, and some of these can identify QTLs for yield, and drought adaptive and agronomic traits in CIMMYT and Chinese elite lines. Drought phenotyping sites have been developed, and a MARS breeding project for drought tolerance has been established in India and China that will continue through 2014. The Review Team is impressed by the level of activity in the wheat RI and with its leadership and mentoring activities, and finds progress to be **highly satisfactory**.

Research Initiative 7: Comparative genomics

RILs have been established between a lowland upland Indonesian rice to allow efficient introgression of *Pup1* to improve low P tolerance. NILs for introgression of Alt_{SB} (sorghum) and *ZmMATE1* (maize) for Al tolerance have been generated and are being tested. Cloning of Alt_{SB}, *ZmMATE1* and *Pup1* has taken place and BAC libraries generated for each of the cloned genes. Gene specific markers and gene-linked markers for *ZmMATE1* (maize) and *Pup1* (rice) have been developed. *Pup1* has been introgressed into IR64 and IR74 rice mega-varieties. The Review Team is very impressed by the progress made in identifying key genes that are effective across these three species for tolerance to low P and Al, but notes lack of progress in genes related to drought tolerance. Progress is nevertheless assessed as **highly satisfactory**.

Achievements across Research Initiatives

All of the crop-based initiatives have developed reference sets and have evaluated their performance in a number of environments. Most have created carefully structured crosses with an exciting set of new recombinations using MAGIC crossing plans, with accompanying marker information. All have developed validated sets of markers, associated with those reference sets, and SNP sets have been converted to the KASPar markers in numbers that range from 1122 in cowpeas up to 2714 in wheat. Groundnuts have a KASPar converted-SNP marker set of only 90 markers, and progress in that crop appears to be lagging. The Review Team is impressed by the numbers of countries (34) involved in supporting the nine crops and their testing and breeding activities. The strength of the partnerships underlying the crop-specific RIs is impressive

9. LESSONS AND CONCLUSION

9.1. Introduction

As previously noted, the GCP resembles the current CGIAR Research Programmes (CRPs) in several respects, e.g., a single unifying theme, multi-centre collaboration, a focus on partnerships, a life longer than that of a typical project but with clear phases, and a requirement to be hosted by a CGIAR Centre. Offsetting these features have been the transaction costs associated with diverse partnerships, the intermediate or upstream nature of most of GCP's research products (vs. varieties for direct use by resource-poor farmers), and GCP's geographically dispersed model of staff placement.

One advantage that CRPs have over the GCP is the possibility of learning from the GCP experience. GCP began operations in 2004, fully 7-8 years before the CRPs were launched, and they are yet to develop proposals for their second phase, so some of the crop CRPs could perhaps extract useful lessons from the GCP's acquired know-how. In this chapter the Review Team summarizes the science-oriented lessons, followed by lessons that it has drawn from the GCP experience in governance and management.

9.2. Science-oriented Lessons

Partnerships and collaboration

- *Research partnerships provide gains that are more than the sum of their parts:* Partnerships developed by GCP have provided synergies and benefits that appear to have enduring value. Characteristics of these partnerships have been inclusiveness and mutual respect for all partners, open data sharing, strengthening of the roles that NARS have played in project leadership, appropriate and equitable funding, and attribution to all partners according to their contribution. Such partnerships have provided a conduit for mentoring, orientation, project design and publication, and scientific standards have steadily increased. Links have also enabled NARS and CGIAR scientists to access cutting edge MB expertise via the ARIs. IP problems have been largely avoided by a humanitarian use agreement. Transaction costs of partnerships can be significant; but the GCP-instilled culture of using regular teleconferencing and prompt replies to emails has facilitated collaboration substantially.

- *Government policies and regulations need to be addressed:* It was envisioned that CGIAR centres, ARIs, NARS and others would be sharing their diverse crop genetic resources freely among GCP partners and collaborators. However, issues due to IP and movement of genetic resources across country borders restricted sharing among and between GCP project teams. Significant difficulties have been encountered in international transfers of germplasm, especially from India and China, and to a lesser extent Brazil. The Review Team **suggests** that the CGIAR redouble its efforts to establish binding germplasm exchange agreements with these countries to facilitate open access to germplasm developed through the CRPs

- *Limitations of collaborative approaches without strict product specifications:* Partnerships have not worked well when research product specifications were not well defined early in the project. Examples are programming of the IBP by several different institutions and a subsequent failure to reach uniform standards; and genotyping of parts of reference collections in different laboratories to different standards, accompanied by inadequate phenotyping in poorly managed environments. In each case the lack of clear enforceable specifications and protocols led to costly delays. On the other hand GCP has linked payments to collaborating researchers with meeting specific delivery commitment milestones in many of its projects, thus encouraging project completion and accountability. While the GCP has taken an appropriate approach with reference sets, in the future community-based efforts in evaluating genetic variation should be carefully managed by a few well equipped laboratories and field facilities, backed by clear protocols and ontologies endorsed by the crop community.

Importance of transparency for enhancing quality of science

Transparency of decision processes enhances quality of science: A transparent process for determining the choice of methodologies adopted and quality assurance mechanisms such as peer-review of publications helped improve the quality of science undertaken in many projects. The choice of which crops to drop and which to continue as the GCP transitioned from Phase I to Phase II was also a thorough and transparent process and resulted in general agreement with the procedures taken to halve the number of target crops.

The role of GCP and the NARS

The GCP has served a key role as an honest broker of resources – a role that would need to be taken up by CRPs. In doing so, GCP has encouraged a shift towards NARS in leadership of projects (from 25% in Phase I to 50% in Phase II), with a concomitant shift in budget responsibilities. In theory this should happen with all CGIAR Programmes, but in reality it has probably been rare so far. This success in empowering NARS is a significant accomplishment of GCP, and the Review Team **strongly suggests** that CRPs be encouraged to replicate it.

Research management issues

- *Competitive vs. commissioned research*: GCP's experience shows that many competitive grants have delivered projects with a higher standard of research, when compared with commissioned research projects. Commissioned research projects have in some cases been viewed by busy scientists as doing GCP 'a favour', and adherence to timelines and product specifications has been quite variable. The Review Team **suggests** that the CRPs consider devoting a significant proportion (at least 20%) of their research budget to support competitive research grants, even where the base of possible applicants for a specific project area is small. This would help CGIAR Centres to 'lift their game' since they would be competing with other institutions for some of their research budget.

- *General Research Meeting*: This has played an important role in communicating research, developing partnerships and coherent research plans, encouraging accountability among collaborators, mentoring, and in fostering the GCP spirit. The Review Team **strongly suggests** that an annual or biennial meeting of Principal Investigators and Programme staff be organized by CRPs, especially when research is conducted over widely dispersed locations by staff from many diverse institutions. Having the meeting within reach of key research sites is always a plus. Although such meetings are expensive, the Review Team regards them as indispensable for generating productive partnerships and delivering quality products of collaborative research. However, the Review Team suggests that innovative ways be found for more equitable contribution, i.e., not just the brightest and the best repeatedly demonstrating their brilliance. Suggestions include meetings led by NARS; and separate sessions for women scientists.

- *Data management*: Some donors (e.g., B&MGF) insist on project data being made available publicly within a year of collection, and also insist that data be held in a professionally designed and managed database. Databasing of all data is preferred but especially those related to crop performance, since these have considerable value for genomic selection and other genomic-based applications in the future.

- *Proof of concept through product-oriented projects*: The RIs developed in Phase II of GCP represented hands-on opportunities to demonstrate proof of concept of molecular breeding to NARS partners. These also demonstrate the need to coordinate the collection of molecular and field data within a tight time frame in order to boost genetic gain, while at the same time developing improved cultivars or genetic materials with new and interesting genetic combinations. They are in essence another form of education/capacity building beyond their primary aim, and are a means of coalescing relationships in CoPs.

- *Need for field-based data*: The Review Team notes that field-based yield data on the efficacy of Alt_{SB} and *ZmMATE* genes are rarely found in GCP reports, even though this is the ultimate measure of effectiveness. Validation of QTLs and genes in pertinent genetic backgrounds and environments and comparisons of field performance against other standard sources of Al tolerance in target species, especially maize, is needed, and would provide a further convincing demonstration of effectiveness. Every effort should be made in the remaining life of GCP and in the CRPs to show efficacy of selection under realistic and representative field conditions.

- *Flexibility*: The proof of concept for drought tolerance has not been fully established thus far using MARS, MAS and candidate gene approaches, largely because the trait in most species is controlled by many loci, each with relatively small effects. GCP however, has shown commendable flexibility in adopting new methods as they arise – e.g., the use of genomic selection for drought tolerance as a sensible alternative to MARS in maize. We note, however, that despite the changes in breeding methodology the necessary checks were still maintained to compare rates of genetic gain as proof of superiority of the modified method.

GCP has allowed design flexibility that permitted this change to the project mid-way through its execution without reducing the focus on project effectiveness.

- *Exploring and exploiting genetic variation*: GCP invested heavily in characterizing and tagging genetic variability using reference sets of germplasm that represented 70-80% of the genetic variation in the species. Other programmes, especially CRPs, will hopefully follow this approach during association studies. Because of adaptation challenges, there is a need for overlapping subsets of reference set entries when phenotyping. The Review Team **strongly suggests** that the degree of overlap of entries be at least 10%, and that broadly adapted 'anchor' entries be included as checks in subsets during evaluations. High quality phenotyping and genotyping data from references sets are a valuable resource for the future, and should be passed to their respective CRPs or the IBP for annotation and archival.

- *Importance of phenotyping*: Investments in field sites and training in phenotyping have been strategic, relevant and essential to the success of GCP, and are becoming more important as molecular breeding increasingly exploits gene-phenotype associations to speed gain from selection. Resources to maintain equipment and improvements in irrigation and drainage will be needed, and the CRPs may have to assume this role. A second important strategic issue relates to how limited phenotyping resources are best deployed to maximize efficiency in selection for adaptation to the major agroecologies of sub-Saharan Africa and South Asia. The Review Team **strongly suggests** that GCP (and the CRPs) examine the cost effectiveness of such investments at specific NARS sites vs. investments in the regional testing networks managed collaboratively by the CGIAR centres and the NARS in sub-Saharan Africa.

Capacity building and its role

Capacity building has been an indispensable part of the GCP, yet it is unclear how trained staff will be linked to the CRPs, or how training materials will be handed over to the CRPs. Ongoing work on PhD and Masters theses initiated through GCP projects must be supported with adequate budgets after programme closure. Lessons learned during the GCP tenure include:

- Learning by doing (vs. generic training) is a highly effective approach, has an immediate impact on research efficiency, and appears to add efficiency to the capacity building process.

- Synergies with capacity building and training across the CGIAR might have been possible and could have led to efficiency gains.

- On-line learning: Direct costs of travel and accommodation, and opportunity costs of absences of scientists from their research programmes during training are considerable. The direct cost per student for the IB-MYC per year, for example, has been about $5,700. The Review Team **strongly suggests** that distance-learning platforms be increased significantly. The Review Team also notes that more localized positioning of trainers (as in the IBP Phase 2 proposal for geographically dispersed hubs offering training) will also increase the cost-effectiveness of training.

- Monitoring and follow-up: It would be useful to build measures of effectiveness into all capacity building activities, by self-assessment or skill testing. A systematic follow-up of trained Postgraduate staff in the year after completion of their training is **suggested**.

- An investment of professional and financial resources into CoPs that are functioning well seems fully justified, as is an evaluation of the growing roles of social media in promoting traditional communities of practice through new means.

Communications as a tool

GCP's use of varied communications methods has been impressive, and its communicated messages are professional and upbeat. The key tool used was the Programme website (www.generationcp.org), which is both rich with material and deep in terms of its levels of data and different applications. An updated and enriched website as a 'one stop shop' is now essential for any large and complex programme.

Product focus and market orientation

The GCP product catalogue currently contains 284 products, including genetic and genomic resources, validated marker sets for breeding, new tools and methodologies, training materials and datasets that have specific uses. The catalogue is searchable and is a key component of sustainability, since it outlines the nature of outputs, how they can be accessed and the use to which they can be put. It helps define the legacies of the GCP in molecular breeding and germplasm and how these can best be used. The Review Team **strongly suggests** that updating the catalogue and maintaining access to it be essential transition commitments. Given the size of the catalogue the Review Team **suggests** that it be prioritized by GCP to show what it considers the 20 or so most important products of its work.

Need for adequate M&E and impact assessment

Monitoring and evaluation were the biggest shortfalls in GCP. After the departure of the first Capacity Building specialist (also responsible for M&E) the Review Team notes a number of individual projects failed to meet agreed-upon deadlines – partly due to the science, but also because of management shortfalls in monitoring progress and ensuring adequate and timely corrective action. The IBP initially fell into this category, but has consistently met its product release deadlines since June 2012 following changes in Project leadership and the transfer of coding responsibilities to a private sector supplier. The Review Team **strongly suggests** that a programme of GCP's scale needs a stand-alone M&E component. As well, baselines are needed in research and in capacity building, so that the impact of investments can be assessed. The Review Team **suggests** a combination of baseline surveys of farmer circumstances and counterfactual study areas to establish initial conditions. In their absence, a series of case studies can be established to illustrate changes in farm family circumstances with time. There is a need for a formal assessment of impact from GCP, since much of its impact will occur well after the Programme ends.

R11. The Review Team recommends that formal impact assessment of GCP genetic enhancement activities be undertaken in 2016–2017 using some of the 14 user case studies that form part of the IBP Phase 2.

Lessons from the development of the Integrated Breeding Platform

The IBP is a significantly larger platform than a set of linked software modules, since it includes the service component of GCP (communications and access to services; genomics and MB informatics; support for genomics research and breeding, genotyping services; service communities, including CoPs and product delivery), but the heart of the IBP is efficient and reliable software. The development of sophisticated software packages is increasingly likely among the CRPs as the role of modelling as an experimental tool grows in importance, and as purpose-built analytical packages become a necessity for specific tasks in plant breeding. The GCP experience in developing the IBP software suggests the following lessons:

- *Roles*: The programming of software, especially the middleware that links analysis modules or handles 'shells' for modules already developed should be undertaken by professional software developers. The role of the GCP (or CRP) should be confined to developing product specifications, defining the applications and developing the algorithms, lists of available inputs and needed outputs, testing of developed modules, and clear and specific timelines, all in close collaboration with the software programmers. GCP has learned the hard way that collective programming by IBP development partners is ineffective. Experience suggests that the appointment of a single point of contact between software developers and the Programme (GCP/CRPs) improves the management efficiency of the software project, provided these contacts are backed by users' groups. Consistent leadership should be a high priority – the GCP has had three leaders in Phase I and this may have sent mixed messages to developers and clients.

- *Importance of engaging clients appropriately from the outset*: The IBP development process in its early stages was somewhat disengaged from the needs of main line breeders, and this has been addressed effectively only in the past year. Relatively small issues such as the use of common names for processes, the specifics of how pedigrees and field books are generated, the 'feel' of the software and its ease of installation often determine its appeal to breeders. The mistake made by GCP was not formulating specified user groups until very late in the development of the modules making up the IBP. The Review Team **suggests** that there is a need to develop a service attitude from the outset, and that a strategy be developed for systematic user input/feedback during product development. The process of obtaining input and feedback before/during software development from specified users working in various target crops requires careful planning.

- *Use rollout dates to build credibility*: When a rollout date is announced managers of software products should strive to deliver a product that meets advertised specifications. This has not been the case with the IBP, which was initially oversold and under-delivered (in the 2010-12 period). The Review Team notes that the IBP is an excellent system, and that a considerable improvement in performance has occurred since June 2012 - though a fully-functional version of the IBP was delivered only in early 2014.. The Review Team **strongly suggests** that every effort be made to ensure that publicized rollout dates coincide with a market-ready product.

- *The one-stop shop concept:* If this is an important goal, then all issues related to the efficient use of the platform and its easy adoption should be addressed. For example, it is not clear to the Review Team if on-going funding of the IBP includes financial support for genotyping services, or if that requires support from other sources. It is also unclear if help will be available to migrate older databases to the newer IBP formats. The use of small competitive bids for support to NARS for specific projects of this nature has considerable merit.

- *One size does not fit all*: There is a need for more flexibility in building workflows, which will provide for greater flexibility among users and also greater adaptability to the inevitable evolution of statistical analyses and genotyping techniques.

- *Marketing*: A careful assessment of competing products and alternative suppliers is needed to determine market niches and key selling points. A strong programme dedicated to raising awareness through product testing and demonstration is essential in key sectors, such as the CGIAR Centres and leading SMEs. Demand can also be built through purpose built and high-visibility training programs like IB-MYC, and through promotion of the software as a research and teaching tool in key universities in the developed and developing worlds. It is important that the software meet the basic needs of a large proportion of clients. In the case of line breeders, the IBP needs robust conventional selection routines (e.g., pedigree management, seed inventory, field book and label generation, direct data uploading, single and multi-environment analyses, and easy access to historical datasets); whether marker application is utilized or not, conventional breeding is still the cornerstone of genetic improvement. It is vital that the IBP (and software packages like it) meets the majority of breeder's needs and

remains a cutting edge package of technologies in molecular breeding, available to NARS and SMEs.

- *Maintenance of the software as a cutting edge tool*: A stable budget is essential for software maintenance and further development of its research capabilities. Initially this budget should not depend on license fees from SMEs, since its appeal to that sector depends on the IBP being seen as a reliable long-term cutting-edge research tool. At every key decision point in software development a readiness for future changes could be engineered in the system, e.g., it is becoming clear that the IBP will need to cope with large datasets from GBS and perhaps remote sensing in the next five years, so the development of a seamless strategy for coping with these (probably by condensing datasets outside the main framework of the IBP) requires foresight and planning.

- *Benefiting from private sector experience*: In retrospect, if private multinational seed companies that invest heavily in IBP-like proprietary software had been engaged to provide a software system suited to NARS needs, this may have sharply reduced the development time and costs.

Managing the IBP and similar projects

- *Aids to deployment of the IBP and its adoption*: CGIAR regional plant breeders are likely to be the best ambassadors for the IBP among the NARS. The Review Team **strongly suggests** that IBP at the outset of Phase 2 create a staff member role with prime responsibility to include the persuasion of CGIAR breeders to test the IBP while providing assistance in using the software and with migrating historical data.

- *Prioritizing hubs*: The Review Team agrees with GCP that there is a need for regional hubs where technical support and training can be offered within the country or region. The Review Team however cautions against overstaffing in regional hubs, unless financial support is forthcoming from the host institution. The region with the greatest unmet needs is sub-Saharan Africa, so it is logical to develop hubs first in East and West Africa at institutions where breeder-clients are based.

- *Thinking long-term: Beyond Phase 2*: Because of the challenges of learning new software and the costs of transferring existing databases to IBP, managers of SMEs are understandably hesitant to commit to the IBP unless they believe it offers guarantees of continued software development beyond 2019 (the anticipated completion of Phase 2). The Review Team notes that this can only be resolved when the updated business model and hosting arrangements are decided.

Leveraging the GCP legacy by the CRPs

This obviously depends on a CRP's strategic vision, work plans and budgets; so each CRP may have to be considered on a case-by-case basis. Negotiations with CRP managers will be needed on completing research projects in the nine target crops, estimated by GCP in March 2013 to cost about

$0.7- 1.3 million (being updated), with the major cost element being activities associated with MARS breeding schemes. The Review Team **strongly suggests** that costs for legume crops be incorporated into the proposal for Tropical Legumes 3 that may be submitted to B&MGF. Proposed activities for the remaining crops should be built into their respective CRP workplans and budgets. The Review Team concludes that almost all the research, capacity building, seed and data storage and use of genetic and genomic resources and communications functions of the GCP, including the CoPs, can be transferred to the CRPs. GCP will need to ensure that lists of trained staff, training materials and course outlines, CoPs, and trained national staff are successfully transferred to the CRPs. To avoid "dropping the ball", however, will take a concerted effort by GCP and CRP management in 2014. There is no obvious justification in setting aside GCP funds to complete what are mainly open-ended breeding activities, and CRPs could be expected to complete these, if they meet their own priorities and there is a budget. The Review Team has therefore recommended that during 2014 the GCP focuses its attention on the detailed transition to the CRPs of specific germplasm and data generated by high value research initiatives.

The GCP legacy: maintaining it outside the crop CRPs

The IBP is a major GCP legacy, which in due course might prove to be its most significant product. It is a tool suited to all crop CRPs, and could be hosted by a CGIAR Centre, but in the Review Team's view it could well be housed in a cross-cutting CRP dedicated to system wide applications. A second significant legacy depends on the suitable hosting and updating of the IBP website for the next five years – as a continuing resource providing access to open-source publications on molecular breeding and to the updated GCP catalogue. The Review Team's views on how this might best be accomplished have been discussed in previous science-oriented chapters, as well as in Annex 7.

Efficiency of the Challenge Programme approach

Was the formation of the GCP the most cost effective way of identifying, tagging and exploiting new sources of genetic variability vs. sharing the funds among the CGIAR Centre breeding programmes? The Review Team believes that the answer to this question is yes, since GCP mobilized new sources of funds from donors, allowing GCP and collaborators to focus on specific aspects of MB. As noted previously, the IBP is one important outcome of the GCP that is meeting the needs of most of the crop CRPs, but is being developed by GCP rather than being duplicated by each. GCP has spent a considerable amount of funds – almost equivalent of 2 full years of a major CGIAR crop Centre's annual budget. The Review Team believes that in general it has been well spent, though hindsight suggests that in developing the IBP or evaluating reference sets considerable savings could have been made by outsourcing key functions at an earlier stage (e.g., software development; genotyping).

A constructive attitude to external reviews

The Review Team recognizes that GCP has taken an open and pro-active attitude towards external reviews – commissioning their own independent reviews (the case of the current one) as well as welcoming a number of donor reviews. There have been clear benefits, such as the major governance and research reforms that followed the EPMR and EC Reviews of 2008. These changes

sharply increased the efficiency of GCP in delivering benefits to the poor. The Review Team **suggests** that further benefits could also have been obtained from rapid appraisal or subject-specific CCER reviews conducted at strategic moments in key activities – for example, specific areas related to the IBP, training NARS scientists, establishing and maintaining phenotyping capability in Africa, etc.

9.3. Governance and Management Lessons

The Review Team's conclusions and lessons on GCP governance and management, outlined below, are intended to facilitate sustainability of GCP products after 2014 and contribute to further thinking in the CGIAR about CRP governance.

Systematic learning-by-doing is essential for continued programme success

Learning-by-doing has been a key feature of GCP since programme inception in 2004. The GCP's governance reforms in 2008 were the result of lessons learned during its Phase I (2004–2008) operations. In February 2009, staff of GCP and the three other CPs then being implemented identified lessons of their collective experience. In a useful paper titled 'The CGIAR's Challenge Programme Experiences: A Critical Analysis', the considerable benefits of the CP's 'programme' approach were recognized, and several conclusions and lessons were highlighted, covering the time period roughly corresponding to GCP Phase I. The Review Team's comments on GCP governance as of November 2013, in light of the CO governance lessons, are given in Table 9.1 below.

Table 9.1: CP lessons (2009), and Review Team comments on these lessons on governance

CP governance lessons (2009) (As per the February 2009 paper)	**Review Team comments on 2009 lessons on GCP governance** (as of November 2013)
1. CPs and MPs [now CRPs] have many obvious similarities that mark them as different from CGIAR Centres: they are both programmatic in nature, they both depend for success on broad partnerships beyond the CGIAR, aiming to treat CGIAR and non-CGIAR partners equally, yet both can function only if they have access to skilled researchers lodged in thriving CGIAR Centres	*This lesson is only partially valid now*. The GCP experience in Phase II has benefited from the programmatic nature of GCP, its reliance on partnerships, its equal treatment of all partners, and the availability of skilled researchers. However, some of these features now characterize the CGIAR Centres and CRPs as well; and researchers could be from CGIAR Centers as well as other reputable institutional partners in developing and developed countries
2. CPs' relative independence has been critical for objective priority-setting	*This lesson remains valid*. For the GCP, the replacement of the PSC with an independent EB enabled more objective priority-setting and resource allocation in Phase II
3. MPs [CRPs] may have the advantage of operating under a purpose-designed legal entity which will act as their legal and fiduciary representative, as opposed to CPs experience in operating under the policies and procedures of their individual host institutions	*This lesson is largely invalid now*. Most CRPs are now not operating 'under a purpose-designed legal entity'. While it may be true that CRPs might have benefited from such a governance arrangement (which is a key feature of CGIAR Centres), the GCP has not been unduly constrained by operating under CIMMYT's policies and procedures (as the Host Agent, with legal and fiduciary responsibilities)
4. Our experience has demonstrated the wisdom of independent legal status for the MP [CRP] structure	*This lesson is not valid for GCP now*, based on its Phase II experience. Both independence and legal status are necessary for effective governance, but they are separable requirements that can be provided by two different bodies, such as an independent Executive Board (with autonomy, effective oversight, and full decision-making authority), and a suitable Host Agent (with independent legal status). This structural arrangement is not without its pros and cons, but it is workable under the right circumstances and in combination with other functional requirements of good governance, as GCP Phase II experience shows
5. An approach that leaves creative space for innovation by scientists must be combined with the need for focus and advance programming, inter alia	*This lesson remains valid even now*. In GCP, the advisory Consortium Committee, the GCP's partnership mode, the science-focused advisory body (SiMAC) for IBP, and the science-oriented annual/ general research meetings are important; as are the strategic focus, implementation oversight, and transition planning provided by the independent Executive Board which has full authority for setting program direction and overseeing its effective implementation.

At least three reasons underlie the Review Team's comments on the continued validity (or lack thereof) of the governance lessons identified in 2009: (a) the lessons highlighted in the 2009 paper were broad generalizations from the aggregated experience of four CPs, each with different governance arrangements, and were presumably not fully applicable to any one of them, including the GCP; (b) the 2008 GCP reforms essentially created a new governance structure, reflecting the lessons of its Phase I experience, so it is not surprising that some 2009 lessons are no longer valid for the current GCP; and (c) some process-oriented features of GCP governance have existed since programme inception in 2004, so the 2009 lessons associated with these processes remain valid even now.

The latter conclusion is equally relevant for the broad management lessons identified in the 2009 paper on CP experiences. As noted in Table 9.2 below, most of the 2009 lessons relating to the good management processes and practices of GCP remain partially or largely valid.

GCP has taken seriously the lessons identified in 2009, and adapted them pragmatically to its own circumstances and needs. In differing somewhat from the 2009 lessons, the Review Team draws attention to the new aspects introduced in programme management in 2008, particularly the increased emphasis on product delivery (without compromising the collegial processes for working through partnerships), and the benefits that have come from a sharper focus on fewer crops and clearer accountability to the Executive Board for all aspects of programme design, monitoring, and implementation.

Table 9.2: CP lessons (2009), and Review Team comments on these lessons on management

CP management lessons (2009) (As per the February 2009 paper)	**Review Team comments on 2009 lessons on GCP management** (as of November 2013)
1. A significant amount of time needs to be spent on process and team building, as is necessary for effective science	*This lesson remains partially valid*. Process and team building are means to an end; and GCP's focus in Phase II on product delivery provided a much-needed balance between process and outputs
2. All CPs needed approximately one year after the Program leader's appointment for hiring staff, setting up administrative processes, conducting planning meetings among collaborating organisations and launching the first calls for research. This reflects the fact that such programs change the way of doing things among people as much as they change the science	*This lesson remains valid*. GCP introduced major changes in 'the way of doing things among people', and this took time. GCP has benefited from this 'process-orientation' throughout the past 10 years as both the people and the programme changed. Inculcation of the 'GCP spirit' noticeably changed the science undertaken, in both Phase I and Phase II. The time and money needed to properly establish the structures and staffing at start-up also suggests that CRPs need long-term funding (say for 10 years or more) to reap the full benefits of the initial investment and to fully implement the change in 'mind set' for managing both the people and the science
3. Process should not be criticized as somehow inferior to science, as can happen in the CGIAR community. Insufficient initial attention to process will almost certainly lead to problems for science development	*This lesson remains valid*. In GCP, sufficient attention to 'process' facilitated good science; and (in contrast) for the IBP, initial inattention to effective processes and client-feedback hampered product design and development
4. At the same time, processes need to be tested and to evolve; design is iterative and the advantages of learning from mistakes are indispensible	*This lesson remains valid*. Learning from mistakes and making suitable changes are necessary for success, as was the case for GCP governance reforms in 2008, reference set evaluations, investments in field phenotyping, and IBP development more recently
5. It is useful to remember that successful research activity depends on low frequency and often unpredictable events and, therefore, requires investment across a range of concepts, not all of which are easy to map from the beginning	*This lesson is partially valid now*. In Phase I, GCP invested in a diverse set of crops and activities, with predictably mixed results. In Phase II, success was predictably higher due in part to a sharper focus on fewer crops, and the strenuous pursuit of time-bound delivery of quality products. Good science management increases the predictability of events that affect the outcome of the research process

<u>The governance structure and management processes need to be aligned, and work well together</u>

The GCP's 'consortium governance' structure, complemented by a participative and collaborative management and partnership approach, has served the programme well. Throughout the past ten

years, the GCP has served as an effective agent of change, helping ensure that its partners collectively achieved much more than any one of them could have accomplished on their own, acting separately. In GCP Phase II, a well-functioning independent Executive Board, a sound advisory Consortium Committee, a responsive and supportive Host Agent, and an effective management approach and team, working collegially with diverse partners in a shared 'GCP spirit' of mutual respect and learning, have collectively enabled the programme to make significant progress towards its objectives and develop useful products that deserve to be sustained after GCP ends in December 2014.

In Phase II particularly, the benefits of ensuring that the governance structure and management approach fit the unique circumstances of the programme and remained flexible in response to changing external and internal requirements, were significant. It is the combination of effective governance and good management practices, as well as GCP's adaptive learning-by-doing approach and systematic application of lessons of experience that have worked well for GCP. They have underpinned the effective response of GCP's Executive Board and Management to changing external opportunities and risks, and to evolving internal requirements as the Programme completes its 10-year lifespan and transitions to the post-GCP phase after 2014.

The governance functions performed are more important than the structural configuration

In the Review Team's view, the main structural components of GCP's 'consortium governance' approach have served the same functions in GCP Phase II as they do in the more 'traditional' governance structures of CGIAR Centres. For example: (a) GCP's independent Executive Board, with full decision-making authority, has served much like a traditional Centre Board; (b) parallel sessions of the EB (for research and finance) have served like traditional Board sub-committees, respectively for Programmes, and Finance and Audit; (c) the Consortium Committee, like an advisory Stakeholder Committee, has provided inputs from the perspective of stakeholders and research partners; and (d) the Host Agent has provided the legal status and legitimacy considered essential for CGIAR Centres (whose legal status serves the same function for CRPs). For CRPs, the implication of this lesson could be that CGIAR's emphasis may need to shift from seeking structural uniformity of their governance arrangements to ensuring that adequate provisions are made, on a case-by-case basis, for all key governance functions to be effectively undertaken in all programmes.

In addition, the GCP Phase II governance model shows that it was essential that its components function in a mutually supportive manner at all times, in service of GCP's overall interests and goals rather than the components' own separate interests. Each component was necessary, and none was sufficient by itself, for ensuring that GCP's governance structure performed as intended. The lesson drawn from this for CRPs is that the various components of the governance structure need to operate in an integrated manner, with effective functional inter-relationships among the parts.

Some management processes are very desirable, and could be relevant for all CRPs

Based on the 10-year GCP experience, included among this set of 'desirable management processes', and the values underpinning them, are an emphasis on: (a) partnership relationships that encourage openness, collaboration, learning, equitable resource allocation, and joint-production of high-quality

science and research products; (b) cooperative research based on mutual-respect and 'equality' among partners (and researchers, project- and sub-theme leaders, principal investigators, and product development coordinators) from a wide range of NARS, ARIs, and Centres; (c) an increase in science-focused meetings, e.g., of a consortium committee or an annual/general research meeting; and (d) improved balance between the complementary emphases on research excellence and product-delivery. Also included are a focus on 'process' and team building, caring for people as much as science, and balancing these with a clear focus on outputs. And also, inculcation of a 'spirit' of scientific inquiry, mentoring, sharing and mutual-support, which GCP researchers say they will miss most when the program ends, and which they most wish to replicate in other programmes/CRPs.

The above-noted 'desirable' management processes need to be undertaken in a spirit of collaboration and mutual respect, along the lines of what has come to be accepted among its closest collaborators as the worth-replicating 'GCP spirit'. Developing this approach and maintaining this spirit is, however, not easy, for it must be locally grown from the ground-up on a case-by-case basis; and it has implications for both the science undertaken and the way it is done.

The observation that many of GCP's management processes have served it well during both Phase I and Phase II leads the Review Team to the conclusion that these processes could be valuable for other multi-partner crop research programmes, irrespective of the governance structure within which such programmes operate. This lesson could have implications for CRPs (as well as Centre-based research programmes) that rely on extensive partnerships for research and product delivery, but operate with very different governance arrangements. For the CRPs, it may be desirable to utilize as many of these management processes as possible, and as much as possible, given each programme's objectives, particular circumstances, and resources.

Other specific features of GCP governance could also be relevant for CRPs

Other specific lessons of the GCP Phase II experience, that could be relevant for CRPs, are that: (a) it is essential to ensure the independence of the governing Board; (b) there are clear benefits of ensuring unambiguous and direct chains of command that help ensure oversight and accountability; (c) the complementary roles and responsibilities of Centres as Host Agents (or as lead Centres, in some cases) and CRPs should be clearly-stated in formal Agreements; (d) there are potentially-large efficiency gains in locating CRPs at supportive Centres (like CIMMYT) that have a significant commitment to the CRP's goals and activities; and (e) both the governing Board and Programme Management benefit from independent advisory committees on research, IP etc.

In addition: (a) gender diversity and regional balance on governing bodies are desirable, without compromising on relevant experience and functional expertize; (b) it is desirable to avoid part-time or joint appointments of programme leaders, but since the quality of contributions is more important than mere quantity, exceptions can sometimes be justified; and (c) where programme staff are widely dispersed (as in GCP and CRPs), an annual (research) meeting could serve as an essential vehicle for upgrading scientific knowledge and building team spirit.

These lessons would need to be suitably adapted for other programmes, such as CRPs

GCP's governance and management practices are broadly aligned with the expected practices of CGIAR Centres and CRPs, but the 'GCP approach' would need to be suitably adapted to suit each CRP's needs and context. The GCP experience shows that the hard work involved in developing effective partnerships and a collaborative *esprit de corp* ultimately pays off in concrete and sustainable results, thus making the research programme more effective despite the inherent challenges and additional time and resources involved. For this and related reasons, the Review Team considers that a modified version of the GCP governance approach could be suitable for IBP Phase 2 in the short term; and a cross-cutting CRP consistent with GCP's approach and goals could be a good bet for sustaining IBP in the longer term.

9.4. Conclusion

In conclusion, the Review Team finds that the GCP has performed well, has met the majority of its crop improvement goals and surpassed others, and will leave a formidable legacy of useful and accessible products and information. The Review Team also finds that the GCP is approaching its impending closure logically, systematically, and with a view to maximizing its impact beyond closure by ensuring that key products such as the IBP are suitably positioned and supported to continue to deliver benefits.

The GCP governance bodies, staff and management, and especially the Director and the Executive Board have shown dedication to the task and exceptional leadership. In addition, GCP's many partners and collaborators — particularly the ARIs, CGIAR Centres, NARS, and other institutions that have helped develop and implement GCP projects, as well as the host centre CIMMYT deserve a lot of credit for developing productive and mutually-supportive relationships with the GCP. The strength of these continuing collaborative relationships will help ensure the sustainability of GCP activities that will hopefully continue after 2014 through the various CRPs and IBP Phase 2.

The contribution of GCP's major donors—the EC, the B&MF, DFID, the World Bank, the CGIAR and other investors—needs to be recognized, they took the initial risk with what was in 2003 an unproven consortium and partnership approach, and have provided strong financial support for developing and maintaining Programme activities since then. The EC and CGIAR have also commissioned several external reviews of the programme or significant parts of it, and this emphasis on programme evaluation and results has helped the GCP make much-needed mid-course corrections in 2008 and subsequently. The B&MGF has provided significant financial support for development of the IBP since 2009, and has expressed a strong interest in funding IBP Phase 2 for at least 5 years after GCP closure in 2014. Without this tremendous donor support and confidence in GCP's governance, management, staff and partners, the Programme could not have achieved very much.

Looking to the future, the Review Team is cautiously optimistic that GCP's activities will continue to be effectively implemented through the CRPs after 2014, and that the arrangements for housing IBP Phase 2 at a suitable location, both in the short-term as well as longer-term (beyond Phase 2, possibly in a cross-cutting CRP), will be agreed upon with relevant stakeholders without undue

difficulty. It wishes GCP staff and the Programme's partners a smooth transition to the post-GCP period; and is very hopeful that GCP's investors, Consortium members, governance bodies, partners, and other stakeholders who have contributed significantly to GCP's progress thus far will remain fully committed to sustaining this successful Programme's considerable achievements and benefits in the coming years.

ANNEXES

Annex 1: Terms of Reference

IEA

GENERAL TERMS OF REFERENCE
FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

1. Background

The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. The Challenge Programs represented a major component of the CGIAR reform of 2001 and were intended to foster a programmatic approach to research in the CGIAR. They were large, independently governed, multi-partner programs that were intended to be time-bound and oriented towards topics of high priority in an attempt to open up the CGIAR and raise the quality of its research. Of the five Challenge Programs that were created, all except the GCP have been merged into the new CGIAR Research Programs (CRP) approved in 2010–2013.

From the outset the GCP was planned to run for ten years. It links several CGIAR Centers and numerous other major partners in a research consortium. The GCP was founded on the theme of 'unlocking genetic resources for the resource-poor'. Thus, the GCP's mission became one of promoting the use of genetic diversity and modern plant science for crop improvement in developing countries by adding value to breeding for drought-prone and harsh environments. This is done through a series of Research Themes, each of which comprises several projects. CIMMYT, in Mexico, remains the host agent of the GCP and provides the legal framework within which it operates.

The GCP comprised two phases: Phase I (2004–2008) concentrated on exploration and discovery in crop diversity through genomic research and molecular breeding. Phase II (2009–2014) focuses on delivering services to breeders via research-for-development networking. An independent, external review in 2008 commissioned by the CGIAR made several recommendations on governance, management and program content that largely shaped the direction of Phase II. Program governance was reformed principally to enhance independence from GCP consortium members. The GCP has had an Executive Board since 2008 for setting scientific direction and for managing finances and risks. The Executive Board reports to the GCP Consortium Committee.

During Phase I, the GCP supported work on all 21 CGIAR mandate crops, and the objective was to explore crop genetic diversity in general terms. During Phase II, breeding efforts are focused more narrowly on nine priority crops, and the work is being implemented through a set of crop- and region-specific Research Initiatives (RIs) addressing drought tolerance, complemented by an Integrated Breeding Platform (IBP– https://www.integratedbreeding.net).

Other platforms have been developed in the areas of crop information, capacity-building and product delivery. The RIs focus on promoting the use of modern, integrated breeding approaches, while the IBP seeks to generate knowledge and technology to facilitate the dissemination of germplasm. The IBP includes molecular, genomics and informatics technology and information, high-throughput laboratory services and capacity-building components.

The five Research Themes are:

1) Comparative and applied genomics
2) Integrated crop breeding
3) Crop information systems
4) Capacity building
5) Product delivery

The seven Research Initiatives (Phase II) that cut across the Research Themes are:

1) Cassava
2) Legumes (beans, groundnuts, cowpeas, chickpeas)
3) Maize
4) Rice
5) Sorghum
6) Wheat
7) Comparative genomics

The GCP operates through partnerships and non-CGIAR partners receive a substantial portion of its funds. Multiple projects are included under each Research Theme. Projects under Theme 3, for example, cover four objectives: (i) user support (ii) data management and quality (iii) methodology development and (iv) infrastructure. Under Theme 4 the RIs and an IBP were addressed via establishment and support of communities of practice (COPs) supplied with breeding services and research support. Theme 4 also provides a genotyping support service (GSS) that facilitates access to modern breeding technologies.

A key feature of the GCP approach is one of partnerships spanning CGIAR centers, ARIs, NARS, academia, regional and national research programs, and private firms. The GCP states[1] that **'"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."** The extent to which this has been the case will be evaluated during this review.

[1] http://www.generationcp.org

2. Rationale for the review

The GCP Management and Executive Board (with the consent of the GCP Consortium Committee) have requested the IEA to undertake an independent external review of the Program. The review will take place towards the end of 2013, approximately one year before the ten-year program is set to close. It will provide an opportunity to look back on the evolution of the Program and all its component activities and to determine whether or not it has met its objectives. Furthermore, it will provide an opportunity to learn from one of the first multi-Center, multi-partner programs that were the predecessors of the current CRPs.

In this review it will be determined to what extent the GCP has provided support to genomics research and molecular plant breeding for developing country partners. In addition, as the GCP represented a new business model for international agricultural research in the CGIAR, the review should determine whether the model has been useful and to what extent particular aspects of it might be replicated in the current CRPs.

It will be important to identify and document lessons that can be drawn upon to assist in designing better programs for the future. It is planned to transfer the crop-specific programs into the appropriate CRPs, and while there are no specific plans for extending the GCP beyond its ten-year mandate, it is possible that the IBP and other activities will be continued. Determining what these activities might be will represent a facet of this review, although not necessarily a major one.

Attempts must be made to canvass the opinions of all major stakeholders in the GCP and to determine whether the requirements of the primary beneficiaries have been met. In this way the results of this review will be useful to a broad audience.

3. Purpose of the review

The principal purpose of the review is to provide an account of achievements of the ten-year program to all the major stakeholders, including donors, member centers, CRP representatives, national programs and other beneficiaries. The review is also expected to identify lessons for the CGIAR on the programmatic approach to research and partnership. The review will not be a full-scale evaluation – it will be an assessment of accomplishments of the GCP over its nearly ten-year lifetime. The review will also provide advice on assessing planned GCP activities until the end of 2014 for i) ending, ii) transferring into CRPs, or iii) perpetuating elements of GCPs work. To the extent possible, the review will make recommendations for future activities relating to genomics research and molecular breeding.

With a view to reducing duplication, and in coordination with the EC, the review will make all efforts to meet the EC requirements for terminal review.

4. Stakeholders

The stakeholders of this review comprise:

(i) Those primarily interested in the performance of the Program and lessons that can be learned: resource partners (in particular the EC), the GCP Consortium Committee, the GCP Executive Board and partners who have been associated with the Program. The donors will be interested in seeing the value of their investments and the partners will be interested in seeing how certain activities will be continued beyond the end of the GCP.

(ii) Those who potentially can help sustain the results of the GCP: *inter alia* the GCP management, CGIAR centers and plant breeders. The GCP management will be keen to bring the program to closure efficiently and effectively while other stakeholders will be more interested in building on the successes of the GCP and replicating useful models developed by the GCP.

5. Scope and evaluation criteria

The review will cover both Phase I and Phase II of the GCP. Since a thorough external review was carried out in 2008, the emphasis of this review will be put on developments during Phase II, many of which were based on recommendations made at the end of Phase I. In addition, results are available of numerous internal and donor-commissioned external reviews and these will be useful for this end-of-program review. This review is not intended to be a fully-fledged evaluation of the GCP over its ten years of operation, but rather a review of the most important issues associated with the GCP.

The review will cover all aspects of the GCP, including, research, service provision activities, partnerships, management and governance. This will allow the Review Team to identify the achievements of the Program (possibly relative to other comparable programs) and will represent the major part of the review. The review will address issues associated with the use of technologies and methodologies developed by the GCP.

The review might also identify components of the GCP that could be continued beyond the 2014 deadline by other organizations or programs within or outside the CGIAR. Therefore, recommendations based on lessons learned will be provided by the Review Team that will have a bearing on future activities in genomics research and molecular breeding as initiated by the GCP. This forward-looking component will not represent full-scale planning for the post-GCP period. Such an exercise would require a different participatory process and far more time and resources than are currently available.

The GCP will be evaluated according to **evaluation criteria** appearing in the attached Evaluation Matrix. The evaluation criteria are consistent with the Evaluation Policy and Standards of the CGIAR. They cover relevance, effectiveness, efficiency, impact, sustainability and quality of science. Visibility of donor co-financing is also included. Some of the many questions that might be answered are included in the matrix, but the main purpose of the matrix is to promote discussion among the Review Team members. The matrix is a framework and some of the questions may remain unanswered. The Review Team will further refine the matrix and will focus on issues that require addressing, in consultation with stakeholders, during the initial stage of the evaluation.

Relevance: The relevance will be assessed of both the scientific and organizational aspects of the GCP. The review will analyse important Program activities throughout its ten-year evolution. An attempt should also be made to assess future relevance of components of the GCP that could be continued as part of the activities of another organization or program. Much of the assessment of scientific relevance will be comparative given that molecular biology and genomics, and their application to plant breeding, are areas of science that are in a state of continual change and advance. Specifically, this will mean comparing activities of other organizations that can do what the GCP was originally set to do and assessing the comparative advantage of the GCP.

Effectiveness: The GCP has set itself targets in terms of outputs and outcomes and general objectives for enhancing the efficiency of plant breeding. Effectiveness refers to the extent to which the targets and objectives have been met or exceeded during the course of ten years and fact that impeded or contributed to these achievements. The extent to which GCP products (particularly information, technologies and methodologies) have been used to improve the application of knowledge to plant breeding among the partners, in particular the NARS, in practical terms should be gauged. Effectiveness also applies to organizational aspects of the GCP, including management, governance, partnerships and communication.

Efficiency: Efficiency deals with resource use and will therefore inevitably be assessed in terms of finance, human resources, communication infrastructure, timeliness of delivery, networks and coordination.

Impact: Impact will not address areas such as poverty alleviation and other issues that lie at the end of long and complex pathways, but the review should look at whether such impact pathways exist and if they are plausible and based on sound assumptions. The review will, moreover, attempt to gauge what has changed among partners as a result of the GCP in its attempts to apply the results of genomics and molecular biology research to plant breeding in developing countries. To the extent possible, the review will assess how scientific approaches and techniques in genomics, informatics and training have advanced accessibility and capacity for NARS, including the extent of development of genomic and informatics tools made available to NARS. Some of the potential impacts will be difficult to quantify, but an attempt should be made to describe them if they exist and validate them through triangulation. Examples of areas of influence and impact to be explored could include raising scientific research standards with respect to drought tolerance in the mandate crops among direct partners, and even beyond them, and improving capacity among partner organizations.

Sustainability: The review will examine the extent to which benefits generated by the GCP are likely to continue beyond the life of the Program and to describe the conditions for sustainability. It might be considered useful were some of the GCP components to be made the responsibility of other organizations or programs in the future. This applies to web-based information systems, including the IBP and genomic and trait databases, and genomic resources. The assessment will therefore take into account the resources necessary to maintain such products, keep them up-to-date and relevant, or even merge them with other products. An attempt should be made to determine if some GCP components could be usefully maintained in the future, by whom and by which means. Options to maximize sustainability in a cost-effective

manner should be considered, realising that for public goods this is not necessarily easy, or indeed feasible.

Quality of science: One of the standard ways of assessing quality of science is to analyse data on publications in terms of numbers and journal impact factors, but alone this is insufficient. Qualitative assessment through peer review by members of the Review Team of a sample of random publications, or 'best' publications, could be used. The Review Team could also look at Program management processes by which quality has been enhanced, such as use of competitive grants. A partnership survey should yield information on what has changed in plant breeding programs, in terms of the application of modern scientific methods, in partner organizations. If information is sought from outside the GCP partner organizations, it might be determined whether the GCP has had a general effect on the quality of science in terms of molecular biology and genomics and their application to breeding specific crops to improve drought tolerance.

Lessons learned: Because the GCP will be terminated in 2014, the recommendations will mostly relate to sustainability of some of its outputs – how the activities and achievements will be carried forward. The lessons learned from the GCP experience will be very useful to a broad range of interested parties, particularly donors and project planners. Lessons learned in terms of both research and organizational performance will not only help the CGIAR in planning future programs, but also national programs will benefit from this knowledge. Lessons from the competitive grants and M&E processes and partnership management, for instance, would be useful. It will be important that the Review Team detail comprehensively lessons learned from the GCP from its inception to its closure.

Visibility of donor co-financing: Is the fact that the GCP has been co-funded by the EC (and other donors) visible in terms of vehicles, equipment, buildings, publications, reports and conference/meeting attendance? The Review Team should include in their assessments an overall performance rating for each of the above seven ROM review criteria, using the following scale:

- highly satisfactory – fully according to plan or better
- satisfactory – on balance according to plan, positive aspects outweighing negative aspects
- less than satisfactory – not sufficiently according to plan, taking account of the evolving context, a few positive aspects, but outweighed by negative aspects
- highly unsatisfactory – seriously deficient, very few or no positive aspects

Each rating should be stated as part of the conclusions for each of the seven criteria.

6. Team composition, roles and responsibilities

The Review Team will comprise five persons led by an evaluator with competence to assess management, governance and partnerships. In addition to the Team Leader, the core Review Team will also include a technical specialist who will take responsibility for the scientific aspects of the GCP. The skills of the Team Leader and the technical specialist will be

complemented with those of a genetic resources/genomics expert, an expert on molecular breeding and an expert on economics/M&E with previous experience in evaluation of similar programs.

All Review Team members will be internationally recognized in their own fields of expertise. Other requirements include: evidence of being able to work well in a team, familiarity with CGIAR research and experience in reviewing technical projects. Each Review Team member will be issued with specific TOR in addition to these general TOR.

The team will work under the general guidance of the CGIAR-IEA Evaluation Manager and will have final responsibility for the report and all findings and recommendations, subject to adherence to the IEA Evaluation Standards.

The IEA will be responsible for:

- Planning and managing the review
- Appointing the Review Team
- Quality control of the review process and outputs
- Making the final report and intermediate outputs publically available
- Supporting such follow-up processes as may be agreed upon

Special modalities: The GCP administration will be responsible for the provision of administrative and logistical support. It will issue contracts and facilitate payments subject to clearance by the IEA Head through the IEA Evaluation Manager.

7. Methodology

The review is to be carried out in conformity with the CGIAR Standards for Independent Evaluation. The review will adopt a consultative and transparent approach with internal and external stakeholders throughout the evaluation process. Triangulation of evidence and information gathered will underpin the validation of evidence collected and its analysis and will support conclusions and recommendations.

The review will use a mix of methods and tools, including:

- Review of extensive documentation and outputs produced by the GCP, including impact studies, using common assessment templates
- Review of evaluation and strategic reports etc. on the GCP
- Scientific article survey (products of the GCP), including assessment of participation of non-CGIAR partners (e.g. using Scopus)
- Structured interviews of the GCP staff and with other key stakeholders; and
- Surveys of partners, potential users and beneficiaries

8. Review process and timetable*

June-July 2013: Define needs for Review Team, write TOR, estimate a budget, recruit Review Team members.

August 2013: Initiate the review following issue of contracts.
September 2013: GCP General Research Meeting 27th – 30th (Lisbon). Core Review Team briefing and opportunity for Review Team to speak with range of partner representatives. Output: refinement of the evaluation matrix, methodology and workplan for the review.
October–November 2013: Review, including presentation of preliminary findings to the GCP Executive Board in November.
December 2013: Preparation of a draft report for comment by stakeholders (after review by the IEA Evaluation Manager)
January 2014: Final editing and distribution of the review report. Reporting back to the GCP management and Executive Board on review findings.
2014: Report results of the review to the ISPC meeting.

**This timetable may be subject to changes.*

9. Review deliverables

- Presentation by the Team Leader to the GCP management and the GCP Executive Board on preliminary findings and conclusions
- Draft report for feedback to stakeholders
- Final review report for e-distribution to the GCP staff

SPECIFIC TERMS OF REFERENCE FOR THE TEAM LEADER, SENIOR ORGANISATIONAL EVALUATOR, FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

The Independent Evaluation Arrangement (IEA) of the CGIAR is organizing the final review of the Generation Challenge Program. The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. It will end in 2014.

These Specific Terms of Reference should be read in conjunction with the General Terms of Reference for the review.

1. Overall responsibilities

Under the overall guidance of the IEA Evaluation Manager, the Team Leader will take the lead role for the organisational content of the final review of the Generation Challenge Program and will coordinate the work of the five-person review team.

The assignment will take place between August 2013 and January 2014 for up to a total of 60 days, including travel to the GCP in Mexico (CIMMYT) and the GCP General Research Meeting in Lisbon from 27th to 30th September. The Team Leader will be responsible for:

- Planning the review and determining a timetable of operations

- Identifying specific questions within the general Terms of Reference for evaluating the GCP against the core criteria (with the Senior Technical Evaluator)
- Organizing surveys, questionnaires and other means of collecting data and information deemed necessary (in consultation with other team members)
- Organizing communication among the review team members
- Modifying the provisional Evaluation Matrix according to needs
- Evaluating all non-technical aspects of the GCP, including governance, management, partnerships, 'synergy of collective action' etc. and lessons from these areas that could apply to the new CGIAR Research Programs (in consultation with other team members)
- Presenting preliminary findings of the review at the GCP Executive Board meeting in November
- Writing the review report based on contributions from all team members (with the Senior Technical Evaluator)
- Revising the review report based on comments made on initial drafts
- Liaising with the Evaluation Manager over all activities and expenses

The Team Leader will be expected to have read the documentation provided by the GCP Director relevant to the topic of the review and to share this information with team members. The Team Leader will be assisted by the IEA when necessary.

2. Deliverables

- A preliminary report (in November 2013) on major findings from the review
- A presentation of these findings to the GCP in Mexico
- A final report on the results of the review by a date agreed upon with the Evaluation Manager
- Timely comments on the draft versions of the report
- A presentation of the final report (to be specified later)

3. Specific modalities

- Prior to recruitment, the consultant will sign a standard letter confirming the absence of conflict of interest between the proposed assignment and past assignments with the CGIAR
- The consultant will also take note of the evaluation policy, standards and guidelines of the CGIAR

The Team Leader will work in close collaboration with the team members regarding their contributions for planning the review and preparing the report and feedback on report drafts. The Team Leader will be paid in a single instalment based on the delivery of outputs and for the number of days planned to produce these outputs as stated in the above TOR and after clearance by the Evaluation Manager, who will confirm that the outputs meet the quality standards of the IEA. The Team Leader will be expected to provide an account of the activities carried out together with a breakdown of time allocated to these activities. If advances for travel and expenses are needed, they will be arranged with the GCP Director, otherwise they will be reclaimed on production of receipts at the end of the review.

SPECIFIC TERMS OF REFERENCE FOR THE SENIOR TECHNICAL EVALUATOR FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

The Independent Evaluation Arrangement (IEA) of the CGIAR is organizing the final review of the Generation Challenge Program. The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. It will end in 2014.

These Specific Terms of Reference should be read in conjunction with the General Terms of Reference for the review.

4. Overall responsibilities

Under the overall guidance of the Team Leader, the Senior Technical Evaluator will take the lead role for the technical content of the final review of the Generation Challenge Program.

The assignment will take place between August 2013 and January 2014 for up to a total of 40 days, including travel to the GCP in Mexico (CIMMYT) and the GCP General Research Meeting in Lisbon from 27th to 30th September. The Senior Technical Evaluator will be responsible for:

- Review of all technical aspects of the GCP, including those related to application of technologies to plant breeding for particular crops and traits, and the influence and impact of the GCP (in collaboration with the other scientific experts)
- Advising and liaising with the Team Leader on relevant technical aspects of the GCP and contributing to questionnaires, surveys etc. as determined to be necessary
- Identifying those aspects of the GCP that should be evaluated to provide an assessment of the success of the GCP as a model for communicating research results (with the Team Leader)
- Analysis and reporting of the technical findings from surveys, questionnaires and other information sources (with the other scientific experts)
- Assessing the technical information and communication (websites and other means of information dissemination) in terms of technical content, relevance and quality
- Assessing capacity building in the GCP (with the Team Leader)
- Writing the review report based on contributions from all team members, ensuring that all technical aspects of the review are accurately reported (with the Team Leader)
- Other responsibilities identified with the Team Leader

5. Deliverables

- Contribution to a preliminary report (in November 2013) on major findings from the review
- Contribution to the final report on the results of the review using a format and by a date agreed with the Team Leader and the Evaluation Manager
- Provision of timely comments on the draft versions of the report

6. Specific modalities

- Prior to recruitment, the consultant will sign a standard letter confirming the absence of conflict of interest between the proposed assignment and past assignments with the CGIAR
- The consultant will also take note of the evaluation policy, standards and guidelines of the CGIAR

The consultant will work in close collaboration with the Team Leader to provide the required contributions for planning the review and preparing the report and feedback on report drafts. The consultant will be paid in a single instalment based on the delivery of outputs and for the number of days planned to produce these outputs as stated in the above TOR and after clearance by the Evaluation Manager, who will confirm that the outputs meet the quality standards of the IEA. The consultant will be expected to provide an account of the activities carried out together with a breakdown of time allocated to these activities to the Team Leader. If advances for travel and expenses are needed, they will be arranged with the GCP Director, otherwise they will be reclaimed on production of receipts at the end of the review.

SPECIFIC TERMS OF REFERENCE FOR THE MOLECULAR BREEDING EXPERT FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

The Independent Evaluation Arrangement (IEA) of the CGIAR is organizing the final review of the Generation Challenge Program. The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. It will end in 2014.

These Specific Terms of Reference should be read in conjunction with the General Terms of Reference for the review.

7. Overall responsibilities

Under the overall guidance of the Team Leader, the Molecular Breeding Expert will take the lead role for the molecular breeding component of the final review of the Generation Challenge Program.

The assignment will take place between August 2013 and January 2014 for up to a total of 17 days. The Molecular Breeding Expert will be responsible for:

- Advising the review team on relevant aspects of molecular breeding
- Reviewing relevant (to GCP) documents regarding applications of molecular biology to plant breeding
- Contributing to surveys, questionnaires etc.
- Interviewing by phone key GCP staff and partners working on molecular breeding
- Analysis and reporting of the findings as related to molecular breeding from surveys, questionnaires and other information sources
- Reviewing the IBP with the Genetic Resources/Genomics Expert

- Preparation of a draft report on GCP molecular breeding
- Other responsibilities identified with the Team Leader

8. Deliverables

- Contribution to a preliminary report (in November 2013) on major findings from the review
- Contribution to the final report on the results of the review using a format and by a date agreed with the Team Leader, the Senior Technical Evaluator and the Evaluation Manager

9. Specific modalities

- Prior to recruitment, the consultant will sign a standard letter confirming the absence of conflict of interest between the proposed assignment and past assignments with the CGIAR
- The consultant will also take note of the evaluation policy, standards and guidelines of the CGIAR

The consultant will work in close collaboration with the Team Leader to provide the required contributions for planning the review and preparing the report and feedback on report drafts. The consultant will be paid in a single instalment based on the delivery of outputs and for the number of days planned to produce these outputs as stated in the above TOR and after clearance by the Evaluation Manager, who will confirm that the outputs meet the quality standards of the IEA. The consultant will be expected to provide an account of the activities carried out together with a breakdown of time allocated to these activities to the Team Leader. This consultancy will not involve any travel.

SPECIFIC TERMS OF REFERENCE FOR THE GENETIC RESOURCES/GENOMICS EXPERT FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

The Independent Evaluation Arrangement (IEA) of the CGIAR is organizing the final review of the Generation Challenge Program. The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. It will end in 2014.

These Specific Terms of Reference should be read in conjunction with the General Terms of Reference for the review.

10. Overall responsibilities

Under the overall guidance of the Team Leader, the Genetic Resources/Genomics Expert will take the lead role for the genetic resources/genomics component of the final review of the Generation Challenge Program.

The assignment will take place between August 2013 and January 2014 for up to a total of 17 days. The Genetic Resources/Genomics Expert will be responsible for:

- Advising the review team on relevant aspects of genetic resources and genomics, including data management and use
- Reviewing relevant (to GCP) documents regarding genetic resources/genomics
- Reviewing the IBP with the Molecular Breeding Expert
- Contributing to surveys, questionnaires etc.
- Interviewing by phone key GCP staff and partners working on genetic resources/genomics
- Analysis and reporting of findings as related to genetic resources/genomics from surveys, questionnaires and other information sources
- Preparation of a draft report on GCP genetic resources/genomics
- Other responsibilities identified with the Team Leader

11. Deliverables

- Contribution to a preliminary report (in November 2013) on major findings from the review
- Contribution to the final report on the results of the review using a format and by a date agreed with the Team Leader, the Senior Technical Evaluator and the Evaluation Manager

12. Specific modalities

- Prior to recruitment, the consultant will sign a standard letter confirming the absence of conflict of interest between the proposed assignment and past assignments with the CGIAR
- The consultant will also take note of the evaluation policy, standards and guidelines of the CGIAR

The consultant will work in close collaboration with the Team Leader to provide the required contributions for planning the review and preparing the report and feedback on report drafts. The consultant will be paid in a single instalment based on the delivery of outputs and for the number of days planned to produce these outputs as stated in the above TOR and after clearance by the Evaluation Manager, who will confirm that the outputs meet the quality standards of the IEA. The consultant will be expected to provide an account of the activities carried out together with a breakdown of time allocated to these activities to the Team Leader. This consultancy will not involve any travel.

SPECIFIC TERMS OF REFERENCE FOR THE ECONOMIST/M&E EXPERT FOR THE FINAL REVIEW OF THE GENERATION CHALLENGE PROGRAM 2004 – 2014

The Independent Evaluation Arrangement (IEA) of the CGIAR is organizing the final review of the Generation Challenge Program. The Generation Challenge Program (GCP – http://www.generationcp.org) was devised by the CGIAR and began operations in September 2004. It will end in 2014.

These Specific Terms of Reference should be read in conjunction with the General Terms of Reference for the review.

13. Overall responsibilities

Under the overall guidance of the Team Leader, the Economist/M&E Expert will take a lead role for the components of the GCP review that relate to social sciences and M&E processes and practices, with particular reference to evolution of the Program over ten years.

The assignment will take place between August 2013 and January 2014 for up to a total of 11 days. The Economist/M&E Expert will be responsible for:

- Advising the review team on aspects of GCP evolution that relate to social science and economics
- Contributing to surveys, questionnaires, partnership issues etc.
- Interviewing by phone key GCP staff and partners working on economics/M&E
- Assessing the GCP M&E information and its use
- Economic analysis of program components as required
- Preparation of a draft report on GCP economics/M&E
- Other responsibilities identified with the Team Leader

14. Deliverables

- Contribution to a preliminary report (in November 2013) on major findings from the review
- Contribution to the final report on the results of the review using a format and by a date agreed with the Team Leader, the Senior Technical Evaluator and the Evaluation Manager

15. Specific modalities

- Prior to recruitment, the consultant will sign a standard letter confirming the absence of conflict of interest between the proposed assignment and past assignments with the CGIAR
- The consultant will also take note of the evaluation policy, standards and guidelines of the CGIAR

The consultant will work in close collaboration with the Team Leader to provide the required contributions for planning the review and preparing the report and feedback on report drafts. The consultant will be paid in a single instalment based on the delivery of outputs and for the number of days planned to produce these outputs as stated in the above TOR and after clearance by the Evaluation Manager, who will confirm that the outputs meet the quality standards of the IEA. The consultant will be expected to provide an account of the activities carried out together with a breakdown of time allocated to these activities to the Team Leader. This consultancy will not involve any travel.

Annex 2: Short Bios of Panel Members

SACHDEVA, Paramjit S. (Pammi)

Position: Independent Consultant
Expertise: Program and institutional assessment, governance, program and project management, and human resource management in the agricultural research and public health sectors
Education: Ph.D., Social Systems Sciences, the Wharton School, University of Pennsylvania, Philadelphia, 1988; MBA, Organizational behavior and human resource management, the Indian Institute of Management, Ahmedabad, 1971
Experience: As independent consultant, recent clients include the World Bank, FAO, WHO, AGRA, several CGIAR Centers, Islamic Development Bank, and the Global Water Partnership. Prior to this, he worked for over twenty years in the World Bank and the CGIAR, retiring in 2001 as adviser. At the CGIAR Secretariat, he undertook or facilitated comprehensive external assessments (EPMRs) of the governance, strategy, programs, organization, and management of almost all of the CGIAR-supported international agricultural research Centers; and served as member of the CGIAR gender and diversity advisory board, and of various CGIAR task forces and working groups. At ISNAR, he served as Chair of HRM working group and head of training program; and led a research project on the organization and structure of national agricultural research systems in developing countries. More recently, for the CGIAR he has served as a Panel member or Chair for the external reviews of the Sub-Saharan Africa Challenge Program (2010), AfricaRice (2010), and IRRI, IITA, and WARDA (2007). He has also undertaken external reviews of the global LF program (2009 and 2007) and TDR (2004) for the Gates Foundation, WHO, and the World Bank.

EDMEADES, Gregory O. (Greg)

Position: Independent Consultant
Expertise: Agronomy, Plant Physiology and Plant Breeding
Education: Ph.D., University of Guelph, Guelph, Canada, 1976; M. Agric. Sci., Massey University, New Zealand, 1972; B. Agric. Sci, Massey University, New Zealand, 1968
Experience: Greg Edmeades was raised on a dairy farm in New Zealand. Following his education he joined CIMMYT in Mexico in 1976 as a Post Doc. From 1979 to 1984 he led a Canadian-funded project in Ghana, West Africa, aimed at increasing maize and cowpea production at the farm level. He returned to CIMMYT, Mexico where he led a research program focused on developing maize varieties tolerant to drought and low soil fertility. In 1999 he joined Pioneer Hi-Bred Int., and was based in Hawaii but continued to work on field aspects of drought tolerance. In 2004 he returned to New Zealand where he consults as a project reviewer in Africa, SE Asia, East Timor and USA. Greg is a Fellow of the Crop Science Society of America with 50+ peer reviewed publications. As an independent consultant, recent clients include the Bill & Melinda Gates Foundation, ACIAR, the CGIAR, and CIMMYT. He has participated in EPMRs of IRRI (2009) and IITA (2007).

MUMM, Rita H.

Position: Assoc. Professor Emerita; Principal, GeneMax Services
Expertise: Quantitative Genetics, Plant Breeding, Molecular Breeding, Biotechnology, Seed Product Development
Education: Ph.D., University of Illinois, USA, 1993; B.S. Agric. Sci., University of Illinois, USA, 1989; A.S., Joliet Junior College, Joliet, IL, USA, 1987.
Experience: Completing a PhD under John Dudley who was pioneer in molecular marker applications, Rita Mumm joined the seed industry with responsibilities to enable molecular breeding applications for corn breeders at DEKALB Genetics. DEKALB was the first company to develop a breeder-based molecular breeding system, complete with proprietary analysis software, high throughput genotyping services, and databases/flows to bring together field performance data and genotyping information. Rita founded a consulting company in 1999, offering services in molecular breeding applications as well as biotechnology to the wider seed industry. She led development of transgenic product development in cotton, rice, wheat, and specialty crops at Syngenta Biotechnology in 2002 through 2005. And she joined the University of Illinois in 2008 to lead establishment of the Illinois Plant Breeding Center. Rita served as President of the National Association of Plant Breeders in 2011-2012, raising visibility of needs of public breeders and plant breeding education. As a consultant since 1999, programs reviews have been conducted for a number of private and public organizations.

RAFALSKI, Antoni J.

Position: Independent consultant
Expertise: Agricultural Biotechnology and Plant Genomics
Education: Ph.D. and M.Sc. in chemistry, Adam Mickiewicz University, Poznan, Poland
Experience: Until 2013, Antoni Rafalski was a Senior Research Fellow at DuPont Pioneer, Genetic Discovery Group, and headed a research group in Wilmington, Delaware (USA). He was born and educated in Poland. He spent several years as a Visiting Scientist at Yale University, with Prof. Dieter Söll, before joining DuPont Co. At DuPont, Dr. Rafalski was a member of the team which obtained the first DNA sequence of the HIV virus, he was a co-discoverer of RAPD markers, and was involved in the development of SSR markers for soy and maize, in plant EST sequencing program and in the development of maize SNP markers. He was involved in positional cloning of agronomically relevant maize genes and in whole genome scan association mapping (GWAS). He is an Adjunct Professor at the Department of Plant and Soil Sciences, University of Delaware, and serves on the editorial board of several journals. His scientific interests include analysis of organization of plant genomes, plant genetic diversity at the DNA sequence level and application of molecular techniques in plant breeding. http://www.udel.edu/plants/rafalski.htm

BENNETT, Christopher (Ben)

Position: Head, Food and Markets Department, Natural Resources Institute, UK
Expertise: Agricultural trade and marketing economist
Education: M.Soc.Sc, Development Administration, University of Birmingham, 1987; Dip.Ag.Econ University of London, 1993; BA (Hons) Economics, University of Liverpool, 1983

Experience: Ben Bennett started his career in rural Nigeria with the UK agency VSO and, following a research project on international evaluation methods, joined the Evaluation Department of the UK Department for International Development from 1987 to 1989. He then moved to the Natural Resources Institute and was seconded to the European Commission as an agricultural marketing economist in the Philippines (1994-98) and as a agricultural trade adviser in Namibia (1998 to 2005). He has led research and consultancy on a range of socio-economic issues for many donor and private sector organisations. He is currently Head of a Team of 27 natural and social scientists undertaking projects for a range of clients including EC, World Bank, BMGF, Dfid and the Millennium Challenge Corporation. He was Team Leader of the EC Generation Challenge Evaluation in 2008 and has undertaken five external reviews of the CGIAR for the EC.

Dr. Paramjit Sachdeva Independent Consultant 430 Glyndon St., NE Vienna, VA 22180, USA Phone: +1-703-242-8892 Email: pssachdeva@aol.com	**Dr. Gregory Edmeades** Independent Consultant 43 Hemans Street, Cambridge, New Zealand Phone: International: +64-7-823-0918 National: 07-823-0918 Cell: 021-179-1212. Skype contact: Greg.Edmeades Email: greg_edmeades@msn.com
Dr. Rita H Mumm University of Illinois at Urbana-Champaign 1102 South Goodwin Avenue Urbana, IL 61801 Office: 217-244-9497; 217-344-9181 Mobile: 217-778-2969 Email: ritamumm@illinois.edu ; rita.mumm@genemaxservices.com	**Dr. J. Antoni Rafalski** Independent Consultant 908 Fairthorne Avenue Wilmington, DE19807-2266 Mobile: 1-302-893-7147 Email: antoni@rafalski.net ikslafar@gmail.com
Prof. Christopher (Ben) Bennett Head, Food and Markets Department Natural Resources Institute University of Greenwich Medway Campus, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK Tel: +44 (0) 1634 883449 Skype ben.bennett123 Twitter @Bennett123123 ben.bennett@gre.ac.uk; Web: www.nri.org	**Dr. Jonathan Robinson** Independent Consultant (Evaluation Manager, IEA) Via dei Casali delle Cornacchiole, 192, 00178, Rome, Italy Mobile: +358 45 6321443 Email: jrobinsonsirkka@gmail.com

Annex 3: List of Persons Met or Contacted

GCP Executive Board (EB):
Andrew Bennett, EB Chair
Calvin Qualset
Andreas Graner
Harold Roy Macauley
Jeff McElroy
Markus Palenberg

GCP Consortium Committee (CC):
David Hoisington, CC Chair
Fred van Eeuwijk, Wageningen University
Hei Leung, IRRI
Melaku Gedil, IITA
Rajeev Varshney, ICRISAT
Marten van Ginkel, ICARDA
Jurandir Magalhaes, EMBRAPA
Leon Kochian, Cornell University
Reinhard Simon, CIP
Stephen Beebe, CIAT
Ruilian Jing, CAAS
Elizabeth Arnaud, Bioversity International
Jean-Louis Pham, Agropolis
Marie-Noelle Ndjiondjop, AfricaRice

CIMMYT (Host Agency):
Thomas Lumpkin, Director General
Marianne Banziger, DDG Research & Partnership
Kevin Pixley, Program Director, Genetic Resources Program
Tom Short, DDG Corporate Services
Bodupalli Prasanna, Director Global Maize Program
Johanna Herremans, Director, International Finance
N. P Rajasekharan, Director, International Human Resources
Adriana Gonzalez, Head of Finance
Marisa De La O Elizagaray, Risk Management & International Policy Manager
Isabel Vianey Pena Mendoza, Institutional Relations for Latin America
Dave Watson, Program Manager - MAIZE
Victor M. Kommerell, Program Manager - WHEAT
Susane Dreisigacker, Wheat Molecular Breeder
Jens Riis-Jacobsen, Director, Int. Systems and Info. Technology
Jose Crossa, Consultant
Matthew Reynolds, Wheat Physiologist

Denise Costich, Maize Germplasm Bank Curator

GCP staff:

Jean-Marcel Ribaut, Director
Xavier Delannay, ex-Acting Research Director and ex-Leader, Theme 3
Graham McLaren, Consultant, Theme 3 – Crop information systems
Ndeye Ndack Diop, Leader, Theme 4 – Capacity building; TLI Project Manager
Larry Butler, Leader, Theme 5 – Product delivery, Cassava Facilitator
Arllet Portugal, Data Management Leader/Contact Point for Mexico Development Team
Chunlin He, Breeding Services Manager
Mark Sawkins, Configurable Workflow System Manager
Fred Okono, Knowledge Manager and IBP Project Administrator
Adriana Santiago, Project Officer
Antonia Okono, Communications Manager
Gillian Summers, Communications Assistant
Griselda Marquez, Executive Assistant
Sandra Morales, Administrative Coordinator
Shawn Sullivan, Legal Advisor
Rajeev Varshney, ICRISAT, ex Theme Leader, Genomics
Hei Leung, IRRI, ex Theme Leader, Genomics

Stewart Andrews, CEO, VSN International
Harold Urman, survey consultant, Partner, Vital Research

Product Delivery Coordinators:
Pooran Gaur, ICRISAT, chickpea
Emmanuel Okogbenin, NRCRI, cassava
Ousmane Boukar, IITA, cowpea
Vivek Bindiganavile, CIMMYT, maize
Nourollad Ahmadi, CIRAD, rice
Jean-Francois Rami, CIRAD, sorghum
Steve Beebe, CIAT, bean
Hei Leung, IRRI, rice
Ousmane Boukar, IITA, cowpea
Leon Kochian, Cornell University, comparative genomics
Richard Trethowan, University of Sydney, wheat
Niaba Teme, IER

Donors:
Carmen Thoennissen, Swiss Development Corporation (SDC)
David Berginson, Deputy Director, Bill & Melinda Gates Foundation
Gary Atlin , Projects Officer, Bill & Melinda Gates Foundation

GCP Consultant

Hannibal Muhtar, Agricon, Canada (by Skype)

Consortium Committee and CIMMYT Board of Trustees
John Snape, JIC, United Kingdom (by Skype)

CGIAR Independent Evaluation Arrangement (IEA):
Rachel Bedouin, Head, IEA
Jonathan Robinson, Evaluation Manager, IEA

Annex 4: Documents Consulted

External Evaluations and Reviews of the GCP:

1. Evaluation of the EC Contribution to the CGIAR – Country Note on GCP, CIMMYT, Mexico (2007)
2. Annual Research Meeting (ARM) Survey Results (2007, 2008)
3. First External Program and Management Review (EPMR) undertaken by the CGIAR (2008)
4. External Reviews undertaken by the European Commission (EC) (2008, 2010, and 2011)
5. The CGIAR Challenge Programme Experiences: A Critical Analysis (6 February 2009)
6. Report by the Scientific and Management Advisory Committee (SiMAC) for IBP (2010)

Documents prepared by the GCP:

Formal Agreements:

7. Consortium Agreement (10 August 2004)
8. Amended Consortium Agreement (15 July 2009)
9. Host Agent Agreement (1 January 2007)
10. Resolution of the Program Steering Committee (PSC) of the GCP regarding deference by the Committee to Certain Governance Decisions of an Executive Board (9 December 2007)
11. Amended Host Agent Agreement (1 October 2009)
12. Memorandum of Understanding (MoU) with the Global Crop Diversity Trust (GCDT) 2006
13. Memorandum of Understanding (MoU) with iPlant Collaborative (2011)
14. Consortium Termination Agreement (draft) 2013

GCP's Strategies:

15. Proposal to establish the Challenge Program on Genetic Resources (6 February 2003)
16. Product Delivery Strategy 2005
17. Product management, delivery and distribution strategy
18. GCP's Strategic Framework (2007)
19. GCP Transition Strategy 2011-2013 (May 2010)

GCP Policies:

20. Standard terms and conditions for GCP grant recipients
21. Policy on Global Access (May 2011)
22. Policy on IP (June 2008)
23. Subsistence Use Agreement (November 2005)
24. Statement on the Use of Transgenics (9 November 2005)
25. Policies on Data availability, and Publications

Annual Reports and Mid-Term Plans:

26. All Annual Reports and workplans, for each of the years 2003-2010
27. Technical Report for 2011
28. All seven Mid-Term Plans, on a 3-year rolling basis, for the period 2005-2013

Impact:

29. All five Pathways to Impact briefs, and associated reports
30. Research, partner & product highlights 2005-2006
31. Project Briefs, for each of the years 2007-2012
32. Project Updates (2013)
33. List and overview of variety releases and updates
34. List and overview of socio-economic studies

Project Management:

35. Workflow Management System (WMS)
36. System for managing contracts and subcontracts
37. System for project reporting (including project finance)
38. Project Delivery Plans and DPKit (2007)
39. Templates for commissioned projects and competitive projects

Capacity Building:

40. CB Strategy in GCP Phase II
41. CB Strategy-budget
42. Integrated Breeding—Multi-Year Course (IB-MYC) description
43. Agenda for various courses (data management, molecular breeding, statistics etc.)

African Stations Reports (2010-2012):

44. Reports on stations at Egerton University, Moi University, and various research centers
45. Reports on visits to Burkina Faso, Niger, Nigeria, Mali, Ghana, Ethiopia, and Kenya

GCP's Transition:

46. Videos interview with the GCP EB's Chair relating to the GCP's sunset
47. All eleven White Papers related to GCP's sunset, covering: (1) Programme overview; (2) Research synthesis; (3) Genetic stocks; (4) Genomic resources; (5) Informative molecular markers; (6) Cloned genes; (7) Molecular breeding; (8) Services: the Integrated Breeding Platform; (9) Capacity building and learning materials; (10) GCP's scientific and social network; and (11) GCP's institutional memory (drafts, 2012-2013)
48. "Mapping the Future", preliminary summary report on a broad survey of a possible post-GCP successor entity, (March 2012)
49. GCP Transition Overview Paper (March 2013)

Integrated Breeding Program (IBP) documents:

50. White Paper: Moving towards Phase II of the Integrated Breeding Platform (draft for discussion, 14 August 2013)
51. Concept Note Integrated Breeding Platform (IBP): Phase II (October 2013)
52. Draft Project Proposal submitted to the Bill & Melinda Gates Foundation (2013)

Minutes, Background Papers, and Power-point Presentations for:

53. All eleven Executive Board (EB) meetings (2008-2013)

54. All five Consortium Committee (CC) meetings (2009-2013)
55. All five Program Steering Committee (PSC) meetings (2004-2008)
56. The General Research Meeting (GRM) and IBP Phase II Brainstorming, Lisbon (September-October 2013)
57. The Transition Taskforce, IBP Phase II Governance Taskforce, and Closure Working Group meetings (2013)

Documents on the GCP website:

58. Brochures, slides and introduction video on the GCP
59. Early History – the GCP Manual and its related Appendixes
60. Brochure (December 2008) – "Looking back on Phase I and moving on to Phase II and the future"
61. Overview of GCP's vision, mission, objectives, and research organization
62. Overview of GCP's governance and advisory bodies (Executive Board, Consortium Committee, Intellectual Property Advisory Committee (IPAC; for the EB), Scientific and Management Advisory Committee (SiMAC; for the IBP), and the Transition Taskforce
63. List of Principal Investigators (PIs) for 2006-2009, and for each of the years 2010-2013
64. List and profiles of Product Delivery Coordinators
65. List of GCP staff (2013) for Management, Finance and Project Management, Communication, Integrated Breeding Program (IBP), and Administration
66. List of GCP Funders for each of the years 2003-2013
67. List and overview of consortium members, network partners, and collaborators
68. Overview of research (initiatives, themes, projects, and the general research meeting (GRM))
69. Agenda, programme, participants, and updates on the GRM for each of the years (2004-2013)
70. Brochures, slides, and videos on GCP's platforms (Integrated Breeding Platform (IBP); Capacity Building; and Crop Information systems)

Media:

71. News and updates, press releases, GCP in the media, feature stories, and events (on a sample basis)

Other Reports:

72. Audit of the GCP Risk Management System (2007 and 2010), prepared by CGIAR's Internal Audit Unit (IAU)

Publications:

73. Working and Discussion Papers, for 2006-2008 (on a sample basis)
74. Conference and workshop proceedings, for 2005-2012 (on a sample basis)
75. Journal articles published by GCP staff and partners, for 2006-2013 (total 448; on a sample basis)
76. Book chapters published by GCP staff and partners, for 2009-2012 (total 7; on a sample basis)

Other CGIAR Documents:

77. Proposals and selected reports for CRPs on maize, wheat, rice, grain legumes, and dryland cereals (2010 and 2011)
78. CIMMYT Staff Handbook of Human Resource Management Policies (2013)
79. CIMMYT Combined Financial Statements and Schedules (December 31, 2012 and 2011), with Independent Auditor's Report Thereon)
80. Guidance for CRP 2nd Call (draft, version 2), Consortium Office (August 2013)

Annex 5: Evaluation Matrix for the GCP Review2 (as received with TORs for rough guidance)

Criterion	Evaluation question	Expected evaluation product	Expected approach and information sources[3]
Relevance – past, present and future	• To what extent has the GCP provided for people of diverse backgrounds to think collectively about solutions to complex problems and to learn from one another? • What was the extent of the demand for GCP products from intended and other, potential beneficiaries? • At its inception, was there a founding logic, logframe, baseline, or theory of change of GCP? • To what extent were the issues addressed by the GCP the most important being faced by national crop improvement programs? • Was GCP developing a suite of procedures, germplasm and databases that were a "solution" looking for a problem? • To what extent has the GCP provided essential genomic services to plant breeders in developing countries? • Did the GCP build on the comparative advantages of international partners in delivering its products/messages? • Did the GCP crowd out any competitors in terms of research institutions/programs, including those in the private sector? • Did the GCP build on the latest scientific thinking and research results? • Were the objectives of the GCP and the methods it promoted always valid through changing circumstances and evolution of the science? • Is there evidence that GCP objectives have been changed since program inception? • Did the GCP have clear impact pathways for its activities and outputs?	• Concise synthesis of GCP activities in comparison with evolving needs of clients and developments in the applied science. • Time series data and analysis of use of GCP products. • Assessment of the extent to which services have been offered and taken up by prospective clients.	Partner survey. GCP data from its monitoring and evaluation activities. Interviews with GCP staff. Discussions with donors and other stakeholders.

[2] This matrix is not meant to represent a recipe for carrying out the review; it is meant to stimulate discussion among the Review Team members and help identify the most important questions that need answering. Some of the most important questions might not be apparent until the review has got underway.

[3] A considerable amount of information will be got from project documentation held by the GCP.

Effectiveness	• To what extent were planned outputs and outcomes achieved? • What factors had a major effect on GCP outputs and outcomes? Were these external or internal to the GCP? • Were rapid technological change and change in scientific understanding of the complexity of the targeted traits a factor? • Were staff turnover in key positions, and transaction costs of projects and networks, reasonable? • How were the GCP activities monitored and evaluated and how successful were these? • Did the GCP set new standards for provision of information, data collection etc.? • Did GCP clearly indicate a pathway for determining the value of traits being measured? • Recognizing that 10 years is a relatively short time span, is it possible to give examples where molecular breeding methods and resources developed by GCP are increasing the rate of genetic gain? • What were the unforeseen outputs and outcomes? • Is the GCP's organisational structure and partnership network still appropriate and could this represent a model the future? • Was the governance structure adopted appropriate? • How effective were GCP at communicating their results? • How were overarching issues covered – eg. Gender, poverty impact, environment? • What was the role of scientifc advisory boards in determining the changing scientific focus of projects?	• Analysis of documented expectations versus realised achievements. • Documentation of progress in achieving expectations with changes in management, funding, developments in science, client requirements etc.	GCP documentation. GCP staff interviews. Partner survey.
Efficiency	• Were adequate resources available and used according to plan and adjusted appropriately? • Were all potential partnerships realised? • What evidence is there for adaptive management in the GCP? • Were there any clear areas of inefficiency? • Were costs commensurate with outputs in (a) NARS of developing countries and	• Summary of resource inputs and outputs over ten years. • Description of coverage of GCP partnerships and identification of gaps by location, organization type	GCP monitoring and evaluation data. GCP staff interviews. Partner survey.

	(b) Collaborating ARIs and IARCs? • How well did partnerships and networks function? What measures were used by GCP to minimise transaction costs of these? • Could the same result have been achieved more cost effectively another way? • What voice have development partners, clients and stakeholders had in GCP implementation • Did CIMMYT provide good value for the overhead it received? • Did the host center CIMMYT contribute to increasing the efficiency of GCP, and in what ways?	etc.	
Impact	• Have there been major impacts of integrated breeding approaches on crop productivity in developing countries as a result of the GCP? What processes in the food production value chain have been most affected by the GCP? • What GCP sponsored training activities have had the greatest impact in changing client behaviours? • What have the major spillover effects of the GCP been? Have these been greatest among NARS in developing countries or in ARIs? • To what extent has the GCP been influential within the research community? • Have the GCP communications products and website played an important role in determining impact? • Where have the major impacts of the GCP been measured? • Have all opportunities to register an impact been taken by the GCP? • What impact has GCP had on policy?	• Synthesis of GCP activities and changes that have come about from partners' viewpoints. • Identification of unplanned outputs and outcomes (positive and negative) that have made a difference to partner operations.	Partner survey. Staff interviews. Bibliometric analysis. Analysis and interpretation of indicator data.
Sustainability	• What plans have GCP made for delivery of its services ex-post? • How are these facilities going to be continued after the end of the project? • Does the GCP need to be sustained (wholly or in part) or has it achieved its goals? • What is the time frame for sustaining GCP activities? • What are the components of the GCP that should be sustained and those that need not be?	• An assessment of whether the GCP as a program type and as a specific entity could be usefully sustained. • Identification of GCP components that	Discussions with GCP staff and donors. Partner survey. Discussion with leaders of commodity CRPs.

	• What will happen to the GCP databases and should attempts be made to merge them with others (such as GENESYS)? • What estimates are available for the costs of sustaining the various GCP components? • What are the specific plans for the Integrated Breeding Platform and other web-based tools and information sources? • What is the nature of alternative suppliers for GCP-type outputs now and in the future? • What business cases have been developed to sustain future germplasm delivery? • What is the envisaged role of private vs. public breeding in assuring transfer of the germplasm resources and deverlopment / acceptance of the finished line/cultivars?	could/should have life beyond the Program deadline. • Assessment of the extent to which the commodity CRPs are able to take on parts of the GCP agenda.	
Quality of science	• What effect has the GCP had on the quality of science of other programs in terms of breeding and genomics (particularly, but not solely, in the CGIAR and in NARS)? • Has the quality of science in GCP been "fit for purpose"? • Has the GCP been up-to-date or even leading in particular areas of science (has it set new standards in any areas)? • Were processes such as competitive grants used appropriately to assure quality and meet ambitions? • What have been the main scientific outputs of the GCP and how have they been rated? • Is the emphasis on peer-review publications appropriate to the mandate of the GCP? • How would you rate the processes of internal review in GCP? • To what extent did GCP staff benefit from in-service training offered by CIMMYT or other IARCs? • Role of scientific advisory boards in assuring quality of science?	• An assessment of the influence that the GCP has had in its areas of expertise/intervention on other programs within and outside the CGIAR. • An assessment of the extent to which the GCP has remained up-to-date with molecular biology applied to plant breeding and communication of information useful to its partners.	Discussions with representatives of similar programs within and outside the CGIAR. Bibliometric analysis. Survey of the quality of GCP products such as publications, patents etc. Personal expert opinions.

Annex 6: Review Team's Assessment of selected scientific papers and literature cited

Table A6.3. GCP peer-reviewed journal articles evaluated by the Review Team

Statistics: Number of articles = 29; Average number of citations: average = 45 (Standard deviation = 55; Maximum = 236; minimum = 0; average year of publication 2010). Sample selected by the Panel on the basis of its ability to evaluate the quality of the science in genomics and to a lesser degree phenotyping and prioritization. It represents only 6% of total papers, so statistics should be treated with considerable caution.

No. Year	Citations	Article	Comments
1 2013	2	Billot C, Ramu P, Bouchet S, Chantereau J, Deu M, Gardes L, Noyer J-L, Rami J-F, Rivallan R, Li Y, Lu P, Wang T, Folkertsma RT, Arnaud E, Upadhyaya HD, Glaszmann J-C, Hash CT (2013). Massive sorghum collection genotyped with SSR markers to enhance use of global genetic resources. PLoS One 8(4): e59714. (DOI: 10.1371/journal.pone.0059714	Germplasm genotyping and genetic resource development, although SNPs would be better than SSRs for this application. Still, the results of SSR genotyping are valid (even though heteroplasmy and homoplasmy may in some cases confuse results). So far not highly cited, but only published in 2013.
2 2011	21	Chin JH, Gamuyao R, Dalid C, Bustamam M, Prasetiyono J, Moeljopawiro S, Wissuwa M, and Heuer S (2011). Developing rice with high yield under phosphorus deficiency: Pup1 sequence to application. Plant Physiology 156(3):1202–1216.	Salt tolerance and P utilization efficiency are among the important successes of GCP, based on understanding the genes involved. Pup1 was fine mapped to 278 kb, and the three haplotype groups were characterized, one of them tolerant to low P. Diagnostic markers throughout the region were developed, and *Pup1* tolerant allele was introgressed into two irrigated varieties which lacked the tolerant allele. Important paper with good science and applied aspects.
3 2008	16	Conte M, Gaillard S, Droc G and Perin C (2008). Phylogenomics of plant genomes: A methodology for genome-wide searches for orthologs in plants. BMC Genomics 9:183	Example of a paper in the area of computational comparative genomics – identification of (putative) orthologs is very important step and could be quite challenging between more distantly related species.
4 2009		Ehlers JD, Sanden BL, Frate CA and Roberts PA (2009). Registration of 'California Blackeye No. 50 Cowpea'. Journal of Plant Registrations 3:236–240.	This is the ONLY variety registration paper in the available list!
5 2010	47	Famoso AN, Clark RT, Shaff JE, Craft E, McCouch SR, Kochian LV (2010). Development of a novel	Useful but limited study. Rice is more tolerant of soil Al than other cereals and may have unique

		aluminum tolerance phenotyping platform used for comparisons of cereal aluminum tolerance and investigations into rice aluminum tolerance mechanisms. Plant Physiology 153: 1678–1691	tolerance mechanisms. Developed a modified hydroponic medium that maintained Al in solution and showed tolerance by relative root growth. Tolerance was rice>maize>sorghum >=wheat. Mechanism in maize was citrate /malate exudation, but not in rice which has higher tolerance of Al in the root tip. Regrettably this was not extended to test differences in tolerance during the reproductive and grain fill stages.
6 2008	27	Gao S, Martinez C, Skinner DJ, Krivanek AF, Crouch JH and Xu Y (2008). Development of a seed DNA-based genotyping system for marker-assisted selection in maize. Molecular Breeding 22:477-494	Seed-based genotyping has now been well established and it helped accelerate molecular breeding. Currently dry (non-imbibed) seeds are used.
7 2009	41	Ghislain M, Núñez J, Herrera MdR, Pignataro J, Guzman F, Bonierbale M and Spooner DM (2009). Robust and highly informative microsatellite-based genetic identity kit for potato. Molecular Breeding 23:377–388	Tools for molecular breeding of potato. SSRs are slowly becoming obsolete, due to high labor cost of genotyping. However, SSRs are very informative in a forensic type application -- unambiguous identification of specific varieties. Potato is not a focus crop for GCP at this point.
8 2014	0	Hamidou, F., A. Rathore, F. Waliyar, and V. Vadez. 2014. Although drought intensity increases aflatoxin contamination, drought tolerance does not lead to less aflatoxin contamination. Field Crops Research 156: 103-110.	Useful and very relevant study, just published. Aflatoxin is a major contaminant of groundnuts and is carcinogenic. Drought increased aflatoxin levels in the reference groundnut set, but within drought levels there was no relationship between aflatoxin levels and drought tolerance suggesting independent mechanisms. Aflatoxin measures had low heritability, and may explain results.
9 2009	41	Heuer S, Lu X, Chin JH, Tanaka JP, Kanamori H, Matsumoto T, De Leon T, Ulat VJ, Ismail AM, Yano M and Wissuwa M (2009). Comparative sequence analyses of the major QTL Phosphate uptake 1 (Pup1) reveal a complex genetic structure. Plant Biotechnology Journal 7:456–471.	One of a number of papers on phosphate uptake trait.
10 2008	57	Hougaard BK, Madsen LH, Sandal N, Moretzsohn MC, Fredslund J, Schauser L, Nielsen AM, Rohde T, Sato S, Tabata S, Bertioli DJ and Stougaard J (2008). Legume anchor markers link syntenic	Example of a comparative genomics paper establishing syntenic regions between relevant target species, using genic polymorphisms that could be used across several species. A larger

		regions between Phaseolus vulgaris, Lotus japonicus, Medicago truncatula and Arachis. Genetics 179:2299-2312.	number of markers would be desirable, but the work represents state of the art at the time. Publication in a highly visible journal and important topic, as well as relevance for several legume species including models contributed to good citation frequency.
11 2008	29	Hyman G, Fujisaka S, Jones P, Wood S, de Vicente MC and Dixon J (2008). Strategic approaches to targeting technology generation: Assessing the coincidence of poverty and drought-prone crop production. Agricultural Systems 98:50-61	Paper widely used by GCP, used to define crops forming RIs, yet little cited. Describes frequency of poverty (stunting) and drought in major farming systems in the tropics using GIS and subjective boundaries based on expert knowledge. Study shows 13 crop species mainly affected but predominance of rice based systems when weighted by population. Study criticized by PSC for use of failed seasons as indicator of incidence of drought.
12 2007	3	Jayashree B, Hanspal MS, Srinivasan R, Vigneshwaran R, Varshney RK, Naya S, Eshwar K, Ramesh N, Chandra S and Hoisington DA (2007). An integrated pipeline of open source software adapted for multi-CPU architectures: use in the large-scale identification of single nucleotide polymorphisms. Comparative and Functional Genomics 2007, Article ID 35604 7 pp (DOI: 10.1155/2007/35604)	Example of a paper describing development of computational tools for the discovery of SNP markers. Panel was not able to examine to what extent this tool was adopted and is in use. The pipeline was established at ICRISAT, and reported to be available for non-profit use. The web address given in the paper is no longer functional, which may explain its poor citation record. Also, many similar pipelines have been established so users have a choice of tools. ICRISAT web site has a link to another SNP discovery pipeline, which may be related to the one described here.
13 2007	236	Magalhães JV, Liu J, Guimarães CT, Lana UGP, Alves VMC, Wang YH, Schaffert RE, Hoekenga OA, Piñeros MA, Shaff JE, Klein PE, Carneiro NP, Coelho CM, Trick HN and Kochian LV. 2007. A gene in the multidrug and toxic compound extrusion (MATE) family confers aluminum tolerance in sorghum. Nature Genetics 39:1156–1161.	Example of successful gene discovery for a trait of importance in GCP target geographies. Excellent science with important applications. Positional cloning was used to clone the gene, and mode of action was proposed: Al-inducible production and root secretion of citrate which complexes aluminum in the soil. This work enabled the identification of different functional alleles of the Al-tolerance gene. One of a series of papers on this topic from L. Kochian and collaborators. Well cited and highly visible work in a high impact journal.
14	10	Maron LG, Guimarães CT, Kirst M, Albert PS,	This is one of a series of high impact papers from

2013		Birchler JA, Bradbury P, Buckler ES, Coluccio AE, Danilova TV, Kudrna D, Magalhães JV, Piñeros MA, Schatz MC, Wing RA, Kochian LV (2013). Aluminium tolerance in maize is associated with higher MATE1 gene copy number. PNAS, published online March 11, 2013	Leon Kochian and collaborators. These authors have elucidated mechanism of aluminum tolerance in several crop species, including sorghum and maize. This paper shows that copy number variation of the MATE1 gene underlies resistance in rare tolerant lines. It is one of the first examples demonstrating the phenotypic effect of copy number variation in maize.
15 2006	94	McNally KL, Bruskiewich R, Mackill D, Leach JE, Buell CR, Leung H (2006). Sequencing multiple and diverse rice varieties: Connecting whole-genome variation with phenotypes. Plant Physiology 141:26-31.	Large scale discovery of SNPs in 20 rice varieties. Data is available on the Web. This article provides a general description of GCP-supported rice SNP discovery / genotyping / phenotyping project, and essentially represents a review-type article. The actual data are in an important PNAS paper (McNally KL et al, PNAS July 28, 2009 vol. 106 no. 30 12273-12278). The PNAS article is widely cited = 187 citations. Resequenced microarrays were used to interrogate 100 Mb of the single-copy fraction of the reference genome for 20 diverse varieties and landraces that capture genotypic and phenotypic diversity of domesticated rice. Distribution of 160,000 non-redundant SNPs was reported. The Affymetrix array re-sequencing was appropriate at the time. Today, one would probably use a next generation sequencing approach.
16 2009	184	McNally KL, Childs KL, Bohnert Regina, Davidson Rebecca M, Zhaoe Keyan, Ulata Victor J, Zellerc Georg, Clark Richard M, Hoeng DR, Bureaug TE, Stokowskih R, Ballingerh DG, Frazerh KA, Coxh DR, Padhukasahasrame B, Bustamantee CD, Weigelf D, Mackill DJ, Bruskiewich RM, Ratschc G, Buell CR, Leung H and Leach JE (2009). Genomewide SNP variation reveals relationships among landraces and modern varieties of rice. PNAS 106:12273–12278.	Important work on genome diversity in rice, in a high-impact journal. See notes above under Nature Genetics paper by McNally et al.
17 2008	21	Muchero W, Ehlers JD and Roberts PA (2008). Seedling stage drought-induced phenotypes and drought-responsive genes in diverse cowpea genotypes. Crop Science 48:541-552	An incomplete study of moderate to low relevance, of staygreen effects on 14 cowpea genotypes conducted in California. No grain yields are measured and no quantitative justification of the choice of the trait – is it correlated with grain yield under stress?
18	75	Muchero W, Diop NN, Bhat PR, Fenton RD,	Genetic map of cowpea – important step

2009		Wanamaker S, Pottorff M, Hearne S, Cisse N, Fatokun C, Ehlers JD, Roberts PA and Close TJ (2009). A consensus genetic map of cowpea [Vigna unguiculata (L) Walp.] and synteny based on EST-derived SNPs. PNAS 118:849–863.	towards understanding the genome and developing most effective molecular breeding tools. High-impact journal.
19 2010	36	Raju NL, Gnanesh BN, Lekha P, Jayashree B, Pande S, Hiremath PJ, Byregowda M, Singh NK and Varshney RK (2010). The first set of EST resource for gene discovery and marker development in pigeonpea (Cajanus cajan L.). BMC Plant Biology 10:45	Development of marker resources in pigeonpea – one of the major objectives of GCP is development of resources for such crops. Sequences were deposited in GenBank. Since four different genotypes were used for making the EST libraries, polymorphic genic markers were also identified (SNPs and SSRs). Highly relevant.
20 2010	15	Rudi N, Norton GW, Alwang J, and Asumugha G (2010). Economic impact analysis of marker-assisted breeding for resistance to pests and post harvest deterioration in cassava. African Journal of Agricultural and Resource Economics 4: 110-122.	One of v. few papers addressing economics of MAS. Probably deserves more attention, but publication in a relatively obscure journal may limit access.
21 2013	6	Schroeder JI, Delhaize E, Frommer WB, Guerinot ML, Harrison MJ, Herrera-Estrella L, Horie T, Kochian LV, Munns R, Nishizawa NK, Tsay Y-F, Sanders D. 2013. Using membrane transporters to improve crops for sustainable food production. Nature 497: 60–66.	This is a review/concept article in a very high impact journal. Written by several well-respected authors it is likely to have high impact and influence future research.
22 2010	14	Shrestha R, Arnaud E, Mauleon R, Senger M, Davenport GF, Hancock D, Morrison N, Bruskiewich R and McLaren G (2010). Multifunctional crop trait ontology for breeders' data: field book, annotation, data discovery and semantic enrichment of the literature. AoB Plants Volume 2010: plq008 11 p. ISSN: 2041–2851 (online: DOI:10.1093/aobpla/plq008	This important but not widely cited paper describes the thorough approach taken by GCP to defining crop ontologies (traits) and standardizing their measurement. Have crop-specific ontologies in 6 crops. These were validated by breeders, arranged in subclasses and form an important part of the IBP database. Available as a look-up service. Useful to have shown relationship of traits to yield under drought.
23 2007	84	Spooner DM, Nuñez J, Trujillo G, del Rosario Herrera M, Guzmán F and Ghislain M (2007). Extensive simple sequence repeat genotyping of potato landraces supports a major re-evaluation of their gene pool structure and classification. PNAS 104(49):19398–19403 (DOI:	This paper uses SSRs to address gene pool structure of potato. Example of germplasm resource paper, although we now know that SSRs may not be the most appropriate tool (this work was done before SNPs became widely used in potato).

		10.1073/pnas.0709796104).	
24 2013	2	Swamy BPM, Ahmed HU, Henry A, Mauleon R, Dixit S, Vikram P, Tilatto R, Verulkar SB, Perraju P, Mandal NP, Variar M, Robin S, Chandrababu R, Singh ON, Dwivedi JL, Das SP, Mishra KK, Yadaw RB, Aditya TL, Karmakar B, Satoh K, Moumeni A, Kikuchi S, Leung H, Kumar A (2013). Genetic, physiological, and gene expression analyses reveal that multiple QTL enhance yield of rice mega-variety IR64 under drought. PLoS ONE 8(5):e62795. (DOI: 10.1371/journal.pone.0062795).	Shows remarkably large effect QTLs for drought that have been successfully transferred from the donor lines to IR64 using MABC, affecting mainly root traits and giving yield increases of 528-1875 kg/ha under reproductive-stage stress. No apparent yield drag. This paper presents one of the most striking outcomes from GCP-led research in drought tolerance identification and exploitation.
25 2008	51	Upadhyaya HD, Dwivedi SL, Baum M, Varshney RK, Udupa SM, Gowda CLL, Hoisington D and Singh S (2008). Genetic structure, diversity, and allelic richness in composite collection and reference set in chickpea (Cicer arietinum L.) BMC Plant Biology 8:106.	Development of a germplasm set representing SSR allelic diversity in chickpea. This is a useful approach to the development of a "maximum alleles in minimum number of lines" set of germplasm. Relatively few SSR markers were used (48), which was appropriate at the time the work was done, but currently one would use a larger number of SNPs. Rather well cited, given that chickpea is not a model species.
26 2012	5	Upadhyaya HD, Kashiwagi J, Varshney RK, Gaur PM, Saxena KB, Krishnamurthy L, Gowda CLL, Pundir RPS, Chaturvedi SK, Basu PS and Singh IP (2012). Phenotyping chickpeas and pigeonpeas for adaptation to drought. **Frontiers in Plant Physiology** 3:179. (DOI: 10.3389/fphys.2012.00179).	A general overview of the role of phenotyping in characterizing genetic variability through reference sets and minicore collections. Several putative drought tolerance traits are suggested but in only one (root depth) is the relationship between and grain yield explored quantitatively, and no indication is given of yield penalties under unstressed conditions. Rigour of science is therefore less than satisfactory.
27 2010	43	Varshney RK, Penmetsa RV, Dutta S, Kulwal PL, Saxena RK, Datta S, Sharma TR, Rosen B, Carrasquilla-Garcia N, Farmer AD, Dubey A, Saxena KB, Gao J, Fakrudin B, Singh MN, Singh BP, Wanjari KB, Yuan M, Srivastava RK, Kilian A, Upadhyaya HD, Mallikarjuna N, Town CD, Bruening GE, He G, May GD, McCombie R, Jackson SA, Singh NK, Cook DR (2010). Pigeonpea genomics initiative (PGI): an international effort to improve crop productivity of pigeonpea (Cajanus cajan L.). Molecular Breeding 26(3):393–408.	This initiative was successful – see one of the later papers.

28 2011	83	Varshney RK, Chen W, Li Y, Bharti AK, Saxena RK, Schlueter JA, Donoghue MTA, Azam S, Fan G, Whaley AM, Farmer AD, Sheridan J, Iwata A, Tuteja R, Penmetsa RV, Wu W, Upadhyaya HD, Yang S-P, Shah T, Saxena KB, Michael T, McCombie WR, Yang B, Zhang G, Yang H, Wang J, Spillane C, Cook DR, May GD, Xu X and Jackson SA (2011). Draft genome sequence of pigeonpea (Cajanus cajan), an orphan legume crop of resource-poor farmers. Nature Biotechnology. Published online November 2011.	First draft genome of pigeonpea – an important example of the contributions of GCP funded research to the understanding of underfunded crops. This work will provide basis for molecular studies of Cajanus species for years to come.
29 2013	26	Varshney RK, Song C, Saxena RK, Azam S, Yu S, Sharpe AG, Cannon S, Baek J, Rosen BD, Tar'an B, Millan T, Zhang X, Ramsay LD, Iwata A, Wang Y, Nelson W, Farmer AD, Gaur PM, Soderlund C, Penmetsa RV, Xu C, Bharti AK, He W, Winter P, Zhao S, Hane JK, Carrasquilla-Garcia N, Condie JA, Upadhyaya HD, Luo M-C, Thudi M, Gowda CLL, Singh NP, Lichtenzveig J, Gali KK, Rubio J, Nadarajan N, Dolezel J, Bansal KC, Xu X, Edwards D, Zhang G, Kahl G, Gil J, Singh KB, Datta SK, Jackson SA, Wang J & Cook DR (2013). Draft genome sequence of chickpea (Cicer arietinum) provides a resource for trait improvement. Nature Biotechnology (2013). (DOI:10.1038/nbt.2491).	First draft genome of chickpea – an important example of the contributions of GCP funded research to the understanding of underfunded crops, genomics, and tool development for comparative genomics. This work will provide basis for molecular studies of Cicer for years to come.

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Annex 7. The Integrated Breeding Platform (IBP)

The primary goal of the IBP is to improve the efficiency of NARS' plant breeding programmes, especially those involving MB, through 'a one-stop shop' that provides breeder support for a full range of MB activities. The IBP comprises a series of linked computer tools for managing and mining information, supported by documentation, training and user support (Box 5.1) and its own website (https://www.integratedbreeding.net/).

Box 7.1: What is the IBP?

The primary goal of the IBP is to improve the efficiency of NARS' plant breeding programmes, especially those involving MB, through 'a one-stop shop' that provides breeder support for a full range of MB activities. The IBP comprises a series of linked computer tools for managing and mining information, supported by documentation, training and user support. These tools manage seed inventory; assigning of unique germplasm IDs; nursery fieldbook generation; trial design/set-up; analysis/interpretation of phenotypic and genotypic data; and line selection and recombination. The heart of the IBP is the Integrated Breeding Workflow System (IBWS) – where the software tools are arranged in logical order that manages the flow of data in a typical breeding cycle. Common breeding systems such as marker–assisted recurrent selection (MARS) and marker-assisted backcrossing (MABC) are supported by software modules. The IBP facilitates MB and incorporates Crop Information Systems. It is still being developed, though future developments are largely to increase its robustness and its user interface.

In its fully functional form, tools/apps comprising the IBP will include:

- IB WorkBench: configures workflow into series of discrete operations.
- Breeding Manager: manages seed inventory, pedigree information.
- IB Field Trial Management System: based on standardized crop ontology and contains functions for data import/export and analysis.
- IB Genotypic Data Management System: facilitates graphic display of genetic maps.
- IB Analytical Pipeline: single and multi-site data analysis based on GenStat (e.g. Breeding View) and R script, and identifies QTL.
- IB Decision Support System: includes support for selection with MAS, MARS (e.g. OptiMAS, see Valente et al., 2013) and MABC applications, index selection, and cost-benefit analysis.

Services and other resources that are planned to interface with the IBP include:

- Marker genotyping services (LGC Genomics for SNPs and BecA, DNA Landmarks and ICRISAT for SSRs)
- CGIAR centralized crop databases (9) now managed by CRPs, and query tools
- Shared crop databases of phenotypic and genotypic data
- Catalog of predictive markers validated for target traits
- Downloadable trait dictionaries for nine crops
- Protocols for phenotypic evaluation of drought tolerance by crop
- Link to GENESYS (see Global Crop Diversity Trust) for genetic resources
- Portfolio of tutorials, e-learning lessons, and training materials
- Networking assets to connect with CoPs
- Helpdesk for installation support through VSNi

- Professional breeding-focused support services for developing-country breeders
- SNP Mining and Utilization tool for use with GBS data to identify new markers.

The IBP has been supported by B&MGF from 2009-13 with a budget of about $12 million, and additional support is expected from the same donor for a further 5 years.

The IBP has served as the fundamental vehicle to meld research with education to provide the tools needed to produce improved cultivars. The development of the IBP represents a bold initiative to put MB applications and IT support in the hands of breeders everywhere, regardless of professional affiliation or country infrastructure resources. In fact, this software helps greatly to define the development pipeline process, a process in which the larger private sector seed companies make substantial investments. Scientists in NARS, especially those not affiliated with the private sector, may not have access to such support without the IBP.

Comparisons could be drawn between development of process pipeline support in the private sector and the IBP in terms of functionality, ease-of-use, developmental timetable, developmental strategy, rollout and associated training, etc. The breeding applications specifically addressed in the IBP (MAS; MARS; MABC) have demonstrated value and are widely used in the seed industry. The genomic selection (GS) module under development also reflects an increasingly popular application that is used to shorten cycle duration, particularly when coupled with doubled haploid production to create 'instant inbreds' in the case of maize.

Given that a main motivation for the GCP and the development of the IBP in particular was to put modern DNA-based technologies in the hands of breeders as an enhancement to their breeding programs, the specific applications of MB (e.g., MAS) in IBP are highly relevant to GCP's mission and essential to its impact. The IBP embodies the learnings of the many research projects conducted through GCP and makes them available to future users in a practical, immediately-useable manner. The processes supported by the IBP fit the needs of a conventional pedigree line development breeding programme and thereby meet the requirements of an estimated 80% of targeted users. A key feature of the system is its bioinformatics routines, since efficient database design is critically important for large multi-environment datasets.

Challenges in developing the IBP

The challenges encountered by GCP in developing the IBP are worth noting so they can be managed in future software development projects:

- *Lack of system blueprints*: no clear set of system specifications were developed before the software design began. The design of the IBP databasing system has been especially challenging, since the search and retrieval functions of earlier designs proved too slow. This has been resolved by using cloud computing facilities provided by iPlant and the use of the Chado system of database design and management hosted by an international database provider (Amazon).
- *Limits to collective programing and consultation:* Programming of key components by IRRI and CIMMYT was not to a uniform professional standard and had to be repeated by Efficio.

This resulted in a series of delays, and was compounded by failing to build on breeder-tested fieldbook designs already in use by CIMMYT's Maize Program.

- *Changes in leadership*: Project Leaders have changed at least three times in the 2009-13 period.
- *Loss of credibility over rollout date*: The development and deployment of the IBP have proceeded more slowly than anticipated, and this has affected its impact which is obviously contingent upon widespread adoption. The development of the IBP has consistently missed a number of its milestones, and this has shaken the confidence of the donor whose representative estimates that two years may have been lost, largely through lack of consultation with typical potential users. GCP's experience with IBP also has implications for the design and implementation of future software as premature releases with less-than-full capability can spark negative first impressions of new software and 'poison the well' for rapid uptake. This is reflected in the 2013 Stakeholders' Survey where one respondent stated that the GCPs strongest feature was "development (of the) IBP for breeders and enhancing bioinformatics tools in agricultural research", yet another reflected that GCP's biggest failure "was the lack of a functional system in the IBP that was really needed, yet none is yet in sight". In short, the IBP was oversold and under-delivered, even though it is potentially an excellent system.
- *Private/public partnerships*: VSNi is managing the experimental design and ANOVA components of IBP. It is not clear whether the late rollout of basic analyses such as split plots is a strategy adopted to minimize exposure to privately supplied software during the free-license open-source period ahead of 2015 commercialization. This may indicate conflict of interest.
- *Lack of breeder feedback*: Needed was a service attitude that engaged clients throughout the IBP development cycle. The manner used to solicit user input/feedback to guide IBP design and improvement has been inadequate. A more controlled and deliberate means of obtaining input and feedback from a select user group would have helped to abate negative opinions about IBP before its rollout. This is not a fatal flaw in determining the fate of the IBP, but it has reduced its appeal to breeders, since the reputation of the IBP will depend ultimately on user experience with the final product.
- *Benefiting from private sector experience*: In retrospect, if private multinational seed companies who invest heavily in IBP-like proprietary software had been engaged to provide a software system suited to NARS needs, this may have sharply reduced the development time and costs.
- *Uptake of services and software:* The application of line fingerprinting has been less utilized than originally envisioned; however, this may change with expanded use of MB directed to development of improved cultivars and lines. There is also a significant threshold to adoption of the IBP if the database is to be populated by historical files of performance data --the cost of conversion of older data files to new formats may constrain the full implementation of the package.

Future of the IBP

Features of the IBP in the near future

Future capacity is expected to include:

- A genomic selection module, offering statistical analysis with popular methods such as RR-BLUP, Kinship GAUSS, BayesA, BayesB, Bayes Cπ, Bayesian LASSO, and Random Forest.
- GPS capability and access to daily weather data; identification of sites with analogous climates using GCP Atlas software made available through AWARE.
- Cloud-computing and databasing through iPlant. The database can be local but more likely will be a cloud-based Chado design that can be queried for essential information such as head-to-head comparisons of hybrids.
- Operational technical user support located at regional hubs.
- Various IBP language versions will be available, ensuring utility for a broad audience, i.e., Chinese, French, and Spanish in addition to English.
- Discontinuation of genetic simulation capability present in earlier versions.
- Direct access to lines *per se* comprising the crop reference sets, which due to germplasm IP issues were determined best distributed through CGIAR Centers.

Governance options for IBP Phase 2

Long-term governance options. The EB's decision on IBP governance ought to depend in part on IBP's potential market niche, comparative advantages, core elements and products, and likely placement as a service to a variety of diverse target audiences—all of which are being considered, but primarily in the context of the proposed project for the B&MGF. In the Review Team's view, the GCP also needs to consider seriously where the IBP and its associated services might best fit within the evolving landscape of research programs and modalities within the CGIAR, which has provided the IBP a conducive environment for incubation and development thus far (though some Centers have a mixed record of support for IBP software), as well as outside it.

It is from this longer-term CGIAR perspective that IBP's objective of "improving the efficiency of plant breeding programs in developing countries by enabling plant breeders to access modern breeding technologies, breeding materials and related information" is worth reiterating—for it seems to closely match the CGIAR's strategic goals for crop improvement CRPs. The GCP's thematic focus, partnership approach, and results- and client-orientation also seem fully aligned with the expected operational mode of CRPs. Besides benefitting its primary clients (the NARS), the IBP seeks to provide significant benefits to these clients' (CG- and non-CG) partners. And, the applicability of the IBP to a variety of crops and regional locations, as well as its likely benefits for national institutions/systems in developing countries, SMEs, and ARIs could make it an appealing candidate for continuing (and even increased) investment by the CGIAR.

In view of this possibility, and because the likely match between the objectives and modalities of such a CRP and the IBP seems so good, it appears to the Review Team that the long-term future of IBP could well be tied closely to the CGIAR and its CRPs. This option would be consistent with option (ii) of GCP's May 2010 publication titled 'GCP Transition Strategy 2011-2013', which stated that for IBP Phase 2 (then called the Genomics and Integrated Breeding Service, or GIB), "three governance options might be considered: (i) that the GIB remain an independent service under Theme 3 with its own governance structure; (ii) that it be integrated into one of the support service platforms under

the Consortium Board; or, (iii) that it be placed under the governance of one of the crop megaprogrammes" (p. 11). It would also be consistent with the EB's guidance, as per the minutes of its November 2013 meeting, "to protect [the] integrity and longevity of IBP, while also cultivating a wider ownership and continuity of shareholders who would be key for success."

Hence, even though this possibility could take a few more years to become a viable option, the Review Team believes that in 2014 the EB and GCP Management need to intensify consideration of the possible placement of IBP Phase 2 in a cross-cutting CRP for the longer term. At the same time, there is of course the need to find a suitable 'home' for IBP Phase 2 before the GCP closes in December 2014. Accordingly, in the Review Team's view, both the longer-term and (possibly) short-term options for IBP governance and hosting arrangements need to be actively and concurrently pursued at this time.

Short-term governance options. As noted in Chapter 7 (below), a lesson of the GCP experience is that its 'consortium governance' approach—with a Consortium of interested Members, an Executive Board with full decision-making authority, a Consortium Committee for providing scientific advice, and a fiduciary agent for providing administrative and financial services, is workable under the right circumstances. The GCP's experience with CIMMYT as the Host Agent has generally been positive, and both parties seem willing in principle to continue the relationship, though perhaps under somewhat modified terms. In the Review Team's view, the GCP's proper closure in December 2014 (or 2015, if the EB so decides, in consultation with the CC) must remain on track; but once GCP ends, there could still be substantial benefits to both IBP and its host agent if GCP's current governance modality could be continued for the immediate future.

The Review Team notes further that the scope and modalities of IBP Phase 2 would be very different from those of GCP during its Phase II (2009-2014). It expects that even in the short term, IBP Phase 2's governance structure would not simply be a continuation of current arrangements (as if IBP Phase 2 were simply the equivalent of a GCP Phase III). Instead, IBP Phase 2 governance would require that current arrangements be suitably modified to make them fit the specific needs and features of IBP Phase 2 as elaborated in the September 2013 Concept Note.

These modifications would probably involve a reconstitution of the Consortium membership, and some changes in the functions of the (new) Executive Board and advisory Consortium Committee (replacing the current CC), as well as in the specific provisions of a new Consortium Agreement and Host Agent Agreement that would provide the framework and guidelines for the effective functioning of IBP's governance body and management. The new Consortium Committee could conceivably include some representatives of the hubs and SMEs, and be more of a 'Stakeholders' Committee'.

Also, decisions related to IBP Phase 2 would benefit from inputs from private enterprise (e. g., in possibly pricing the IBP and in servicing its maintenance and expansion), thus encouraging consideration of market forces and the involvement of SMEs in the IBP. A 13-member, external, independent, Scientific and Management Advisory Committee (SiMAC) for the IBP is functional at present; and this kind of technical advisory committee (but with fewer members) would be needed after 2014 as well. Details of these new arrangements as well as the operational aspects of IBP

Phase 2 governance, hosting, management, and staffing would need to be worked out by GCP's EB and Management before GCP ends.

Sustainability of IBP: unresolved issues: Here the Review Team draws on a series of discussions and presentations by GCP staff.

- *Continuing renewal of the IBP*: Simply 'maintaining' the IBP will render it obsolete within a short timeframe given the pace of scientific advances (e.g., genotyping technologies, bioinformatics, genomic selection and applications, doubled haploidy). It is not clear to the Review Team that a plan for continued evolution and updating of the IBP has been adequately considered, nor how updating will be funded, implemented, and the product distributed.
- *Emphasis on drought*: It is a priority trait, but experience shows that drought tolerance will rarely be "fixed" by incorporating a few strong QTLs (which are unlikely to be found – rice being the exception). Genomic selection is increasingly popular and the Review Team **suggests** that IBP must gear itself to handle this breeding method if it is to continue to provide cutting edge technologies for drought tolerance research.
- *Host institution*: GCP expects that the host institution would be deeply committed to the use of the IBP in its own breeding programmes, easily reached by air, enjoy excellent internet connectivity and have a commitment to NARS. The Review Team has considered some of the pros and cons of several candidate hosts (these are listed in Table 5. 5), and this preliminary assessment appears to favour the hosting of IBP in a CGIAR Centre that in turn hosts one or more crop CRPs. The GCP has recently (5 December, 2013) issued an open call for applications to host the IBP during its Phase 2.

Table A7.5: Some pros and cons of potential hosts for IBP Phase 2

	Organization	Rationale
1	CGIAR, especially CG crop lead centers	• Pro: Already a key player in maintaining/curating centralized crop databases which are an important component of IBP • Pro: Anticipated to be a primary user/benefactor of IBP • Pro: Globally-dispersed CGIAR staff can directly influence the use of the IBP in NARS through existing collaborations • Pro: Some centers have contributed to IBP tool set, e.g., ICRISAT module on Genomic Selection • Con: some Centres have already adopted alternative MB software
2	ARIs e.g., Cornell Univ., Univ. Hohenheim, Univ. Wageningen, Iowa State U., Univ. of Illinois	• Pro: Internet connectivity, particularly for data analysis and decision support components of IBP • Pro: ARIs contribution to advanced technologies and approaches could continue to factor into leadership, especially for IBP evolution • Con: don't have large diversified breeding programs • Con: may charge high overhead • Con: interest in serving NARS becomes less transparent
3	Commercial entity e.g., VSNi	• Pro: Well-positioned to market IBP, provide technical support, and implement licensing to generate income for support of the platform • Con: May not be aligned with stakeholder needs, particularly breeders in developing countries, since these users won't be paying-customers
4	Global Crop Diversity Trust	• Pro: Leading development of GENESYS to manage genetic resources at CG genebanks; has expressed interest • Con: Not sure that goals or expertise are aligned to maintain software
5	Non-CG organizations, e.g., CORAF/WECARD (Africa), CAAS, ICAR (Asia), EMBRAPA (Brazil), Consortium members	• Pro: Have expressed interest in regional representation • Pro: CAAS is collaborating with BGI and some CG Centers to form the new Biological Breeding Innovation Research Institute in Shenzhen China which may be a suitable host • Pro: May also co-finance the IBP • Con: Unsure of willingness to work for the good of other NARS; may unduly shift the program toward national uses • Con: May discourage or prohibit exchange of data and germplasm

- *Prioritizing hubs*: Growth of the hubs will need to be gradual and linked to actual demand. The Review Team cautions against overstaffing of hubs, unless financial support is forthcoming from the host institution -- Growth of the hub concept will need to be gradual and linked to actual demand, given that support and training can be offered on line and connectivity is increasing rapidly. The neediest region is sub-Saharan Africa, so the Review Team **suggests** that hubs be developed first in East and West Africa – preferably at institutions where breeder-clients are based. The Review Team **strongly suggests** that

partnerships and co-financing by the host be actively pursued, and that the location of hubs be chosen to maximize exposure to crop breeders.

- *Business plan*:
  - *International public goods*: Given that the IBP represents a prominent example of IP developed through the GCP, IP requirements to extend access to the resource-poor on a royalty-free basis (Section 5.6) must be met. The requirements do not prohibit commercialization on a royalty basis for others; the tier system proposed for IBP licensing structure would appear to fit.
  - *Market research*: details of market research by VSNi on contract to GCP were not shared with the Review Team, but the plan to generate income from IBP depends heavily on sales of the IBP package to SMEs – 20 in 2016 and up to 150 in 2019. In an initial survey of potential for income generation, five SMEs have agreed to appraise the IBP ahead of the professional version release in 2014. The Review Team notes that the estimates of the SME market and pricing for the software resemble guesstimates, and **strongly suggests** an external review to assess market potential in an unbiased fashion.
  - *Free software?* Free software is usually undervalued and often discarded before being properly trialed. The Review Team **strongly suggests** that the IBP license be made available at some proportion of cost to NARS to be funded by other projects. Costing could also be linked to the services supplied and by the level of the software supplied -- a 'basic IBP' version suited only to conventional selection, a 'basic + molecular' version for MB programmes, and an 'advanced model' tailored to a customer's specifications.
  - *CGIAR and CRP users of IBP*: CGIAR regional plant breeders are likely to be the best ambassadors for the IBP among the NARS. Can the CGIAR centers, especially CIMMYT and IRRI, be persuaded to use the IPB as their main breeding platform? The Review Team **strongly suggests** that IBP during Phase 2 immediately appoint a staff member whose prime responsibility includes the persuasion of CGIAR breeders to test the IBP, assist them in using the software, and help with migrating historical data.
  - *Open-source software?* Although the IBP is a public good, the Review Team **suggests** there needs to be a level of intellectual protection of the software to prevent its piracy and allow developers to use proprietary software to provide readymade fixes for specific problems. The current plan calls for licensing the IBP to all during 2014, though some will be at no cost, and the license will provide a degree of IP protection. Developer packages could be made available, while individual modules, possibly developed by different public or commercial entities would be proprietary. The Review Team **suggests** that components of the IBWS could be licensed individually to ARIs and larger private breeding companies as a means of revenue generation.
  - *Awareness of competition*: While the present capabilities of the IBP make it a unique product, there are competitors, and it is naïve to think that its unique features will not be copied by other leading software packages if the IBP has

significant market appeal. It is the view of the Review Team that CIMMYT's enthusiasm for IBP is tempered by its in-house development of a competing SeeD-based system. No detailed analysis of the competing products by IBP staff was shared with the Review Team, but the Review Team **strongly suggests** that IBP keep an active inventory of the status and features of competing software.

- *Costs of data migration:* One of the barriers to switching breeding support software is the cost of migration of old datasets, the conversion of pedigrees and seed inventories from one format to another, and the errors these entail. The Review Team **suggests** that the IBP consider small grants to facilitate these conversions, and support a modest level of technical resources dedicated to tailoring software fixes that automate data migration from the more common formats to that of the IBP.
- *A robust business model is needed*: The Review Team prefers an 'updated' model that offers a sustained future for the next 5-10 years for IBP maintenance and development, places a realistic value on the software, yet maintains its primary purpose of extending modern breeding methods to strategic groupings of NARS clients. **The Review Team recommends that a robust 'updated' IBP business model be drafted by April 2014 and be based on credible market research and realistic considerations of long-term viability and sustainability.**

- *System flexibility*: Inherent flexibility in the system to accommodate rapidly increasing data volumes, updates, crop specificities and a user-chosen set of tools (e.g. new "plug-in" modules and apps for data analysis) is needed if the IBP is seen to be adaptable to future applications and methods of analysis. It is unclear why users are restricted to using only modules developed through GCP, e.g., an option suggested by early-IBP adopter Zivan Karaman of LimaGrain should be explored: KNIME is open-source graphical workbench program (http://www.knime.org).
- *Structured feedback*: The most urgent feedback needed at present is from experienced line breeders of major crops who are committed to using MB in their breeding programmes. During Phase 2 users' groups composed mainly of line breeders and IT designers could provide an essential service of feedback on the IBWS on a regular basis. At the same time a CoP for the IBP would provide a useful forum for users helping other users, and for highlighting strengths and weaknesses of the IBP experience.
- *Managing software development*: Contract developers such as Efficio work from detailed specifications and may dislike requests for modification, which are essential in development of innovative and user-friendly software. A single point of contact in IBP must be chosen to ensure there is the authority to hold the company to deadlines while insisting on the minimum number of carefully thought through changes during software development.
- *Cloud computing options*: Relying fully on centralized, remotely accessible services is probably several years into the future. The Review Team **suggests** that cloud computing be phased in concomitantly with the implementation of GS applications and/or use of GBS data and/or remote sensing data, which will place a much greater demand on computing resources than most breeders have locally.
- *Competitive grants*: Given the record of quality research under competitive grants, the Review Team **strongly suggests** that IBP Phase 2 allocate a sufficient proportion (say around

20%) of its research budget for competitive grants oriented towards product delivery**.** This may include research related directly to the 14 case studies being used to bench test the IBP, or may be in an entirely new field.

- *Genotyping services*: Genotyping technologies and price structures are changing rapidly, so outsourcing to centralized services is sensible. New methods (seed chipping, DH line production and analysis) are becoming available commercially. Tracking costs per data point, turnaround times, usage and feedback from users will be essential. Numbers are still modest compared with large private sector companies. Payment of services will remain a problem for NARS and some SMEs, and the Review Team **strongly suggests** that IBP Phase 2 should include grants for specific genotyping projects according to need.
- *Quality control*: The quality of the scientific inputs to key elements of IBP such as experimental design and analysis is world class, but the quality of some of the 'informative' markers used by the IBP may not reach this high standard. Some are of excellent quality (e.g., markers for aluminum tolerance that are based on a cloned gene with established effectiveness). However, some markers could be of poor resolution or poor haplotype definition and result in a relatively large number of missing data points. Markers may have also been used to identify QTL that have not yet been validated, or are located some distance from the trait of interest and therefore less informative. The Review Team **strongly suggests** that the IBP through peer review attach some measure of quality to each 'informative' marker listed in the catalog available through IBP. Note that the quality *per se* of KASP markers available through LGC Genomics is not at issue.
- *Coping with large datasets*: Should the IBP be designed to accept the very large datasets associated with GBS and phenotyping using remote sensing? We note that estimation of breeding values via genomic selection is enhanced by accessing the performance data of relatives of the genotype in question, and may require the computing power offered by iPlant to deal with data volumes and imputation of missing values. The Review Team notes that for most standard applications extremely high marker densities are not needed. Since these methods are still under development and rapidly changing the Review Team **suggests** that the central database architecture be designed to manage significantly more markers than the 2000 per line currently accepted. Furthermore, the Review Team **suggests** for the time being that data reduction to GEBVs or means of phenotypic plot values should occur outside the IBWS system when being used for selection purposes.
- *Promotion*: A clear communications strategy is needed to promote the use of the IBP at scientific meetings, conferences, seed trade meetings of SMEs, CGIAR Centres and in universities. The Review Team **strongly suggests** the promotion of IBP as a tool used during graduate studies in northern and Asian Universities as well as the PASS-supported training centers of ACCI at the University of KwaZulu Natal and WACCI at the University of Ghana Legon. The appointment of senior or retired breeders as IBP 'Champions' at key institutions should also be considered. The use of social networking (Twitter, YouTube, Facebook) vs. conventional helpdesks, will become increasingly important as on-line resources to help resolve common operational problems, and the IBP must be prepared for this opportunity.
- *Rollouts only when product reaches specification*: The loss of credibility from premature rollouts of the IBP seems to have dented demand, reduced confidence of donors, and

disillusioned some loyal advocates of MB. The Review Team **strongly suggests** that every effort be made to ensure publicized rollout dates coincide with a market-ready product.

- *Beyond Phase 2*: Because of the costs of transitioning existing databases to IBP, managers of SMEs are understandably hesitant to commit to the IPB unless they believe it offers guarantees of continued software development beyond 2019. The Review Team notes that this can only be resolved when the updated business model and hosting arrangements are decided.

Annex 8. Data on GCP financial management

Since 2004, GCP has received about US$167 million from thirteen donors (Table A8.1).

Table A8.1: GCP Income (2003–2014; $ M)

Funder	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 (est)	2014 (est)	Total (est)	%
Austria	0.05	-	-	-	-	-	-	-	-	-	-	-	0.05	0
Bill & Melinda Gates Foundation (B&MGF)	-	-	-	-	3.54	3.14	5.38	4.31	5.01	5.48	7.38	-	34.24	21
CGIAR	-	-	-	-	-	-	-	-	4.74	6.29	5.50	-	16.52	10
DFID, UK	-	4.68	4.42	4.73	5.06	3.28	4.74	4.86	-	-	-	-	31.77	19
European Commission (EC)	-	5.23	6.03	5.67	12.12	-	11.23	4.34	4.53	-	8.00	-	57.15	34
Kirkhouse	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02	0
Pioneer Hi-Bred Intl.	-	0.05	0.02	0.02	0.02	-	0.03	0.03	0.03	0.03	-	-	0.21	0
Rockefeller Foundation	-	-	0.84	1.04	0.34	-	-	-	-	-	-	-	2.22	1
Sida (Sweden)	0.11	-	0.19	0.10	0.13	0.06	0.14	0.15	-	-	-	-	0.87	1
SDC (Swiss)	-	-	-	0.37	0.40	0.44	0.43	0.44	0.49	-	0.90	-	3.47	2
Syngenta Foundation	-	0.02	-	-	0.03	-	0.04	0.28	0.28	0.04	-	-	0.69	0
USAID	-	-	-	-	-	-	-	0.40	-	-	-	-	0.40	0
World Bank	3.00	1.00	2.50	3.26	2.00	2.00	2.00	2.00	-	-	-	-	17.76	11
Interest	-	-	0.19	0.33	0.34	0.19	0.10	0.06	0.04	0.01	0.01	-	1.26	1
Total Income	3.16	10.97	14.19	15.52	23.98	9.11	24.08	16.86	15.11	11.85	21.79	-	**166.62**	**100**

GCP has managed its finances well (Table A8.2).

Table A8.2: GCP Financial Reserves (2003-2014; $ M)

Item	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 (est)	2014 (est)	Total (est)
Total Income	3.16	10.97	14.19	15.52	23.98	9.11	24.08	16.86	15.11	11.85	21.79	-	166.62
Total Expenditure	0.50	6.91	15.06	13.03	17.03	17.58	16.62	16.29	17.20	11.31	27.02	7.77	166.33
Transfer to Contingency Reserve	-	0.50	0.50	-	2.00	-	-	-	-	-	-	-	3.00
Excess (Deficit) over income (for year)	2.66	3.56	(1.37)	2.49	4.95	(8.47)	7.46	0.57	(2.08)	0.54	(5.24)	(7.77)	(2.70)
Cumulative Reserves (carry forward, balance)	**2.66**	**6.22**	**4.85**	**7.34**	**12.29**	**3.82**	**11.28**	**11.84**	**9.76**	**10.31**	**5.07**	**(2.70)**	
Contingency Reserve	-	0.50	1.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Total Net Fund	**2.66**	**6.72**	**5.85**	**8.34**	**15.29**	**6.82**	**14.28**	**14.84**	**12.76**	**13.31**	**8.07**	**0.30**	

Prudent programme- and administrative decisions by GCP Management have kept total research at roughly 86% and research management at about 4% of total expenditures (Table A8.3).

Table A8.3: GCP research grants and management expenditures (2003-2014; $ M)

Research Expenditure	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 (est)	2014 (est)	Total (est)
Research grants	-	5.62	13.65	10.90	14.66	15.18	13.81	13.84	14.21	8.68	21.19	3.82	135.56
Research management*	0.12	0.27	0.33	0.28	0.22	0.49	0.85	0.62	0.80	0.81	1.13	1.10	7.01
Total Research	0.12	5.89	13.98	11.18	14.88	15.67	14.66	14.45	15.00	9.49	22.32	4.92	142.57
Total expenditure	0.50	6.91	15.06	13.03	17.03	17.58	16.62	16.29	17.20	11.31	27.02	7.77	166.33
Research as % of total expenditure	**-**	**85**	**93**	**86**	**87**	**89**	**88**	**89**	**87**	**84**	**83**	**63**	**86**

* Research management = Theme Leaders (and Product Delivery Coordinators) and strategic or work planning events

Expenditures on the two governance bodies (PSC/CC and EB) have been reasonable, respectively totaling US$0.26m and US$0.49m for the 12 years (Table A8.4).

Table A8.4: GCP expenditures for governance and management aspects (2003-2014; $M)

Expenditure Item	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 (est)	2014 (est)	Total (est)
PSC/ Consortium Committee (CC)	-	0.02	0.05	0.07	0.03	0.02	0.01	-	-	0.00	0.03	0.03	0.26
Executive Board (EB)	-	-	-	-	-	-	0.08	0.07	0.06	0.07	0.10	0.10	0.49
Salaries and benefits	0.02	0.25	0.26	0.32	0.63	0.49	0.44	0.51	0.58	0.59	0.67	0.72	5.48
Operational	0.04	0.51	0.45	0.97	0.75	0.56	0.58	0.35	0.66	0.42	1.48	0.48	7.24
Transition Strategy	-	-	-	-	-	-	-	-	-	0.03	1.23	1.13	2.38
Indirect costs*	0.33	0.24	0.32	0.49	0.74	0.85	0.84	0.91	0.89	0.70	1.20	0.40	7.90
Total	**0.38**	**1.02**	**1.08**	**1.85**	**2.15**	**1.92**	**1.96**	**1.84**	**2.19**	**1.82**	**4.70**	**2.86**	**23.76**

* Indirect costs = 18% on direct costs; 15% on B&MGF projects; and 4% on services and pass-through funds

Annex 9. Summary of Review Team's overall assessments

Table A9.1: Review Team assessments of GCP's performance during Phase I and Phase II
(Using the 4-point rating scale suggested by the EC)*

Programme Aspect	Rating	Review Team Comments
Sub-programme/Theme		
SP1: Genetic diversity of global genetic resources	Satisfactory	A core activity whose impact was reduced by inefficiencies that could have been anticipated.
SP2/Theme 1: Comparative and applied genomics	Highly satisfactory	Flexible approach; excellent outcomes in Al and low P tolerance but modest in drought tolerance.
SP3/Theme 2: Integrated crop breeding	Highly satisfactory	The tools are in place for widespread application of MB in target crops.
SP4/Theme 3: Crop Information systems	Satisfactory	GCP's main legacy product, the IBP, has been delayed in rollout and has missed important opportunities for early impact, but nonetheless was a bold step.
SP5/Theme 4: Capacity building	Highly satisfactory	Trained staff is a key legacy, and training by doing has increased impact during Phase II. Lacks assessment of changes in skill levels from training. Investments in phenotyping came late to GCP. Provision of services has been excellent, though demand is hard to assess.
Theme 5: Product delivery	Highly satisfactory	Appointments of a Product Delivery Manager, PDCs, and development of the on-line product catalogue are positive; none of these however indicate product use *per se*.
Research Initiatives		
RI 1: Cassava	Highly satisfactory	Excellent local leadership of projects and a strong research portfolio. Will need to link more strongly with IITA for African impact.
RI 2: Legumes (groundnut, chickpea, cowpea, bean)	Satisfactory for groundnut; Highly satisfactory for others	Key accomplishments have been published genomes of chickpea and a non-priority but significant crop, pigeon pea. Progress in groundnut has lagged behind. Achievements have been impressive in these minor crops.
RI 3: Maize	Satisfactory	After a slow start the project has switched from MARS to genomic selection, a good choice for this crop.
RI 4: Rice	Highly satisfactory	The largest of the RIs; Several releases of salt- or low P-tolerant rice varieties in Asia. Large effect QTLs for drought tolerance are impressive.

RI 5: Sorghum	Highly satisfactory	Useful genetic and genomic resources have been created. NAM and MARS selection systems for drought tolerance have been established in this often overlooked crop.
RI 6: Wheat	Highly satisfactory	Strong leadership has supported MB projects in India and China and offered good mentoring advice. Synthetic wheats continue to offer new and useful genetic variation.
RI 7: Comparative genomics	Highly satisfactory	RILs and NILs have been created around cloned genes or QTLs of *ZmMATE1*, Alt_{SB}, and *Pup1* and field assessments are underway. Less progress seen for drought tolerance, however.
Quality/Activity		
Quality of science	Highly satisfactory	489 papers published in peer reviewed journals, though relevance of some questionable. Internal review, updating staff through seminars are areas not strongly emphasized.
Partnerships	Highly satisfactory	These appear to be equitable, interactive and result in considerable mentoring and the development of CoPs. Responsibilities allocated according to resources available.
Communications	Highly satisfactory	The websites and publications are of a high standard, and GCP is considered responsive by collaborators.
Monitoring and evaluation	Less than satisfactory	Effective monitoring and management of projects by milestones, but M&E and impact assessments lack baseline data and/or counterfactuals.
Institutional memory	Highly satisfactory	The website, the central repository for GCP data and public websites hold a large proportion of GCP historical datasets in accessible form. More than 40% of journal publications are open access.
Esprit de corp	Highly satisfactory	The GCP "spirit" has enabled effective collaboration among disparate partners.
Overall assessments		
Relevance	Highly satisfactory	The need for effective MB systems is apparent in all CGIAR mandate crops, and an accelerated increase in yield is urgently needed.
Effectiveness	Highly satisfactory	The GCP has been very effective in establishing MB as an integrated part of conventional breeding programmes. This may have happened without GCP, but more slowly.
Efficiency	Satisfactory	Lower than expected in reference set studies and in establishing improved phenotyping capabilities. Research efficiency is however high.
Impact	Highly	Only short term assessment of impact currently

	satisfactory	possible, and long term is affected by lack of baseline studies. Impact is expected to be notably higher in five years' time. The impacts of partnerships, capacity building and communications are very considerable.
Sustainability	Highly satisfactory	The impending closure of the GCP has been managed well, and the probability of funding for Phase 2 of the IBP is high.
Governance and Management		
Governance	Less than satisfactory in Phase I; and Highly satisfactory in Phase II	As noted in the 2008 EPMR and EC review, governance by the PSC was not as effective as needed. In Phase II, major governance reforms established the EB and CC, and these bodies have performed effectively since 2008.
Strategic planning and implementation	Highly satisfactory	The transition from Phase I to Phase II, as well as the Transition toward GCP closure in 2014 has been effectively guided by the EB; the CC has undertaken its key functions satisfactorily; and programme management has been effectively undertaken by the GCP Management Team.
Program management	Highly satisfactory	Both the Host Agent (CIMMYT) and GCP Management have performed effectively and efficiently since GCP inception.
Leadership	Highly satisfactory	The GCP Director and his Management Team have effectively managed the programme; have developed and sustained a unique 'GCP spirit'; and have responded effectively to changing internal and external needs.
Resource management	Highly satisfactory	In both Phases of GCP, the management of resources (financial, human, and information) has been effective; in Phase II particularly the MT and Taskforces have undertaken transition-related processes effectively; and they are now undertaking activities required for proper Programme closure.

* *Note*: **Rating scale**: Highly satisfactory = fully according to plan or better; Satisfactory = on balance according to plan, positive aspects outweighing negative aspects; Less than satisfactory = not sufficiently according to plan, taking account of the evolving context, a few positive aspects, but outweighed by negative aspects; and Highly unsatisfactory = seriously deficient, very few or no positive aspects.

Annex 10: Stakeholder Survey Key Findings

The Stakeholder survey was distributed online on October 31, 2013 to 382 members. The survey closed on November 19, 2013 with 159 responses, representing a 42% response rate.

The survey included questions on background characteristics and GCP Relevance, Effectiveness, Products/Outputs, Efficiency, Outcomes and Impacts, Partnership, Sustainability and Management. The survey also included 10 open---ended questions, the responses to which were content analyzed and categorized into themes.

Background Characteristics

- The institutional affiliation for over 80% of respondents was from the CGIAR Centre (31%), developing---country partners (national programme) (29%) and developing---country partners (22%).
- While respondents could have more than one professional focus, breeding (74%), followed by genetics (52%) were mentioned most often. This was followed by genomics (35%), capacity building (27%) bioinformatics (22%) and physiology (22%).
- There was a wide range of species focus, which could also be mentioned more than once, from Rice (30%), Maize (26%), Wheat (25%) and Sorghum (22%) to 10% or less for Cowpeas (10%), Cassava (10%) and Beans (8%).
- Over two---thirds of respondents' work was focused in Sub---Saharan Africa (35%), at the international level (20%) and Southeast Asia (13%). All other regions, such as USA or Canada (3%), Latin America (9%) and South Asia (8%) were each represented by less than 10% of respondents.
- Over 60% of respondents had been involved in GCP since programme inception (19%) or Phase I (41%), while 23% have been involved since 2009. Twelve percent have been involved since mid---Phase II and five percent have been involved since late Phase II.
- The basis for respondents' collaboration with GCP is predominantly as a GCP grant recipient and/or partner (82%) whose position is a principal investigator (45%), co---principal investigator (41%), project planner (39%) or workshop participant (26%).

Composite Scores

Overall performance of the eight GCP areas of Relevance, Effectiveness, Products/Outputs, Efficiency, Outcomes and Impacts, Partnership, Sustainability and Management were developed by taking the average agreement of all the survey items in each group. All composite scores were above 90%, which the highest composite score being for Outcomes and Impact (96%), Products/Outputs (95%) and Relevance (94%). Management had the lowest composite score of 90% agreement.

Relevance

- There were four items covering Relevance, which had an overall performance score of 94%.
- Over 95% of respondents "strongly agree" or "agree" that GCP demonstrated the benefits of a new programmatic approach to research in CGIAR (98%) and that since 2004, GCP's promotion of the use of genetic diversity and modern plant science has added value to CGIAR (96%).
- Stakeholders also agreed that in the last 10 years, GCP has been modified to ensure that its objectives, approach, priorities and activities remain relevant (94%), while 86% are in agreement that GCP's emphasis on genotypic and molecular breeding methods have been balanced by its emphasis on field phenotyping.

Effectiveness

- There were eight items covering Effectiveness, which had an overall performance score of 93%.
- Over 90% agreement was found for the following five Effectiveness items:
    - GCP has effectively achieved one of its major objectives – to enable scientists to access new tools and methodologies for breeding (99%).
    - Since 2004, GCP has generated significant output/products in support of genomic research and molecular plant breeding (98%).
    - Since 2009, the research portfolio's focus on priority crops and research initiatives has been appropriate in addressing GCP's global objectives (97%).
    - GCP has appropriately adjusted programme and project plans in response to evolving stakeholder demands for services and products (96%).
    - There has been considerable 'spillover effects' of GCP on other programmes within CGIAR and elsewhere (91%).
- Respondents also agreed that GCP used effective management processes for managing partnerships/projects and allocating funds (87%).
- Finally, 88% agreed that the 2009 governance reform improved GCP's scientific focus and management of resources and 87% believed that the GCP research effort has been effective in accelerating the development/delivery of stress---tolerant and stable varieties of target crops for farmers.
- A number of written comments about GCP's strongest features or greatest strengths addressed the area of effectiveness. Some examples include:

> *"Developing integrated breeding platform for breeders and enhancing importance of bioinformatics tools in agricultural research."*

"Development molecular tools what could be applicable. Availability of Integrated Breeding Platform to the scientists worldwide."

Products/Outputs

- Six items covered the area of Products/Output, which had an overall performance score of 95%.
- Over 90% agreement was found for all six items covering Products/Outputs.
    - Accessing new allelic diversity (94%).
    - Generating new genetic resources (92%).
    - Generating new genomic resources (97%).
    - Identifying new phenotypic traits and/or screening protocols (93%).
    - Generating new markers for breeding (99%).
    - Developing new analytical tools (94%).

Efficiency

- There were four items covering Efficiency, which had an overall performance score of 92%.
- Respondents indicated that decision---making by GCP management has been efficient (90%) and that GCP has efficiently managed its programme resources (91%).
- In addition, stakeholders agreed that GCP established efficient mechanisms for disbursing resources to partners and collaborators (93%), while 95% of respondents agreed that the requirements to engage at least one developed---country research institute, a CGIAR Centre and a national programme has been the most efficient way to establish a true partnership.

Outcomes and Impact

- Four items were used to measure GCP Outcomes and Impact, which had an overall performance score of 96%.
- There is strong agreement among respondents that GCP has raised scientific standards (95%), improved science quality (97%), helped GCP staff in partner institutes through training and professional development (99%), helped attract new funds through proof--of--concept experiments (95%) and effectively used grants to target key research areas (93%).
- GCP is also seen as having been successful in identifying and prioritising specific goals that will have the greatest impact on plant breeding, and will ultimately benefit smallholder farmers (92%).
- Finally, stakeholders were in high agreement that GCP training programmes have significantly enhanced the research skills of GCP collaborators (99%).
- A number of written comments about GCP's strongest features and greatest benefits focused on Outcomes and Impact related to training and capacity building. Some examples include:

"The GCP encouraged effective integration of research between CGIAR and other partners. Both the upstream quality and downstream products of research were always given good consideration, and the program helped implementation of marker technologies through training and providing services."

"GCP training program can help researchers in developing countries to learn new tools for improving their research activities."

"Integrating lentil breeding program in the IBWS in addition to training on project proposal writing and phenoyping for drought related traits. This has helped me to efficiently manage my breeding program."

Partnership

- The overall performance score for the six items measuring Partnership was 91%.
- Respondents agreed that equality, communication, collaboration and organisational structure have resulted in a successful partnership. The specific indicators of this partnership were:

GCP's organisational structure, using the consortium and partnership approaches, has given it a distinct advantage over alternative suppliers (86%).

  - GCP partnerships and networks have functioned effectively (90%)
  - GCP has encouraged proper attribution of all partners when data are shared and publications are generated (97%).
  - GCP has consistently valued and promoted true partnership by treating all partners equally (89%).
  - GCP's methods and procedures for regular communication with partners have worked well (89%).
  - The most important value of GCP has been the opportunities for people of diverse backgrounds to think collectively about solutions to complex problems, and, in the process, to learn from one another (98%).
- Comments about collaboration were mentioned more often than any other area, in terms of GCP features and strengths. Some examples of collaboration include:

"International network where scientists meet and cooperate with each other."

"The establishment of collaborative programs that are funded together where participants all have a stake in the success of each other's contributions."

"GCP helped very much researchers from CGIAR and NARs to establish efficient, collaborative networks. Without GCP and other Challenge programs, CGIAR centers would still work alone."

Sustainability

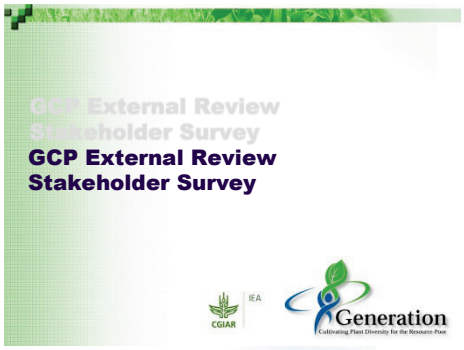
- GCP's overall performance of 92% on Sustainability was based on three items.
- On two items, over 90% of respondents agreed that after GCP's 2014 closure, the IBP should continue (93%) and that genetic/genomic resources that are not within IBP should be maintained (97%).
- To a slightly lesser degree of agreement, stakeholders indicated that GCP's transition planning for an orderly closure will ensure sustainability of its research outputs and outcomes (85%).

Management

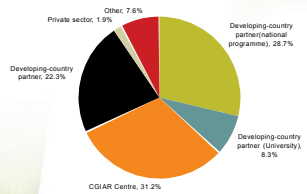
- With 11 items covering the area of Management, the overall performance score of 90% was the lowest among the eight areas covered in the survey.
- Ninety percent of stakeholders agreed that GCP Management Team members interact effectively with collaborators to identify opportunities and support optimal progress towards priority goals.
- Respondents also agreed that their role and responsibility as a GCP partner has been clearly defined and communicated (91%).
- Stakeholders agreed that GCP project management systems enable effective assessment of progress (88%) without excessive burden on participants' time (90%).
- Ninety-three percent of respondents agree that efficient information systems to support GCP priorities have been provided, yet agreement was not as high that GCP sufficiently considered links to the downstream delivery chain (87%).
- Finally, agreement was not as high that Product Delivery Coordinators have made important contributions to achieving research objectives during Phase II (76%).
- A number of comments focused on weaknesses, challenges and improvements in the area of management. For example:

> *"Narrow focus on upstream genetics and germplasm development without integration to end users and where they will use products. Very top---down."*
>
> *"The program was too confusing at times. Possibly because it is supposed to be somewhat independent from the CGIAR, but at the same time it is a spill over from the CG system. Some decisions that make sense for a CG program do not necessarily for an independent program."*
>
> *"GCP has been increasing dominated by the CGIAR Centers, and more become inwards looking. A more balanced treatment of diverse partners would be beneficial. Less focus on products as individual resources could be beneficial."*

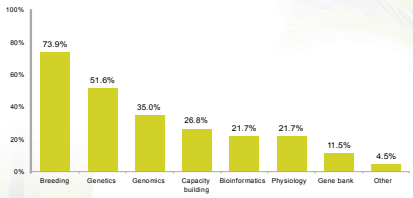
Further details of the GCP Stakeholder Survey results are given below.



Respondent composition (Institutional affiliation):

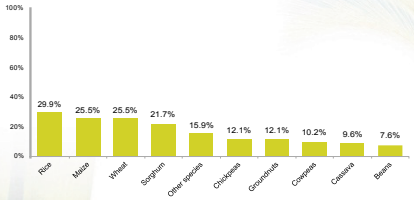


Professional focus:



Respondents could select more than one professional focus

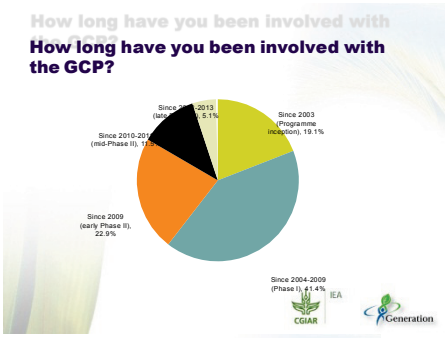
Species focus:

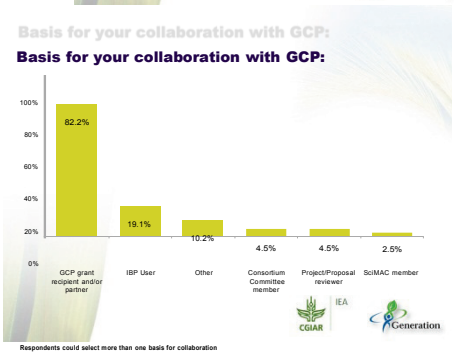


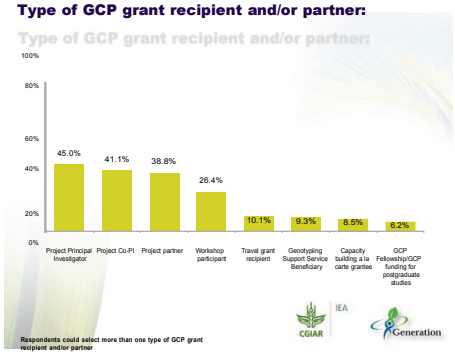
Respondents could select more than one species focus

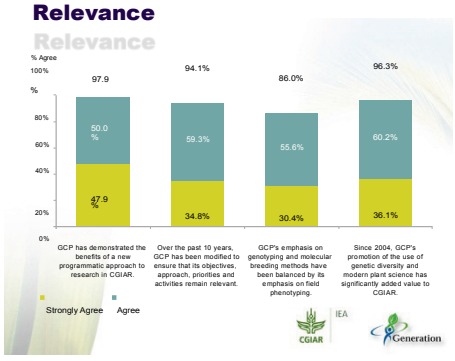
In what region is your work primarily focused?

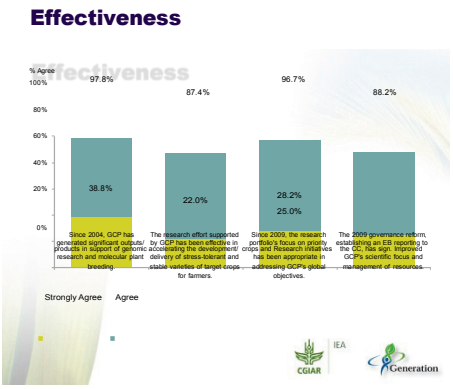
Region	Number	Percent
N/A: operates at international level	32	20.4
Sub-Saharan Africa	55	35.0
Central and West Asia and North Africa (CWANA)	8	5.1
South Asia	13	8.3
Southeast Asia	20	12.7
Caribbean	0	--
Latin America	14	8.9
Europe	8	5.1
Oceania	2	1.3
USA or Canada	5	3.2

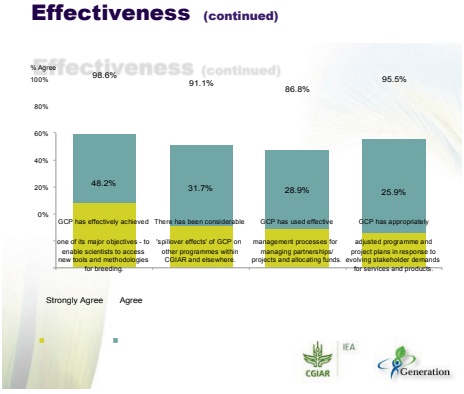

How long have you been involved with the GCP?
Since 2003 (Programme inception), 19.1%
Since 2009 (early Phase II), 22.9%
Since 2004-2009 (Phase I), 41.4%
CGIAR
IEA
Generation


Basis for your collaboration with GCP:
100%
80%
60%
40%
20%
0%
82.2%
19.1%
10.2%
4.5%
4.5%
2.5%
GCP grant recipient and/or partner
IBP User
Other
Consortium Committee member
Project/Proposal reviewer
SciMAC member
CGIAR
IEA
Generation
Respondents could select more than one basis for collaboration


Type of GCP grant recipient and/or partner:
100%
80%
60%
40%
20%
0%
45.0%
41.1%
38.8%
26.4%
10.1%
9.3%
8.5%
6.2%
Project Principal Investigator
Project Co-PI
Project partner
Workshop participant
Travel grant recipient
Genotyping Support Service Beneficiary
Capacity building a la carte grantee
GCP Fellowship/GCP funding for postgraduate studies
CGIAR
IEA
Generation
Respondents could select more than one type of GCP grant recipient and/or partner

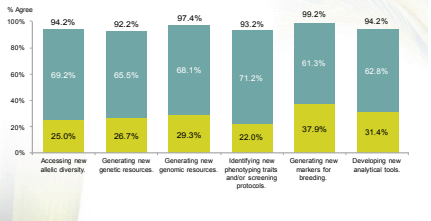

Relevance
% Agree
100%
80%
60%
40%
20%
0%
97.9
94.1%
86.0%
96.3%
50.0 %
47.9 %
59.3%
34.8%
55.6%
30.4%
60.2%
36.1%
GCP has demonstrated the benefits of a new programmatic approach to research in CGIAR.
Over the past 10 years, GCP has been modified to ensure that its objectives, approach, priorities and activities remain relevant.
GCP's emphasis on genotyping and molecular breeding methods have been balanced by its emphasis on field phenotyping.
Since 2004, GCP's promotion of the use of genetic diversity and modern plant science has significantly added value to CGIAR.
Strongly Agree
Agree
CGIAR
IEA
Generation


Effectiveness
% Agree
100%
80%
60%
40%
20%
0%
97.8%
87.4%
96.7%
88.2%
38.8%
22.0%
28.2%
25.0%
Since 2004, GCP has generated significant outputs/ products in support of genomic research and molecular plant breeding.
The research effort supported by GCP has been effective in accelerating the development/ delivery of stress-tolerant and stable varieties of target crops for farmers.
Since 2009, the research portfolio's focus on priority crops and Research initiatives has been appropriate in addressing GCP's global objectives.
The 2009 governance reform, establishing an EB reporting to the CC, has sign. Improved GCP's scientific focus and management of resources.
Strongly Agree
Agree
CGIAR
IEA
Generation

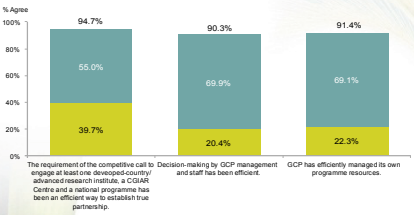

Effectiveness (continued)
% Agree
100%
80%
60%
40%
20%
0%
98.6%
91.1%
86.8%
95.5%
48.2%
31.7%
28.9%
25.9%
GCP has effectively achieved one of its major objectives - to enable scientists to access new tools and methodologies for breeding.
There has been considerable 'spillover effects' of GCP on other programmes within CGIAR and elsewhere.
GCP has used effective management processes for managing partnerships/ projects and allocating funds.
GCP has appropriately adjusted programme and project plans in response to evolving stakeholder demands for services and products.
Strongly Agree
Agree
CGIAR
IEA
Generation

Products/Outputs

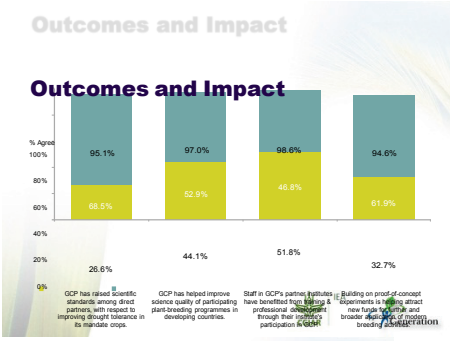
GCP has been instrumental in:



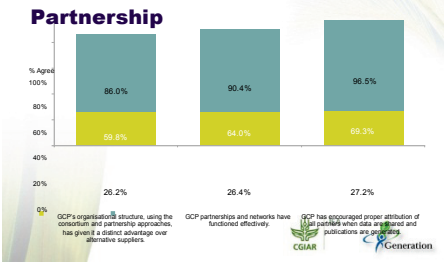
Efficiency



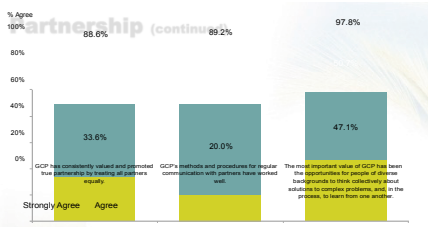
Outcomes and Impact



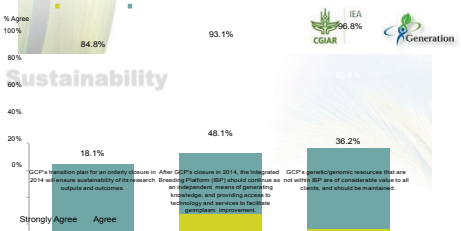
Partnership

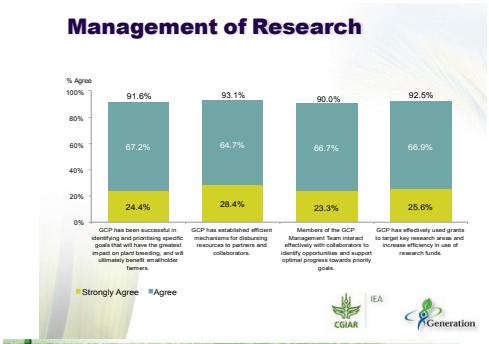


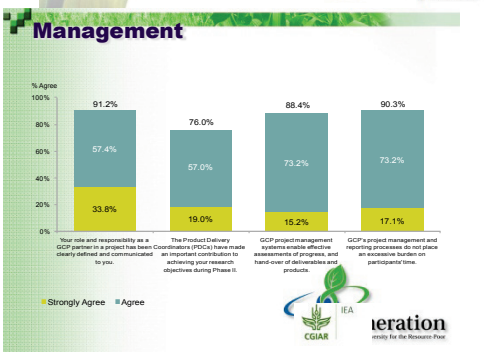
Partnership (continued)

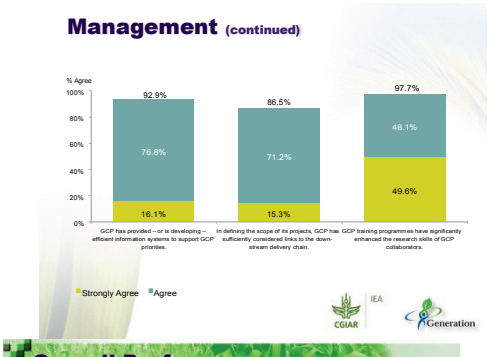


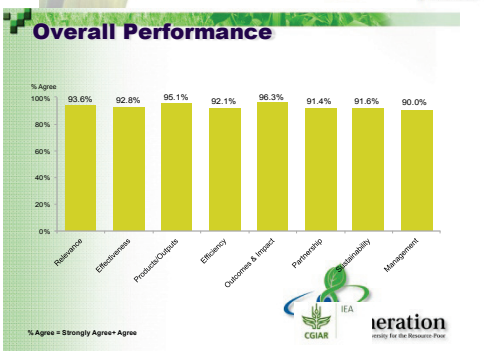
Sustainability




Management of Research
% Agree
91.6%
93.1%
90.0%
92.5%
67.2%
64.7%
66.7%
66.9%
24.4%
28.4%
23.3%
25.6%
GCP has been successful in identifying and prioritising specific goals that will have the greatest impact on plant breeding, and will ultimately benefit smallholder farmers.
GCP has established efficient mechanisms for disbursing resources to partners and collaborators.
Members of the GCP Management Team interact effectively with collaborators to identify opportunities and support optimal progress towards priority goals.
GCP has effectively used grants to target key research areas and increase efficiency in use of research funds.
Strongly Agree
Agree
CGIAR
IEA
Generation


Management
% Agree
91.2%
76.0%
88.4%
90.3%
57.4%
57.0%
73.2%
73.2%
33.8%
19.0%
15.2%
17.1%
Your role and responsibility as a GCP partner in a project has been clearly defined and communicated to you.
The Product Delivery Coordinators (PDCs) have made an important contribution to achieving your research objectives during Phase II.
GCP project management systems enable effective assessments of progress, and hand-over of deliverables and products.
GCP's project management and reporting processes do not place an excessive burden on participants' time.
Strongly Agree
Agree
CGIAR
IEA


Management (continued)
% Agree
92.9%
86.5%
97.7%
76.8%
71.2%
48.1%
49.6%
16.1%
15.3%
GCP has provided – or is developing – efficient information systems to support GCP priorities.
In defining the scope of its projects, GCP has sufficiently considered links to the down-stream delivery chain.
GCP training programmes have significantly enhanced the research skills of GCP collaborators.
Strongly Agree
Agree
CGIAR
IEA
Generation


Overall Performance
% Agree
93.6%
92.8%
95.1%
92.1%
96.3%
91.4%
91.6%
90.0%
Relevance
Effectiveness
Products/Outputs
Efficiency
Outcomes & Impact
Partnership
Sustainability
Management
% Agree = Strongly Agree+ Agree
CGIAR
IEA

Annex 11: Governance and Management Survey Key Findings

The Governance and Management survey was distributed online on October 31, 2013 to 92 members. The survey closed on November 19, 2013 with 40 responses, representing a 43% response rate.

The survey included questions on background characteristics, satisfaction with Governance, Management, Consortium Committee, Executive Board, and the Management Team. Key findings from this survey are described here.

Background Characteristics

- Respondent basis for GCP collaboration was predominantly as a GCP Consortium Committee member (28%), Science and Management Advisory Committee member (18%), GCP Executive Board member (13%) and "Other" role (13%).
- Over 90% of respondents' work is focused at the following levels: international (36%), USA or Canada (23%), Sub---Saharan Africa (21%) and Latin America (10%).
- A majority of respondents have been involved in GCP since programme inception (28%) or Phase I (28%), while 21% have been involved since 2009. Fifteen percent have been involved since mid---Phase II and eight percent have been involved since late Phase II.

Composite Satisfaction

Overall performance of the Consortium Committee, Executive Board and Management Team was calculated by taking the average satisfaction of all the survey items in each group. The highest satisfaction composite score, which represents the "strongly agree" and "agree" responses combined, was for the Management Team (98%), followed by the Executive Board (93%). The Consortium Committee had the lowest composite satisfaction score of 80%.

Governance

- Over 96% of respondents "strongly agree" or "agree" that since 2009 the Executive Board has performed its functions effectively, while 82% feel the same way about the Consortium Committee.
- Interactions between the GCP governance bodies and the host Centre has been seen as effective (95%), while 87% agree that interactions between the Consortium Committee and the Executive Board have been effective.
- A number of written comments about the quality of the GCP governance and management in general were:

  "The GCP Governance and Management are functioning in an open, transparent and efficient way".

  "The GCP has evolved into an efficient governance and management structure and can provide a model for the CRPs".

Satisfaction with the Consortium Committee

- Overall satisfaction with all the Consortium Committee survey items was 79.5%.
- Almost 80% of respondents were satisfied ("Highly Satisfied" and "Satisfied") that the Consortium Committee is providing expert advice to the EB, GCP Director and GCP staff. Seventy---five percent of respondents were satisfied that the Consortium Committee is serving as a medium of communication between GCP and Consortium members.
- Respondents agreed that the composition of the Consortium Committee has not led to conflicts of interest (96%).

Satisfaction with the Executive Board

- All respondents were either "Highly Satisfied" or "Satisfied" with the Executive Board on the following:
    - Determining GCP's strategic direction and setting overall Programme goals.
    - Approving audits, annual operating plans, medium---term plans and budgets.
    - Ensuring the integrity of GCP's accounting and financial reporting systems.
    - Establishing a policy for managing risks and monitoring the implementation of that policy.
    - Monitoring and managing potential conflicts of interest of members of the EB and staff of the GCP Directorate.
- Respondents were also satisfied with the Executive Boards guidance and advisory support and expertise to the GCP Director and staff (96%), as well as making recommendations to Consortium Committee members (86%).
- Respondents were less satisfied with making recommendations to Consortium Committee members and Supporting Participants regarding commercialization of GCP intellectual property (69%).
- All respondents agreed that the Executive Board and Management Team have effectively guided the Programme towards its 2014 closure.
- Respondents also provided written comments about the Executive Board. These were:

    "As a member of the EB, I have been impressed by the deep commitment of most EB members to the success of the GCP".
    "The revised governance arrangements with the EB overseeing and guiding the GCP has worked well and reduced the delays in conflicts of interest experienced".

Management: Program Level Success Criteria

- Based upon the Programme---level success criteria set in the 2008 report of the External Programme and Management Review, over 90% of all respondents "Strongly Agree" or "Agree" that the success criteria resulted in:

- Better focus for the science (100%).
- Reform the governance structure (100%).
- Monitor and carefully manage indirect costs (100%).
- Ensure the sustainability of GCP products (97%).
- Refinement of the management structure (94%).
- Clearer definition of indicators of success (91%).

Management

All respondents "Strongly Agree" or "Agree" that GCP adequately focused on the expected end---products of research initiatives and that the focus on the two---

- dimensional "matrix" organizational structure of five Research Themes and seven Research Initiatives was appropriate.
- To a slightly lesser extent, 89% of respondents agreed that GCP's processes for research planning and management have been effective.

Respondents were in high agreement that GCP has contributed to the objectives of:

- Provide access to and promote the use of genetic diversity in plan---improvement programmes (100%).
- Develop a public platform of genetic and genomic resources and tools (100%).
- Use genetic diversity and advanced science to develop improved products for plant---breeding programmes (100%).
- Generate and apply knowledge across crops and demonstrate potential of comparative genomics (94%).

- Respondents also agreed that GCP's effectiveness has increased as a result of the relationship between GCP and CIMMYT (90%) and that expert and advisory bodies for GCP---funded projects have played a significant role in guiding the evolution of research objectives of individual projects (92%).

Satisfaction with the Management Team

- All respondents showed 100% satisfaction with the following Management Team functions:
  - Project management.
  - Effectively managing GCP resources.
  - Proposing strategic directions for Board consideration.
  - Proposing medium---term and annual work plans and budget allocations across projects for Board consideration.
  - Devising and implementing GCP's public awareness and communications initiatives and activities.
  - Ensuring sound financial management, budget approval and expenditure control.
  - Ensuring compliance with CGIAR administrative and other requirements.
  - Implementing a risk---management policy and revising and updating the

GCP risk---assessment matrix on a regular basis.
- Ensuring compliance with the conflict of interest policies of the respective employers of Management Team members.

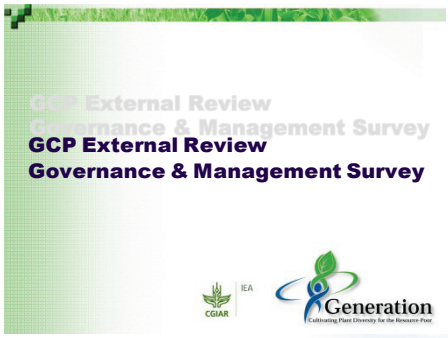
- Other Management Team functions that showed nearly 100% satisfaction were:
  - Ensuring science quality in research on specific topics and products generated (97%).
  - Appropriately utilizing the objectives to focus, measure, monitor and determine end---products and programme effectiveness (97%).
  - Proposing policies for project selection and developing specific work plans for EB approval (96%).
  - Prudently managing indirect costs (94%).

- A satisfaction score of 86% was achieved for the statement on receiving information on, and documenting all intellectual property.
- Satisfaction with the Management Team was also expressed in the following written comments:

> *"I was impressed with the transparency shown by the management team in the change in governance".*
>
> *"The Phase II of GCP was properly focused for delivery and has been effectively managed and guided".*

"The GCP Management Team has done an exceptional job of bringing together diverse teams to address crop improvement in key crop/trait areas".

Further details of the Governance and Management Survey results are given below.

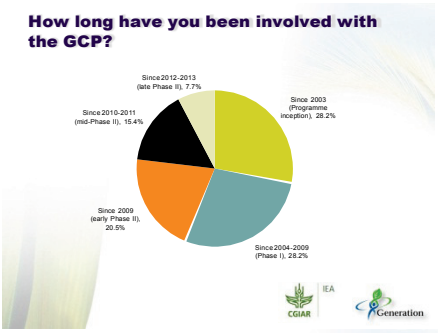


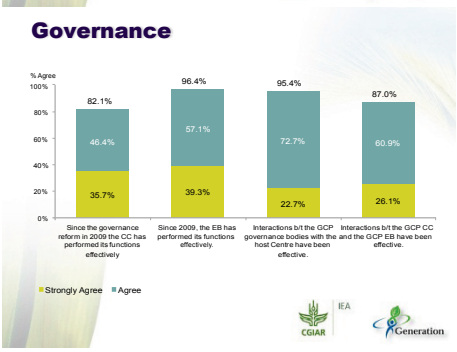
Basis of your GCP collaboration or roles:

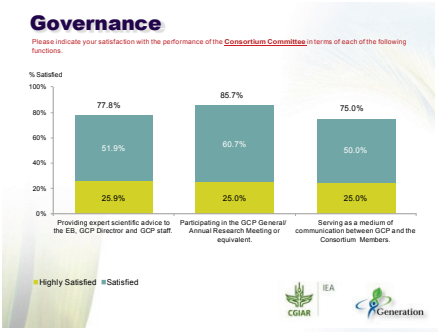
Collaboration	Number	Percent
GCP Consortium Committee member	11	28.2%
GCP Executive Board (EB) member	5	12.8%
Intellectual Property Advisory Committee (of the EB) member	1	2.6%
CIMMYT Board member	2	5.1%
GCP Management Team member	3	7.7%
CIMMYT Management	1	2.6%
Revise and Advisory Panel or Programme Advisory Committee	4	10.3%
Programme Steering Committee	0	--
(IBP) Science and Management Advisory Committee (SIMAC)	7	17.9%
Other	5	12.8%

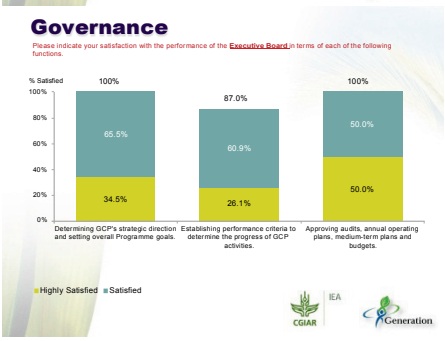
In what region is your work primarily focused?

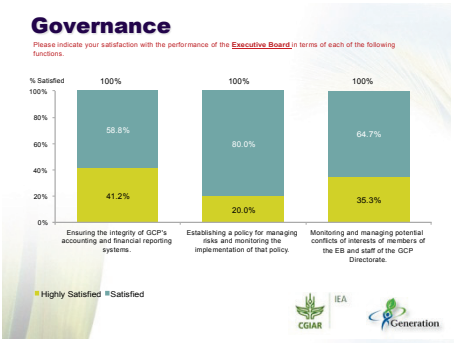
Region	Number	Percent
N/A: operates at international level	14	35.9%
Sub-Saharan Africa	8	20.5%
Central and West Asia and North Africa (CWANA)	1	2.6%
South Asia	1	2.6%
Southeast Asia	0	--
Caribbean	0	--
Latin America	4	10.3%
Europe	1	2.6%
Oceania	1	2.6%
USA or Canada	9	23.1%

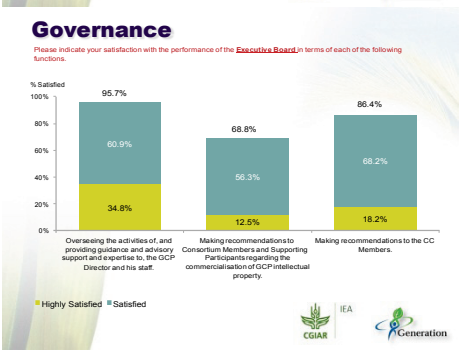

How long have you been involved with the GCP?
Since 2012-2013 (late Phase II), 7.7%
Since 2003 (Programme inception), 28.2%
Since 2010-2011 (mid-Phase II), 15.4%
Since 2009 (early Phase II), 20.5%
Since 2004-2009 (Phase I), 28.2%
IEA
CGIAR
Generation

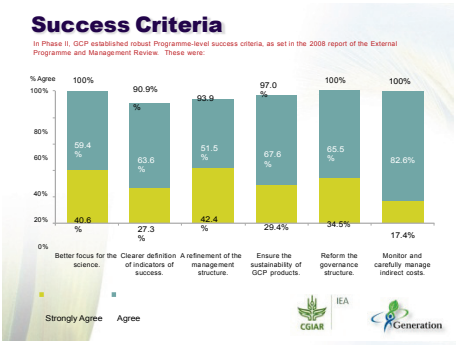

Governance
% Agree
100%
80%
60%
40%
20%
0%
82.1%
46.4%
35.7%
96.4%
57.1%
39.3%
95.4%
72.7%
22.7%
87.0%
60.9%
26.1%
Since the governance reform in 2009 the CC has performed its functions effectively
Since 2009, the EB has performed its functions effectively.
Interactions b/t the GCP governance bodies with the host Centre have been effective.
Interactions b/t the GCP CC and the GCP EB have been effective.
Strongly Agree
Agree
IEA
CGIAR
Generation

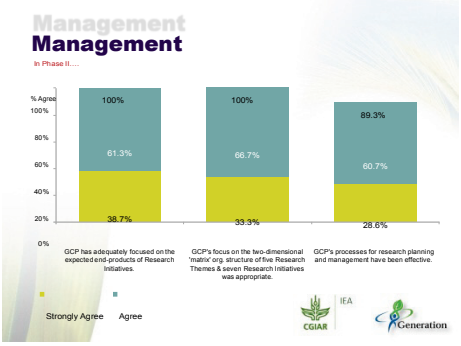

Governance
Please indicate your satisfaction with the performance of the Consortium Committee in terms of each of the following functions.
% Satisfied
100%
80%
60%
40%
20%
0%
77.8%
51.9%
25.9%
85.7%
60.7%
25.0%
75.0%
50.0%
25.0%
Providing expert scientific advice to the EB, GCP Director and GCP staff.
Participating in the GCP General/ Annual Research Meeting or equivalent.
Serving as a medium of communication between GCP and the Consortium Members.
Highly Satisfied
Satisfied
IEA
CGIAR
Generation

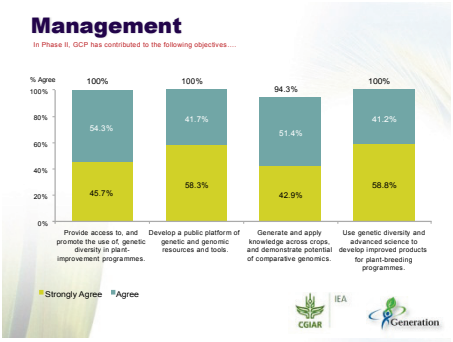

Governance
Please indicate your satisfaction with the performance of the Executive Board in terms of each of the following functions.
% Satisfied
100%
80%
60%
40%
20%
0%
100%
65.5%
34.5%
87.0%
60.9%
26.1%
100%
50.0%
50.0%
Determining GCP's strategic direction and setting overall Programme goals.
Establishing performance criteria to determine the progress of GCP activities.
Approving audits, annual operating plans, medium-term plans and budgets.
Highly Satisfied
Satisfied
IEA
CGIAR
Generation

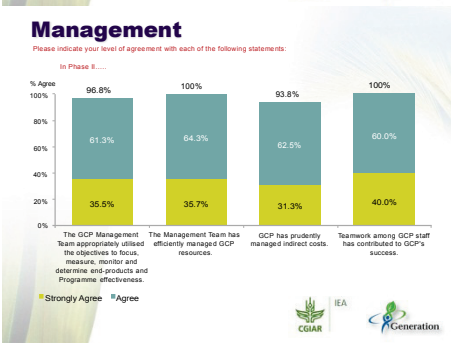

Governance
Please indicate your satisfaction with the performance of the Executive Board in terms of each of the following functions.
% Satisfied
100%
80%
60%
40%
20%
0%
100%
100%
100%
58.8%
80.0%
64.7%
41.2%
20.0%
35.3%
Ensuring the integrity of GCP's accounting and financial reporting systems.
Establishing a policy for managing risks and monitoring the implementation of that policy.
Monitoring and managing potential conflicts of interests of members of the EB and staff of the GCP Directorate.
Highly Satisfied
Satisfied
CGIAR
IEA
Generation

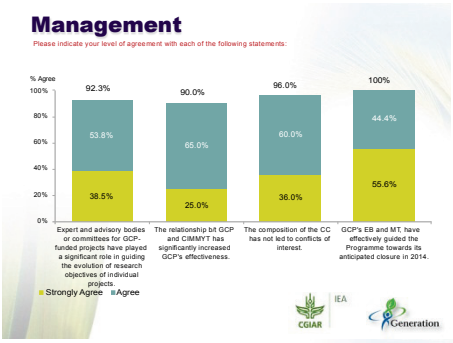

Governance
Please indicate your satisfaction with the performance of the Executive Board in terms of each of the following functions.
% Satisfied
100%
80%
60%
40%
20%
0%
95.7%
68.8%
86.4%
60.9%
56.3%
68.2%
34.8%
12.5%
18.2%
Overseeing the activities of, and providing guidance and advisory support and expertise to, the GCP Director and his staff.
Making recommendations to Consortium Members and Supporting Participants regarding the commercialisation of GCP intellectual property.
Making recommendations to the CC Members.
Highly Satisfied
Satisfied
CGIAR
IEA
Generation

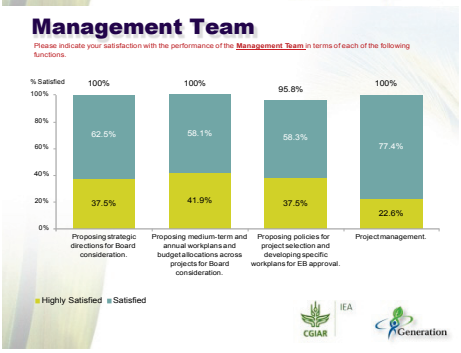

Success Criteria
In Phase II, GCP established robust Programme-level success criteria, as set in the 2008 report of the External Programme and Management Review. These were:
% Agree
100%
80%
60%
40%
20%
0%
100%
90.9%
93.9
97.0
100%
100%
59.4
%
63.6
%
51.5
%
67.6
%
65.5
%
82.6%
40.6
%
27.3
%
42.4
%
29.4%
34.5%
17.4%
Better focus for the science.
Clearer definition of indicators of success.
A refinement of the management structure.
Ensure the sustainability of GCP products.
Reform the governance structure.
Monitor and carefully manage indirect costs.
Strongly Agree
Agree
CGIAR
IEA
Generation

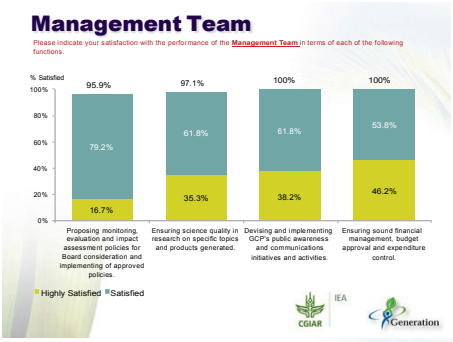

Management
Management
In Phase II....
% Agree
100%
80%
60%
40%
20%
0%
100%
100%
89.3%
61.3%
66.7%
60.7%
38.7%
33.3%
28.6%
GCP has adequately focused on the expected end-products of Research Initiatives.
GCP's focus on the two-dimensional 'matrix' org. structure of five Research Themes & seven Research Initiatives was appropriate.
GCP's processes for research planning and management have been effective.
Strongly Agree
Agree
CGIAR
IEA
Generation


Management
In Phase II, GCP has contributed to the following objectives....
% Agree
100%
80%
60%
40%
20%
0%
100%
54.3%
45.7%
100%
41.7%
58.3%
94.3%
51.4%
42.9%
100%
41.2%
58.8%
Provide access to, and promote the use of, genetic diversity in plant-improvement programmes.
Develop a public platform of genetic and genomic resources and tools.
Generate and apply knowledge across crops, and demonstrate potential of comparative genomics.
Use genetic diversity and advanced science to develop improved products for plant-breeding programmes.
Strongly Agree
Agree
CGIAR
IEA
Generation


Management
Please indicate your level of agreement with each of the following statements:
In Phase II.....
% Agree
100%
80%
60%
40%
20%
0%
96.8%
61.3%
35.5%
100%
64.3%
35.7%
93.8%
62.5%
31.3%
100%
60.0%
40.0%
The GCP Management Team appropriately utilised the objectives to focus, measure, monitor and determine end-products and Programme effectiveness.
The Management Team has efficiently managed GCP resources.
GCP has prudently managed indirect costs.
Teamwork among GCP staff has contributed to GCP's success.
Strongly Agree
Agree
CGIAR
IEA
Generation


Management
Please indicate your level of agreement with each of the following statements:
% Agree
100%
80%
60%
40%
20%
0%
92.3%
53.8%
38.5%
90.0%
65.0%
25.0%
96.0%
60.0%
36.0%
100%
44.4%
55.6%
Expert and advisory bodies or committees for GCP-funded projects have played a significant role in guiding the evolution of research objectives of individual projects.
The relationship bit GCP and CIMMYT has significantly increased GCP's effectiveness.
The composition of the CC has not led to conflicts of interest.
GCP's EB and MT have effectively guided the Programme towards its anticipated closure in 2014.
Strongly Agree
Agree
CGIAR
IEA
Generation


Management Team
Please indicate your satisfaction with the performance of the Management Team in terms of each of the following functions.
% Satisfied
100%
80%
60%
40%
20%
0%
100%
62.5%
37.5%
100%
58.1%
41.9%
95.8%
58.3%
37.5%
100%
77.4%
22.6%
Proposing strategic directions for Board consideration.
Proposing medium-term and annual workplans and budget allocations across projects for Board consideration.
Proposing policies for project selection and developing specific workplans for EB approval.
Project management.
Highly Satisfied
Satisfied
CGIAR
IEA
Generation



Further details of the GCP Stakeholder Survey results are given below.