



The Biofortification Challenge Program

2007 Annual Report for the Executive Council of the CGIAR

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HarvestPlus 2007 Annual Report

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1.0 EXECUTIVE SUMMARY

Program Objectives

The goal of HarvestPlus is to reduce global micronutrient malnutrition by breeding and disseminating staple food crops high in bioavailable iron, zinc, and pro-vitamin A to have a measurable impact on human nutritional status.

Since January 2004, full-time breeding programs are under way for six staple foods—rice, wheat, maize, cassava, sweetpotato, and common beans—that are consumed by the majority of the world's poor in Africa, Asia, and Latin America.

The primary objectives of HarvestPlus' 10-year plan (2004-2013) are to:

- select and breed nutritionally improved varieties of six major staple food crops with superior agronomic properties that make them attractive to farmers to grow;
- establish nutrient retention in promising varieties consumed as staples and that these nutrients are sufficiently bioavailable, and micronutrient status in malnourished human subjects is improved;
- identify varieties with superior agronomic, socioeconomic, and end user-acceptable traits and develop efficient, accelerated mechanisms for testing promising materials with farmers, consumers, and other end users, including those in the most nutritionally disadvantaged areas;
- measure the nutritional and other impacts of these improved varieties in community-based studies where these varieties have been adopted.

Management and Oversight

In 2007, HarvestPlus developed and received approval for a proposal for one-year funding from the Bill and Melinda Gates Foundation to bridge from Phase I (2004-2007) to Phase II (2009-2013). The proposal of US\$8.85 million will be used to continue advancing HarvestPlus's strategy that moves biofortification research from discovery to development and plans for the next phase of the program that will be organized around specific biofortified crop product development for target countries and populations.

HarvestPlus continues to fulfill reporting requirements and the development of the Medium Term Plan of the Executive Committee (ExCo) of the CGIAR, annual reports to donors (USAID and ADB), and to the Bill and Melinda Gates Foundation (2 grants), and responding to comments on reports. In addition to reporting requirements, HarvestPlus was subjected to external reviews commissioned by the Science Council of the CGIAR and the BM Gates Foundation.

The role of the Nutrition Coordinator substantially expanded as HarvestPlus moves toward product testing. Additional 14 contracts under the HarvestPlus nutrition component were implemented in 2007 for several nutrition research in the US, Australia, Denmark, Bangladesh, and Africa. In 2007, a senior research assistant was hired to support the Nutrition Coordinator and a co-coordinator will be hired in 2008 to apportion the expanding research in nutrition.

Since the number of HarvestPlus contracts has increased since the beginning of the program in 2003, a full time Budgets and Administrative Specialist was hired to provide secretarial assistance to the Project Director and the PMT members based at IFPRI, and to monitor budgets of the different components of the program. The existing Senior Administrative Coordinator monitors the contracts and provides administrative assistance to program staff.

Research Accomplishments in 2007

With much biofortification *discovery* research completed under HarvestPlus I, the program can now launch the second phase, which will be characterized by investments on promising crops. In HarvestPlus I, where discipline based *discovery* research drove the research agenda, HarvestPlus II research will concentrate on the *development* of specific biofortified products in target countries for target populations with specific nutrition objectives. HarvestPlus II will make full use of the methodologies, protocols and proof of concept research achieved under HarvestPlus I to move ahead with focused and intensive research related to crop improvement and testing and the establishment of nutritional efficacy in target regions and within specific populations. This new way of doing business in HarvestPlus II (by product rather than across disciplines) allows the team to reshape the program to maximize impact.

Highlights of research accomplishments in 2007 are presented based on the following topics:

- High Zinc Rice for Asia
- High Zinc Wheat for Asia
- Pro-vitamin A Maize for Africa
- Pro-vitamin A Sweetpotato for Africa
- High Iron bean for Africa
- High Iron/Zinc Pearl Millet in India
- Pro-vitamin A Cassava for Africa
- Pro-vitamin A Banana/Plantain for Africa
- Iron Lentil for Asia
- Iron Potato for Africa
- Iron Sorghum for Africa
- Phase-out Activities: Yam and Cowpea
- Analytical Techniques

Sub-programs and Programs

Reaching End Users with OFSP

HarvestPlus REU conducted a diagnostic research on the cost of vine multiplication in Mozambique. The research showed that cost of multiplying vines in the southern Zambézia is higher than the cost for producing the same sweetpotato vines in the north due to differences in agro-ecological conditions. Other diagnostic research focused on the cost effectiveness of existing extension programs promoting OFSP namely “Toward Sustainable Nutrition Improvement” (TSNI) and “Eat Orange”. TSNI seems to be more cost-effective than “Eat Orange” in terms of levels of OFSP adoption, increases in the nutritional knowledge, and increases in the consumption of vitamin A-rich foods, except for OFSP.

HarvestPlus China

Eight research proposals related to the development of biofortified rice, wheat, maize, and sweetpotato have been initiated under HarvestPlus with counterpart funding from Chinese institutions (50% funding from HarvestPlus and 50% funding from Chinese institutions). The HarvestPlus China coordinates and provides oversight for these eight research projects and undertakes promotional activities to encourage investment by the Chinese government in biofortification. An annual meeting was held in 2007 in China.

India Biofortification Program

The Indian parliament has approved \$3 million to be spent over five years in developing biofortified varieties of rice, wheat, and maize. Indian Biofortification Program invited HarvestPlus to participate in planning and coordination meetings. A memorandum of agreement has been signed between the Department of Biotechnology and HarvestPlus to facilitate this collaboration.

Brazil Biofortification Program

The primary objective of the HarvestPlus activities in Brazil is to establish EMBRAPA as a leader in biofortification research in Latin America. EMBRAPA has invested \$1.5 million of its own funds, augmented by funding from HarvestPlus and AgroSalud. Research activities in EMBRAPA focus on beans, cassava, and maize. Biofortification research is also being undertaken for cowpeas, sweetpotato, and wheat. HarvestPlus provides funding to EMBRAPA to coordinate these activities and for advocacy within Brazil, for outreach to other Latin American countries, and for capacity building in nutrient analysis outside of Brazil (training programs in measuring pro-vitamin A carotenoids, run by EMBRAPA, were held in Africa and China).

Finance

As of December 2007, the Cash on Hand for HarvestPlus amounted to \$17.84 million which represents 455 days of projected expenditures of \$14.307 million. Funds from the CGIAR make up merely 27%, or \$17.86 million of total funding of \$52 million. The Gates Foundation, the main donor of the program, has signified funding for the program of up to \$9.0 million per year for 2009-2013. It is vital that the CGIAR come forward with the balance funding required for Phase II, and manifest a commensurate support to the program.

Revenues received for Phase 1 of the program in the amount of \$52.438M supported expenditures of \$51.891 million. Estimated revenues of \$14.0 million for 2008 Bridge Year are expected to fund activities of the same amount. As of the first quarter of 2008, \$12.0 million of Bridge Year funds have already been received.

2.0 BACKGROUND

An estimated 2 billion people in the developing world suffer from the effects of micronutrient malnutrition, in particular iron deficiency anemia, vitamin A deficiency, and zinc deficiency. Micronutrient malnutrition lowers disease resistance, damages cognitive development among children, and increase risks of mortality and morbidity among mothers during childbirth.

The primary underlying cause of micronutrient malnutrition is poor quality diets, characterized by high intakes of food staples, and low consumption of animal and fish products, fruits, legumes, and vegetables, which are rich sources of bioavailable minerals and vitamins. As such, most of the undernourished are those who cannot afford to purchase high-quality, micronutrient-rich foods or who cannot grow these foods themselves.

By developing staple foods whose edible portions are denser in bioavailable minerals and vitamins, a process referred to as “biofortification,” scientists can provide farmers with crop varieties that naturally reduce anemia, cognitive impairment, and other nutrition-related health problems in hundreds of millions of people. Biofortification can serve as an additional instrument to existing nutrition interventions in reducing micronutrient malnutrition, and improve human health.

2.1 Program Objectives and Structure

Program Objectives

The goal of HarvestPlus is to reduce global micronutrient malnutrition by breeding and disseminating staple food crops high in bioavailable iron, zinc, and pro-vitamin A to have a measurable impact on human nutritional status.

Since January 2004, full-time breeding programs are under way for six staple foods—rice, wheat, maize, cassava, sweetpotato, and common beans—that are consumed by the majority of the world’s poor in Africa, Asia, and Latin America.

The primary objectives of HarvestPlus’ 10-year plan (2004-2013) are to:

- select and breed nutritionally improved varieties of six major staple food crops with superior agronomic properties that make them attractive to farmers to grow;
- establish nutrient retention in promising varieties consumed as staples and that these nutrients are sufficiently bioavailable and micronutrient status in malnourished human subjects is improved;
- identify varieties with superior agronomic, socioeconomic, and end user-acceptable traits and develop efficient, accelerated mechanisms for testing promising materials with farmers, consumers, and other end users, including those in the most nutritionally disadvantaged areas;
- measure the nutritional and other impacts of these improved varieties in community-based studies where these varieties have been adopted.

Program Structure

Figure 1 below illustrates the details on the interdisciplinary activities, which are required for development and deployment of each biofortified crop. Crop leaders stationed in different CGIAR centers are assigned to each crop to help manage crop activities vertically along the organizational matrix. Research activities for all crops are coordinated by the HarvestPlus Program Management Team members, who have responsibility for disciplinary activities related to breeding, molecular biology, food science, human nutrition, deployment, and impact and policy (the rows in the matrix below).

Figure 1. HarvestPlus: Coordinating a Multidisciplinary Program.

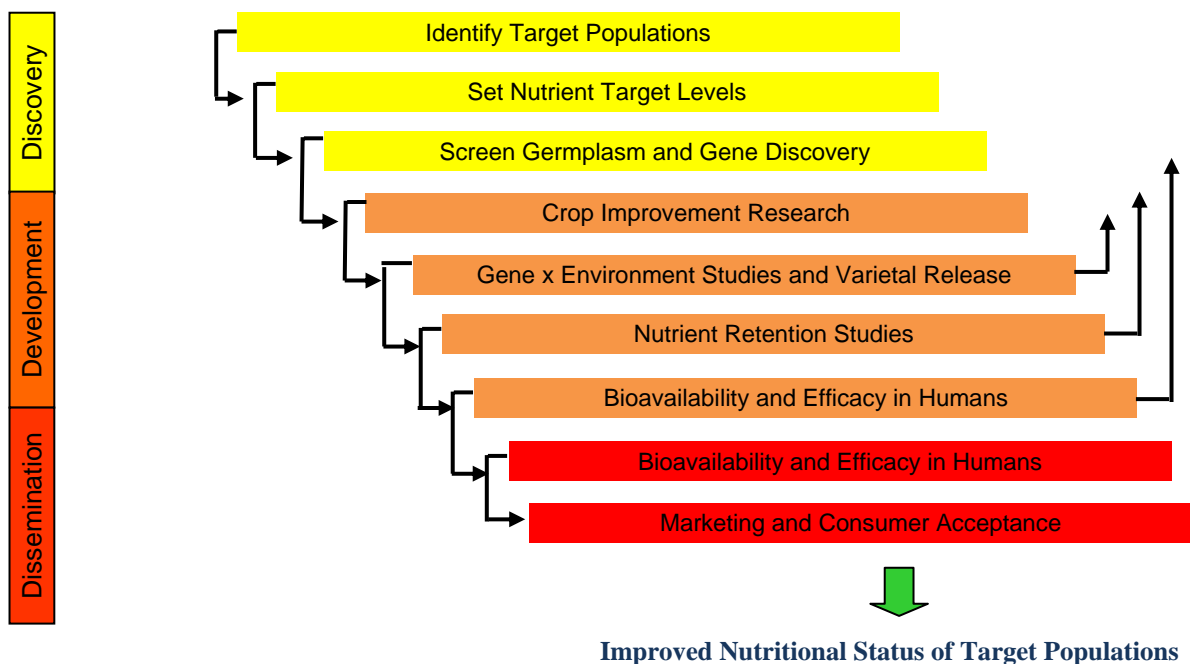
Function	Rice IRRI	Maize CIMMYT	Wheat CIMMYT	Cassava CIAT	Sweetpotato CIP	Bean CIAT	Pearl Millet * ICRISAT
Breeding							
Biotechnology							
Food Processing							
Human Nutrition							
Reaching End-User							
Impact/Policy							
Communication							

* Promoted to focus crop in 2007

2.2 Research Strategy and Priorities

HarvestPlus' biofortification strategy follows an approach to product development that includes stages of discovery, development, and dissemination. As products advance down the impact pathway, research developments at any one stage may necessitate revisiting previous stages to refine and assure the highest quality nutrient-dense product (Figure 2). In this way, the probability of success increases from discovery, through development to dissemination. For each crop developed, each stage of the pathway must be investigated.

Figure 2. HarvestPlus Pathway to Impact



3.0 RESEARCH ACCOMPLISHMENTS 2007

3.1 Overview

With much biofortification *discovery* research completed under HarvestPlus I, the program can now launch the second phase, which will be characterized by investments on promising crops. In HarvestPlus I, where discipline based *discovery* research drove the research agenda, HarvestPlus II research will concentrate on the *development* of specific biofortified products in target countries for target populations with specific nutrition objectives. HarvestPlus II will make full use of the methodologies, protocols and proof of concept research achieved under HarvestPlus I to move ahead with focused and intensive research related to crop improvement, testing, and the establishment of nutritional efficacy in target regions and within specific populations. This new way of doing business in HarvestPlus II (by product rather than across disciplines) allows the team to reshape the program to maximize impact.

3.2 Technical Outputs

HarvestPlus research accomplishments for each crop and target country in 2007 are described below.

High Zinc Rice for Asia

- In anticipation of Bangladesh being formally selected as a flagship target country for high zinc rice, a rice varietal map was developed. Studies were conducted on milling, seed-sourcing practices, rice and zinc intakes of women and children in preparation for the introduction of high zinc rice in that country.
- Having established zinc absorption from test meals in rats, the planning for absorption studies on zinc from biofortified and control rice among young Bangladeshi women and young children was initiated. HarvestPlus anticipates that zinc-biofortified rice will also be an efficacious means of contributing to improved zinc status among at-risk populations. HarvestPlus estimated that the additional zinc attributable to biofortification would provide the equivalent of 40% of the mean daily zinc requirement.
- Germplasm products in early, intermediate and final development stage and platform genotypes from the 1st generation crosses (frequently pre-dating HarvestPlus) were produced. Superior products have emerged from the 2nd generation crosses using a Double Haploid (DH) method. Initial GxE analysis for iron and zinc were determined in different seasons and for a prototype mineral enhanced variety across 30 sites in different districts across the Philippines. Genotypes with stability in iron and zinc expression have been identified.
- Candidate gene are being selected for either transgenic or marker assisted selection strategies to increase iron and/or zinc in rice grain. Gene expression analysis showed metal homeostasis genes active in the rice flag leaf. Metal homeostasis with differential expression of high and low levels of iron and zinc across genotypes were identified. Iron transporter, YS1 gene from rice and maize was amplified by PCR and sequence was verified.

High Zinc Wheat for Asia

- The spring wheat core collection relevant for India and Pakistan were assayed. Both countries are high wheat consuming countries with significant micronutrient malnutrition. Current pre-breeding activities concentrate on transforming genes into adapted backgrounds. To facilitate the development of adapted germplasm, HarvestPlus deployed to the NARES micronutrient dense wild relative species, elite germplasm, germplasm developed from pre-breeding, and elite germplasm developed from 1st generation crosses with enhanced iron, zinc concentration and agronomic attributes.

- The effect of zinc and iron fertilizer on agronomic and minerals performance were investigated in multi location experiments in India, Pakistan, China, Kazakhstan, Turkey, and Mexico. Popular soft wheat varieties were among the highest in iron and zinc in China, while the 1st generation crosses displayed competitive yield with local checks at several locations in India and Pakistan.
- Clones for several metal genes in wheat were obtained by HarvestPlus collaborators at USDA-Baylor. DNA extraction from unique genetic stocks was conducted to facilitate mapping of metal genes in wheat. The tool kits for wheat transformation were developed. The characterization of genomic clones for all the ferritins was achieved. The regulatory motifs in the promoters were characterized and a transformation system was implemented in Denmark.
- On average, zinc and iron levels in milled products at 80% extraction relative to the whole grain were significantly reduced by 57% and 54%, respectively. HarvestPlus estimates zinc absorption from biofortified high zinc wheat produced at CIMMYT would provide a 60% increase in zinc absorption. A 50% reduction in phytate content combined with biofortification increases zinc absorption closer to the physiologic requirements for non-pregnant women. A clinical study by HarvestPlus showed zinc absorption from biofortified wheat among Mexican women was similar to these estimates.

Pro-vitamin A Maize for Africa

- Variation for pro-vitamin A carotenoids in different gene-pools were discovered, which increases the potential for further advancement. Temperate maize were found to have pro-vitamin A carotenoids similar to the target level. Hybrids and African Open Pollinated Varieties were evaluated for use as parents/fast-track in multi-location performance trials in different agro-ecological zones in Nigeria and Mexico. The trials from Nigeria revealed high stability for pro-vitamin A carotenoids and good stability for zinc across environments. For zinc, genetic variation in adapted genotypes suggests reaching target increments in shorter term is feasible, while existing variation in iron allows HarvestPlus to achieve about 50% of target.
- Genetic transformation work on golden maize focuses on improving the pro-vitamin A levels in maize endosperm using phytoene synthase (PSY1) to enhance beta-carotene metabolism. Zm27 promoter element with 5'UTR region from maize was isolated by PCR. The sequence-verified promoter gene was translationally fused to rice and maize PSY1 coding sequences and Zm27 terminator. Transformation was done on maize embryos into agrobacterium with the promoter gene constructs to recover transformation events. Regenerated plants produced seeds with detectable yellow endosperm.
- Retention studies showed approximately 70-75% pro-vitamin A was retained in fermented and unfermented porridges, and 64% in corn chips from nixtamalized maize. This exceed the estimated of 50% retention after processing and cooking.
- HarvestPlus estimates that current prototypes of biofortified pro-vitamin A carotenoid maize would provide the equivalent of 50% of the mean daily vitamin A requirement, and biofortified high zinc maize would provide the equivalent of 40% of the mean daily zinc requirement for adult women.
- A study on the bioavailability of pro-vitamin A from dark orange maize using Mongolian gerbils showed that the conversion factor for pro-vitamin A to vitamin A was approximately 3:1, which is a more efficient conversion than the expected 12:1. A lower bioconversion was corroborated by a controlled human absorption study that indicated the conversion factor of pro-vitamin to vitamin A was approximately 7:1.

Pro-vitamin A Sweetpotato for Africa

- Local African Sweetpotato varieties and accessions were collected and partially characterized for pro-vitamin A carotenoids and minerals. Progenitor and candidate varieties for fast-tracking/release were identified by CIP & NARES partners, and the best clones have been virus cleaned and disseminated to African NARES.
- The best clones from previous screening were evaluated in multi-location trials on-farm and on-station and in Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Rwanda, South Africa, Tanzania, Uganda and Zambia.
- Studies were initiated to quantify the pro-vitamin A content in the four sweetpotato varieties being released in Uganda. Retention studies were also conducted using the most common processing methods (boiling, steaming, chipping & shade- or sun-drying).

High Iron Bean for Africa

- Iron concentration in superior agronomic final products is close to the target increment and can be further increased in bush bean by approximately 25% using the variation discovered in 2007. Breeders at CIAT worked with two breeding cycles for bush bean allowing an additional of $20 \mu\text{g g}^{-1}$ iron per cycle to the baseline. Simultaneously, tolerance to abiotic stress was improved, and relevant end-use quality attributes were incorporated in relevant market classes. Climbing bean achieved the same rate of progress and completed one breeding cycle.
- More than 60 lines were selected by farmers from performance evaluation in Kenya, DR Congo, Rwanda, Burundi, Malawi, Madagascar, Uganda, and Tanzania.
- Nutritional genomics research in beans provides better understanding of the physiological processes involved in iron nutrition in plants. RILs showed a broad capacity for root iron reduction and seed iron concentration. Gene mapping is in progress and iron reductase and transporter genes were sequenced.
- Retention studies on iron, polyphenols, and phytate in beans were finalized using traditional African processing methods. Human studies of iron absorption from beans are currently being conducted with the main objective of determining the relative effects of phytate and polyphenols, and a dose response effects of bean polyphenols on iron bioavailability.
- A meta-analysis on iron status (e.g. serum ferritin), together with at least two indicators of infection and inflammation (e.g., serum C-reactive protein and alpha-1-glycoprotein), was completed. The purpose of this analysis is to develop a statistical method to correct serum iron ferritin for presence of infection.

High Iron/Zinc Pearl Millet in India and Niger

- A review of literature on consumption of pearl millet in West and Central Africa was commissioned. Analysis of consumption expenditure data suggests that there are areas in semi-arid India with high pearl millet consumption, and where seed systems are relatively more developed. Based on this analysis, India and Niger are being considered as target countries.
- A colorimetric method developed at ICRISAT was tested during pre-screening of the core collection. This method allows the separation of high iron beans from low iron beans. Beans high in iron were then assayed using precision methods. Genetic variation in adapted inbred lines and hybrids suggests that it is possible to achieve iron and zinc target increments.
- Preliminary data on transgressive segregation revealed iron and zinc values with 30% more than those previously evaluated. The 1st cycle of recurrent selection was completed from selected crosses.
- Estimates on general combining ability (gca), specific combining ability (sca) and heritability suggested that minerals are controlled by additive gene effects. Products in early and intermediate development stage are now available. Hybrid parents and landraces were evaluated for use as parents/fast-track in different seasons and soils in India and Niger. In Niger, whole and decorticated grain produced from two fertilizer treatments was evaluated.

Pro-vitamin A Cassava for Africa

- Concentration of pro-vitamin A carotenoid in recent breeding populations surpassed the levels discovered in landrace sources. The genetic variation for iron and zinc levels remains below 50% of the target increment. Products with increased pro-vitamin A carotenoid from early to final product development stage have been produced.
- Yellow clones with enhanced pro-vitamin A carotenoid were evaluated in Benin, DR Congo, Ghana, Guinea Conakry, Nigeria, Sierra Leone and Togo in multilocation trials on-farm and on-station for relevant agro-ecological zones. The best performing clones were identified by farmers and researchers. Seeds were multiplied for further distribution to farmers.
- Root specific promoters needed for the transformation experiments were identified and cloned. One cassava root specific promoter, "extensin", was characterized at CIAT. Four putatively storage-root specific promoters were cloned (from cassava, yam and sugar beet). Patatin-CrtB-crtI-crtY (mini-pathway) was provided by U. Freiburg to CIAT for cassava transformation. At least 40 transgenic plants were developed and moved to confined biosafety greenhouse.
- Additional progenitors were identified and seeds were produced from crosses from pro-vitamin A carotenoid and CMD resistance. These seeds were provided to African NARES.
- Two yellow varieties with enhanced pro-vitamin A carotenoid were released in Brazil. The varieties were developed via farmer participatory approaches.
- Several studies on pro-vitamin A retention in cassava from multiple growing seasons were completed and indicated that a wide range of variability in true retention among genotypes. These results suggest that retention may be considered as an important trait in the breeding program. For various cassava processing methods, the retention of beta-carotene was highest from oven-drying, shadow drying and boiling (56-72%), and lowest for gari (~34%). Additional studies on retention with different processing methods are presently being conducted with a set of high pro-vitamin A cassava clones from IITA.
- HarvestPlus conducted analysis of consumption and dietary intake of cassava in DR Congo. Dietary intake was established for Nigeria, and data from areas in DR Congo and Uganda will become available by 2008.
- A human bioavailability study was initiated to determine the retinol equivalency of pro-vitamin A in cassava test meals using a modified plasma response method. Results from the animal and human studies on retinol equivalency and information on pro-vitamin A retention in cassava will be useful for estimating the potential impact on vitamin A intakes in African populations.

Pro-vitamin A Banana/Plantain for Africa

- DALY analysis determined the potential cost effectiveness of breeding pro-vitamin A banana/plantain for Africa.
- Identified additional parents and inheritance patterns, and assessed effects of environment and influence of harvest cycle on micronutrient variability in more than ten multi-location trials in Nigeria and Cameroon.
- Screening banana/plantain germplasm indicates that approximately half of its pro-vitamin A content is in the form of alpha-carotene, which is estimated to have half of the vitamin A activity as beta-carotene, or a retinol equivalency of 24:1.

Iron Lentil for Asia

- More than 700 lentil genotypes from Nepal, Bangladesh, and Morocco were evaluated and parents/genotypes were identified for fast-tracking. International nursery with micronutrient dense lentil genotypes were deployed to target NARES.

- Based on estimates for lentil consumption, iron retention and bioavailability, an additional 33 micrograms iron to an average baseline of 30 micrograms would be needed in order to have a measurable impact on iron status in humans.

Iron Potato for Africa

- More than 600 *S. phureja*, *S. stenotomum* and *S. goniocalix* accessions and potato varieties were characterized for minerals, phenolic compounds, and vitamin C. More than three mixtures of selected native and improved clones were tested in multiplication and/or evaluation with two Andean communities.
- An initial exercise using estimates for potato consumption and iron retention and bioavailability determined that an additional increment of 15 micrograms/gram iron would need to be added to a baseline of 19 micrograms/gram iron in potato.
- Studies using the *in-vitro* Caco-2 cell model suggest that iron bioavailability is inhibited somewhat in the presence of polyphenols from potato. Studies showed that some genotypes contained high levels of ascorbic acid (a known enhancer of iron bioavailability) and other unidentified enhancing organic compound. Results from *in vitro* studies on iron bioavailability will be used as the basis for selecting potatoes for human studies using isotope dilution techniques to measure iron absorption.

Iron Sorghum for Africa

- A review of literature on consumption of sorghum in West and Central Africa was commissioned. The limited evidence suggests that consumption of sorghum is reasonably high in several micronutrient deficient populations.
- Additional sorghum genotypes for high iron from the core collection were assayed, and high iron genotypes were validated from previous screening activities. Genetic variation of varieties adapted to the Savannah in Mali were determined. Additional progenitors were identified and transgressive segregants from crosses between adapted breeding lines. Effects of GxE in Mali on-farm trials across farmers' fields were determined.
- The effects of fertilizer has been assessed from applying two levels of iron fertilizer at two locations in Mali; the effects of NPK and micronutrient fertilizer has been evaluated from an on-station trial in India.

Phase-out Activities: Yam and Cowpea

Due to lack of performance/responsiveness or insight gathered from other components of the program, HarvestPlus has taken a decision to discontinue research on these crops. Funding will be provided by HarvestPlus in 2008 to finish up and summarize ongoing pre-breeding research for these crops. Advances made in these crops are highlighted below.

Yam

- Results from previous screening for pro-vitamin A carotenoids in *D. dumetorum* were validated. A seedling nursery from 2007 crosses was established, and the best germplasm were advanced to next generation. Genotypes x Environment of yams were determined from trials from different agro-ecological zones in Nigeria

Cowpea

- Results from previous screening activities were validated and additional parents were identified. Based on G x E trials, best genotypes will be made available to the NARES.

Analytical Techniques

NIRS

- Calibrations of NIRS were developed as proof-of concept for screening pro-vitamin A carotenoids in OFSP, cassava, maize, and potato as semi-quantitative diagnostics. For minerals, NIRS was calibrated for pre-screening of OFSP, bean, cassava, potato, maize, and rice.

HPLC

- Spectrophometric and HPLC methods for screening pro-vitamin A carotenoids in sweetpotato, cassava, and maize were developed and evaluated. Results from both methods did not differ significantly. A high throughput screening method to estimate pro-vitamin A carotenoids in maize to reduce the number of samples for HPLC analysis was developed. This method identifies low, medium, and high levels of pro-vitamin A carotenoids in maize by semi-quantitative analysis.

Simulation Model

- The efficiency of traditional phenotypic selection in breeding is frequently low with the consequence that populations resulting from seemingly good crosses are discarded during the segregating phase. Simulation by predicting the potential performance of crosses and defining crop relevant conventional and/or marker assisted selection strategies can overcome this problem and increase breeding effectiveness. During Phase I of HarvestPlus, research conducted at the Chinese Academy of Agricultural Sciences (CAAS) in collaboration with the CG Generation Challenge Project focused on i) the collection of micronutrient gene information from published sources and public databases, ii) building additional tools to the genetics and breeding simulation tool, and iii) verification of the optimum crossing and selection strategies from simulation.

CARBO H+

- Related HarvestPlus research is addressing cost assessment in germplasm product development and different breeding options, a major knowledge gap in public sector breeding efforts. HarvestPlus collaborated with the leading expert in this field to develop a program for Cost Assessment of Research and Plant Breeding Options (CARBO H+), building on a previously developed program applied for wheat at CIMMYT. The program is expected to cover all crops, breeding stages, and conventional and marker assisted selection. Prototype versions for wheat, rice, maize, bean and cassava are already available. CARBO H+ in combination with simulation allows consideration of all primary factors related to breeding efficiency (not only nutrient content) and development of strategies based on their contribution to genetic progress and benefit/cost.

3.3 List of Sub-Programs/Projects with a Brief Report on Status and Results

Reaching End Users with OFSP

Collaborators of the HarvestPlus REU include The International Potato Center (CIP-Kampala), Helen Keller Institute (HKI), Natural Resource Institute (NRI), World Vision, National Agricultural Research Organization (NARO), and Regional Potato and Sweetpotato Improvement Network in East and Central Africa (PRAPACE).

HarvestPlus REU conducted a diagnostic research on the cost of vine multiplication in Mozambique. The research showed that cost of multiplying vines in the southern Zambézia is higher than the cost for producing the same sweetpotato vines in the north due to differences in agro-ecological conditions. Other diagnostic research focused on the cost effectiveness of existing extension programs promoting OFSP namely “Toward Sustainable Nutrition Improvement” (TSNI) and “Eat Orange”. TSNI seems to be more cost-effective than “Eat Orange” in terms of levels of OFSP adoption, increases in the nutritional knowledge, and increases in the consumption of vitamin A-rich foods, except for OFSP.

Drying studies were conducted to assess losses of pro-vitamin A carotenoids in two OFSP varieties. Losses associated with drying are much lower than expected. Shade drying was effective in minimizing the losses of pro-vitamin A at less than 30%. Results from the drying studies in Mozambique and Uganda were consistent.

Training courses on agronomy, trading practices, nutrition for the agricultural and nutrition extension workers, and agronomist supervisors were conducted in Mozambique and Uganda. The training course focused on vine multiplication, conservation and improved agronomic practices, importance of vitamin A rich food, including OFSP. Training Manuals were developed in Portuguese.

Four clones of sweetpotato were released nationally in Uganda and were recommended for distribution in the REU project. Two of the varieties were known to be high in beta-carotene, and showed high performance in dry environments.

Demand creation activities included putting together a community drama, six episodes of pro-vitamin A radio programs, integrated nutrition extension programs for mothers with children under 5 years, and promotional activities for OFSP.

The baseline household study was completed in 2007 in Mozambique, and a consumer acceptance study was conducted on orange fleshed sweetpotato varieties to determine the price discount, from biofortified varieties, and the change in behavior from nutrition information. In addition, a review of policies in the agriculture, health and poverty sectors in Uganda was commissioned to assess the niche for biofortification and to facilitate buy-in from policy makers.

Country Programs

HarvestPlus China

Eight research proposals related to the development of biofortified crops for rice, wheat, maize, and sweetpotato have been initiated by HarvestPlus with counterpart funding from Chinese institutions (50% funding from HarvestPlus and another 50% from Chinese institutions). Approximately twenty Chinese research institutions are involved. HarvestPlus China was established under the leadership of Fan Yunliu of the Chinese Academy of Agricultural Sciences. The HarvestPlus China coordinates and provides oversight for these eight research projects and undertakes promotional activities to encourage investment by the Chinese government in biofortification. An annual meeting was held in 2007 in China.

India Biofortification Program

The Indian parliament has approved \$3 million to be spent over five years in developing biofortified varieties of rice, wheat, and maize. Those administering these funds (Indian Biofortification Program) invited HarvestPlus to participate in planning and coordination meetings. To facilitate this collaboration, a memorandum of agreement was signed by The Department of Biotechnology and HarvestPlus.

Brazil Biofortification Program

The primary objective of the HarvestPlus activities in Brazil is to establish EMBRAPA as a leader in biofortification research in Latin America. EMBRAPA invested \$1.5 million of its own funds, augmented by funding from HarvestPlus and AgroSalud. Research activities in EMBRAPA focuses on beans, cassava, and maize. Biofortification research is also being carried out for cowpeas, sweetpotato, and wheat. HarvestPlus provides funding to EMBRAPA to coordinate these activities and for advocacy within Brazil, for outreach to other Latin American countries, and for capacity building in nutrient analysis outside of Brazil (training programs in measuring pro-vitamin A carotenoids, run by EMBRAPA, have been held in Africa and China).

4.0 PROGRESS ON OTHER CP ACTIVITIES

4.1 Capacity Building

CGIAR scientists were/are engaged in supervising more than 15 undergraduate and graduate research projects in the context of HarvestPlus breeding activities. In 2007, support was provided to a Food Science graduate student in Uganda for work on beta-carotene retention in orange-fleshed sweet potato.

Crop specific sampling protocols for analysis of nutrient content of breeding materials that were developed in HarvestPlus I were implemented through on-site training visits at each of the participating CGIAR centers and selected collaborating NARES.

Training was conducted for use of NIRS as a rapid and low-cost screening method for mineral and pro-vitamin A content of germplasm at three CG Centers (CIP, CIAT and CIMMYT).

HarvestPlus conducted several rounds of inter-laboratory studies in which the proficiency of analytical capacity was tested. In 2007, three inter-laboratory studies on pro-vitamin A analysis in sweetpotato/cassava, maize, and for minerals in grain were initiated.

4.2 Data Management

Initial preparation of the HarvestPlus Atlas began in 2007. This is a digitized a compilation of data on production, consumption, and micronutrient malnutrition on a national level. Disaggregated consumption levels in 20 countries were integrated with IFPRI's IMPACT model to generate predictions for consumption patterns.

The HarvestPlus database which is developed at CIAT using commercial software and building on CIAT in-house expertise is operational. The database houses primarily genotypic micronutrient screening data, information/data relevant for the interpretation of results, descriptors and sample details for all crops. The database embraces raw data, processed data and summaries from standard data analysis for all screening data generated during Phase I. The establishment of a literature database for breeding for micronutrients was initiated.

4.3 Communications/Public Awareness

Advocacy

Over 250 presentations were made by the HarvestPlus PMT and Alliance members. Communications has cultivated and technically supported opportunities to present in International Nutrition and Agriculture meetings, UN conferences and at national level enabler meetings in Brazil and East Africa.

Branding

In the first year, HarvestPlus branding and promotion strategy was developed to ensure that all critical audiences were considered, and that effective information channels were identified. Brochures, promotional materials and office support products continue to be developed to reinforce name recognition and branding. In 2007, research and implementation brochure were developed, and new HarvestPlus display stands for use at conferences and meetings were made.

Intra-Alliance communication

In 2004, the HarvestPlus Hub (intranet) was developed as a mechanism for intra program communication. With 250 members in 2007, the Hub now provides a virtual space for sharing information and discussing issues across the program.

Media

Media work makes up a small part of the current communication portfolio but it is expected to grow as more research results come on line. While HarvestPlus focuses on discovery research, stories have been placed

in leading media outlets promoting the promise of biofortification and the formation of HarvestPlus and its partnerships. In 2007, 10 articles appeared in internationally recognized newspapers, newsletters and magazines including a feature article in Conde Naste's award winning magazine *Gourmet* and three international radio programs featured HarvestPlus work including: NPR, VOA – Francais, BBC.

Select Print Media Coverage in 2007

Outlet	Date	Headline	Country	Medium
Hindu Business Line	4/3/2007	"HarvestPlus Aid for Boosting Nutrition Levels"	India	Newspaper
Business Standard	4/6/007	4/6/2007 "Killing Deficiencies" by Surinder Sud	India	Newspaper
CGIAR news	3/2007	3/ 2007 Big Potential for Micronutrient Collaboration	USA	Electronic Newsletter
Greenpeace magazine	5/07	Seltsame Berater	Germany	Magazine
Biotech 360	5/1/2007	Debugging Developing-World Cotton		Online
CGIAR news	6/2007	New Partnership to Improve Nutrition	USA	Electronic Newsletter
SciDev.Net	6/12/2007	Agri-Biotech in Africa: Saironty First?		Electronic
Developments	7/04/2007	Growing Goodness	UK	DFID sponsored Magazine
New Ag International	9/1/2007	Biofortification of Crops: An Interview with Howarth Bouis, Director of HarvestPlus"	USA	Trade Publication
Gourmet	10/23/2007	"Mission Man"	USA	Magazine
ABD Review	11/1/2007	"Better Rice for Asia's Poor"	Philippines	Donor Newsletter

HarvestPlus Publications

The HarvestPlus *Technical Monograph Series* captures the methodologies that are used in the program. *HarvestPlus Working Papers* provide a vehicle to summarize research findings to date, particularly qualitative and quantitative socio-economic research findings generated by the program. *Varietal Maps* and HarvestPlus commissioned *datasets* serve as basic information for targeting the development and dissemination of the crops. *HarvestPlus Protocols* have been developed as laboratory tools to assist HarvestPlus alliance members with standardized analysis of samples in laboratories around the world. *HarvestPlus Abstract series* is as an information exchange device increasing the likelihood for interdisciplinary sharing of relevant research emerging across disciplines.

To maximize the utility of all research emerging from the program, and recognizing that important methods and guideline documents being developed for biofortification may not be journal-worthy, HarvestPlus developed the Technical Monograph and Working paper series to share lessons learned as important public goods. Six technical monographs and two working papers have been published.

HarvestPlus publications and printed materials are listed in Appendix 1.

4.3 External Review of Challenge Programs

An External Review was commissioned by The Science Council of the CGIAR in 2007. The external review rigorously assessed the science, management, and governance of the program. The review was conducted by leading experts in the field of nutrition, agriculture and management. The results of the HarvestPlus external review were very positive and can be found on the CGIAR Science Council website at:

<http://www.sciencecouncil.cgiar.org/publications/pdf/HarvestPlus%20-%20complete.pdf>

In late 2007, the Bill and Melinda Gates Foundation commissioned its own external review of HarvestPlus in preparation for continued support for phase II. HarvestPlus PMT worked closely with ABT associates to provide information for that review. Results of that review are expected in early summer of 2008.

5.0 GOVERNANCE AND MANAGEMENT

5.1 Consortium/Program Steering/Advisory Committee

HarvestPlus is a joint venture between CIAT and IFPRI. The Boards of Trustees of CIAT and IFPRI have delegated the responsibility for oversight of HarvestPlus to a Project Advisory Committee (PAC), which acts in effect as a Board of Trustees for HarvestPlus. The PAC is composed of 17 members: the two Directors-General of CIAT and IFPRI, and one Board member each from the Boards of Trustees of CIAT and IFPRI, and 13 senior, independent, scientific experts from developing and developed countries, covering a range of disciplines (human nutrition and health, food science, plant breeding, molecular biology, economics, management, finance, ethics). The PAC meets bi-annually to review progress to date, to approve budgets, and to provide strategic guidance on the science and management of the program. An audit sub-committee has been formed to review and audit budgets and expenses incurred by the program.

Building consensus among collaborating institutions is key to the success of HarvestPlus. The Program Director reports to the Directors General of CIAT and IFPRI PAC, which has ultimate decision-making power over workplans and budgets. Such a structure inherently forces consensus-building.

Nevertheless, consensus-building requires considerable transactions costs. The Program Management Team (PMT) must have flexibility to make operational decisions, subject to PAC oversight every six months, within the strategic boundaries set by the PAC. PAC members do not represent stakeholder institutions (except for minority representation of CIAT and IFPRI), but do represent a broad spectrum of scientific disciplines

Appendix 2 provides a list of PAC members.

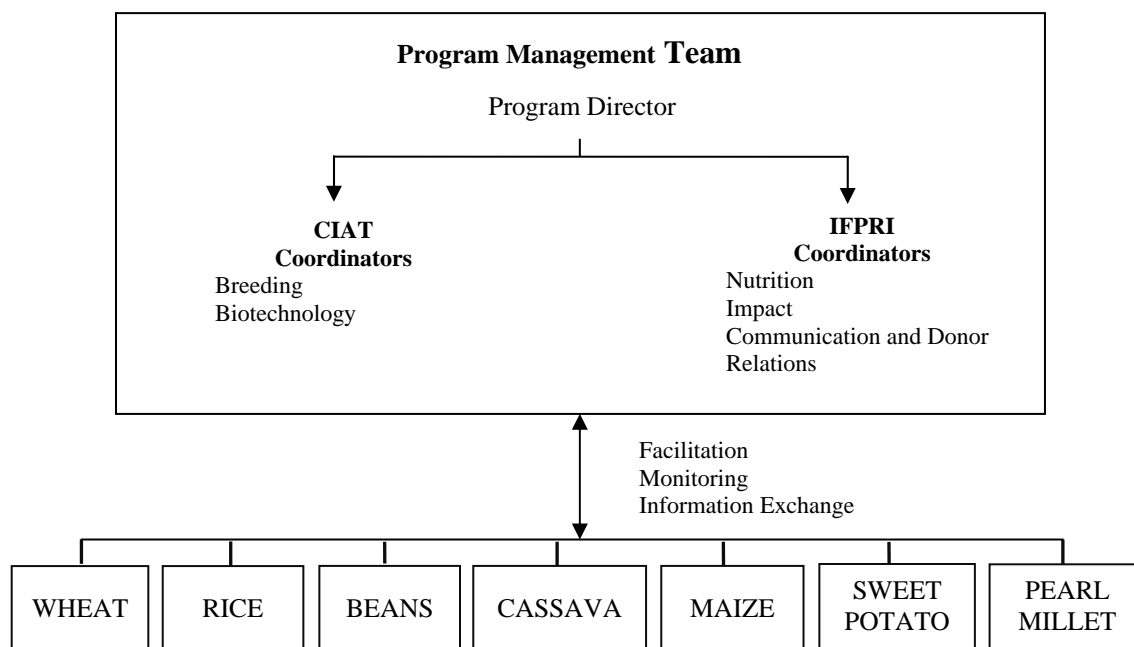
5.2 Program Management Team (structure and activity report)

HarvestPlus is managed by an interdisciplinary Program Management Team (PMT) which reports to the PAC. The Program Management Team (PMT) assembles funding from a consortium of donors, and issues contracts to collaborating institutions, which are organized into crop teams – as illustrated below.

PMT members are based at the International Center for Tropical Agriculture (Plant Breeding, Nutritional Genomics) and at the International Food Policy Research Institute (Nutrition, Impact, Communication) under the leadership of a Program Director who has a joint appointment at CIAT and IFPRI.

Over 250 presentations have been made by the HarvestPlus PMT and Alliance members in 2007. Communications has cultivated and technically supported opportunities to present at International Nutrition and Agriculture meetings, UN conferences and at national level enabler meetings in Brazil and East Africa.

Development and deployment of biofortified crops is accomplished through coordination of contracts issued by the PMT to collaborating organizations. Typically, contracts are issued on an annual basis. Semi-annual and annual progress reports are submitted and reviewed by PMT members. Workplans and budgets for the coming year are reviewed and approved by PMT members, based on progress reported from the previous year. PMT members make site visits to collaborating institutions.



5.3 Operational Issues and Challenges

Management and Oversight

The role of the Nutrition Coordinator substantially expanded as HarvestPlus moves toward product testing. Additional 14 contracts under the HarvestPlus nutrition component were implemented in 2007 for several nutrition research in the US, Australia, Denmark, Bangladesh, and Africa. Aside from monitoring retention and bioavailability studies, efficacy trials, exploring high through-put methods for nutrient analysis in crops and biological samples, the Nutrition Coordinator serves as presenter in international conferences and workshops, and convenes forums for other nutrition experts working with HarvestPlus. In 2007, a senior research assistant was hired to support the Nutrition Coordinator and a co-coordinator will be hired in 2008 to apportion the expanding research in nutrition.

Since the number of HarvestPlus contracts have increased since the beginning of the program in 2003, a full time Budgets and Administrative Specialist was hired to provide secretarial assistance to the Project Director and the PMT members based at IFPRI, and to monitor budgets of the different components of the program. The existing Senior Administrative Coordinator monitors the contracts and provides administrative assistance to program staff.

HarvestPlus continues to fulfill reporting requirements and the development of the Medium Term Plan for the Executive Committee (ExCo) of the CGIAR, annual reports to donors (USAID and ADB), and to the Bill and Melinda Gates Foundation (2 grants), and responding to comments on reports. In addition to reporting requirements, HarvestPlus was subjected to external reviews commissioned by the Science Council of the CGIAR and the BM Gates Foundation. HarvestPlus responses to recommendations from the CPER are in section 4.3.

Technical

- A study of the effect of high inulin content wheat on improving iron bioavailability in pigs was not completed. It took much longer to screen and identify wheat lines with high inulin for the experiment. In 2007, wheat lines were identified and seeds were planted for multiplication. The study is now scheduled for 2008.
- Embryo specific promoter for pro vitamin A maize was phased out based on information provided by Monsanto on effect of promoter on seed germination.
- Implementation of marker assisted selection in wheat was partially completed due to unexpected results and staff changes.
- Due to funding constraints, discussions to establish a HarvestPlus Country Program based in South Africa has been delayed.
- Training courses for capacity in the analysis of pro-vitamin A in various staple food crops were held in Asia and Africa with a large number of participants. However, key laboratories involved in screening material were identified as being more critical and important participants in the training courses. Subsequently, greater effort was put into these key laboratories rather than trying to affect a large number of laboratories with minimal follow-up.

6.0 FINANCE

6.1 Objectives and Outcomes

The accounting, fiduciary, and financial reporting requirements of the HarvestPlus are overseen by CIAT and IFPRI, who have overall leadership responsibility for the program. Financial reports are reviewed by the audit committee of the HarvestPlus PAC, whose membership includes the chairs of the audit committees of the CIAT and IFPRI Boards of Trustees.

From an accounting and reporting perspective, the arrangement is a joint venture, whereby each participating organization recognizes revenue/income that it earns from the provisions of research services under the terms of contractual arrangements. The contractual management of the HarvestPlus Challenge Program includes joint control (CIAT and IFPRI); whereby no single organization is in a position to unilaterally control the activities. The accounting approach therefore underscores the consortium approach for Challenge Programs, which explicitly acknowledges that the desired outcomes cannot be achieved by organizations working alone. CIAT and IFPRI executed a cooperative research agreement in March 2003, which provides that CIAT and IFPRI enter into a contractual arrangement with other participating organizations (CGIAR-supported centers and other institutions) to complete specific program activities with deliverables.

Financial transactions of the HarvestPlus, inflows and outflows of funds, are processed through the accounting and internal control systems of CIAT and IFPRI. The two centers prepare an annual supplemental schedule to their audited financial statements showing sources and application of funding on a cash receipts and disbursements basis. There is not a separate balance sheet for HarvestPlus. The financial performance indicators of the CGIAR are calculated by reference to Net Assets of a particular center as at

the year and Balance Sheet date. It must be stressed however that a Challenge Program is by CGIAR accounting definition a Restricted Project and therefore does not generate Unrestricted Net Assets.

However, the equivalent of short term liquidity performance indicators may be derived from the Undisbursed Cash on Hand in the Supplemental Schedule to the Audited Financial Statements of IFPRI and CIAT. As of December 2007, the Cash on Hand for HarvestPlus amounted to \$17.84 million which represents 455 days of projected expenditures of \$14.307 million.

6.2 Contributions and Disbursements

Tables 1 and 2 below present revenues received and budgeted expenditures for HarvestPlus Phase 1 (2003 to 2007), as well as estimated revenues and PAC approved budgets for 2008 Bridge Year. Revenues received for Phase 1 of the program in the amount of \$52.438M supported expenditures of \$51.891 million. Estimated revenues of \$14.0 million for 2008 Bridge Year are expected to fund activities of the same amount. As of the first quarter of 2008, \$12.0 million of Bridge Year funds have already been received.

Estimated funding requirements and proposed program activities for 2009 to 2011 require an average budget of about \$17.0 million per year, an increase of about 20% from current year levels. As the Program embarks onto the next phase, it is anticipated the investment will increase in Biotechnology and Nutritional Genomics, development of Phase II crops, and the policy components Impact and Reaching End User activities. The collective increase in investment in these activities between 2008 and 2009 is about \$2.3 million. Funds to support HarvestPlus Phase 2 however are still under discussion. Thus, Table 2 below present revenue levels from the Consortium of Donors that have funded Phase 1.

The HarvestPlus Challenge Program has delegated a major part of its activities to CGIAR centers. CGIAR centers comprise 65% or \$33.59 million of the program's \$52.89 million budget over Phase 1 years 2003 to 2007. On the contrary, funding support from the CGIAR do not reflect a similar scenario. Funds from the CGIAR make up merely 27%, or \$17.86 million of total funding of \$52 million. The Gates Foundation, the main donors of the program, have signified funding for the program of up to \$9.0 million per year. It is vital that the CGIAR come forward with the balance funding required for Phase II, and manifest a commensurate support to the program they regard as the "pearl of the CG".

Table 1. Actual and Expected Revenues by Donor by Year (In Thousand Dollars)

Donor	Actual Budgeted						Proposed			
	Phase 1				Bridge Yr					2009-2011
	2003 to 2005	2006	2007	2003 to 2007	2008	2003-2008	2009	2010	2011	2009-2011
	Actual	Actual	Actual	Total	Estimate	Total				Total
Unrestricted										
World Bank	7,500	2,000	2,000	11,500	2,000	13,500				
Gates Foundation	12,500	7,750	8,000	28,250	10,350	38,600				
USAID	1,800	2,355	1,855	6,010	450	6,460				
DFID	452	1,358	950	2,760	1,000	3,760				
SIDA	108	188	155	451	150	601				
USDA			28	28	43	71				
Restricted										
DANIDA	492	743	302	1,537		1,537				
International Life Sciences Inst		200		200		200				
Asian Development Bank		234	234	468		468				
Austria	54			54		54				
Other Income	279	452	449	1,180	200	1,380				
Total Revenues	23,185	15,280	13,973	52,438	14,193	66,631	16,500	17,000	17,500	51,000

Table 2. Expenditures by Type of Activity by Crop by Year (In Thousand Dollars)

Activity	Actual Budgeted						Proposed			
	Phase 1				Bridge Yr	Total 2003 – 2008	2009	2010	2011	Total 2009-2011
	2003 to 2005 Actual	2006 Actual	2007 Actual	2003 to 2007 Total	2008 Estimate					
Crop Breeding & Reg Coll	10,786	6,098	5199	22083	5148	27,231	6,124	6,369	6,623	19,116
Beans	741	352	324	1417	305	1,722	417	434	451	1,302
Cassava	1091	490	375	1956	425	2,381	581	605	629	1,815
Maize	1124	697	660	2481	745	3,226	758	788	820	2,366
Rice	949	474	400	1823	445	2,268	728	757	787	2,272
Wheat	946	641	546	2133	510	2,643	735	765	796	2,296
Sweet Potato	793	495	420	1708	360	2,068	587	610	634	1,831
Phase 2 Crops	1,800	902	839	3541	532	4,073	1062	1104	1148	3,314
Tech Asst+Reg Coll+Coord	2233	1,441	1,131	4805	746	5,551	1256	1306	1358	3,920
Other Restricted	1109	606	504	2219	1080	3,299				0
Nutritional Genomics	2,048	1,515	836	4399	970	5,369	1,566	1,629	1,694	4,889
Human Nutrition	3,229	2,627	2,134	7,990	2,510	10,500	2,492	2,592	2,696	7,780
Impact and Policy Analysis	2,211	1,342	524	4077	965	5,042	1,338	1,392	1,448	4,178
Reaching & Engaging End-Users	293	2,178	2,892	5363	2,865	8,228	3,213	3,342	3,476	10,031
Communications	626	275	193	1094	295	1,389	302	314	326	942
Management and Coordination	3,251	1,417	2,217	6885	1,554	8,439	1,358	1,412	1,468	4,238
Total Expenditures	22,444	15,452	13,995	51,891	14,307	66,198	16,393	17,050	17,731	51,174

Table 3. Expenditure by Object, 2007-2011

Object of Expenditure	in \$millions				
	Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
Personnel	1.092	1.116	1.305	1.357	1.411
Supplies and services	0.000	0.000	0.000	0.000	0.000
Collaboration/ Partnerships	12.903	13.191	15.088	15.693	16.320
Operational Travel	0.000	0.000	0.000	0.000	0.000
Depreciation	0.000	0.000	0.000	0.000	0.000
Total	13.995	14.307	16.393	17.050	17.731

Table 4. Allocation of Member Grants and Center Income to Projects, 2007-2009

		in \$millions		
Project	Member	Actual 2007	Estimated 2008	Proposal 2009
Project: Biotechnology and Nutritional Genomics	Unrestricted + Center Income	0.836	0.970	1.566
	Project Total	0.836	0.970	1.566
Project: Breeding Objectives	Unrestricted + Center Income	0.000	0.000	0.000
	Project Total	0.000	0.000	0.000
Project: Cassava Crop Activity	Unrestricted + Center Income	0.375	0.425	0.581
	Project Total	0.375	0.425	0.581
Project: Common Bean Crop Activity	Unrestricted + Center Income	0.324	0.305	0.417
	Project Total	0.324	0.305	0.417
Project: Communication	Unrestricted + Center Income	0.193	0.295	0.302
	Project Total	0.193	0.295	0.302
Project: Human Nutrition	Unrestricted + Center Income	2.134	2.510	2.492
	Project Total	2.134	2.510	2.492
Project: Impact and Policy Analysis	Unrestricted + Center Income	0.524	0.965	1.338
	Project Total	0.524	0.965	1.338
Project: Maize Crop Activity	Unrestricted + Center Income	0.660	0.745	0.758
	Project Total	0.660	0.745	0.758
Project: Micronutrients Technical Assistance, Strengthening Regional Collaboration, Coordination of Crop Activities	Unrestricted + Center Income	1.131	0.746	1.256
	Project Total	1.131	0.746	1.256
Project: Overall Management and Coordination	Unrestricted + Center Income	2.217	1.554	1.358
	Project Total	2.217	1.554	1.358
Project: Pearl Millet Crop Breeding	Unrestricted + Center Income	0.000	0.000	0.000

		Project Total	0.000	0.000	0.000
		in \$millions			
Project	Member	Actual 2007	Estimated 2008	Proposal 2009	
Project: Phase II Crop Activities	Unrestricted + Center Income	0.839	0.532	1.062	
	Project Total	0.839	0.532	1.062	
Project: Reaching and Engaging End-Users	Non Member	0.032	0.000	0.000	
	Bill and Melinda Gates Foundation				
	Unrestricted + Center Income	2.860	2.865	3.213	
	Project Total	2.892	2.865	3.213	
Project: Rice Crop Activity	Unrestricted + Center Income	0.400	0.445	0.728	
	Project Total	0.400	0.445	0.728	
Project: Sweet Potato Crop Activity	Unrestricted + Center Income	0.420	0.360	0.587	
	Project Total	0.420	0.360	0.587	
Project: Wheat Crop Activity	Unrestricted + Center Income	0.546	0.510	0.735	
	Project Total	0.546	0.510	0.735	
Various HarvestPlus Projects	Member				
		ADB	0.220	0.000	0.000
		Denmark	0.284	0.000	0.000
	Non Member	International Life Science Institute	0.000	0.000	0.000
	Unrestricted + Center Income	0.000	1.080	0.000	
	Project Total	0.504	1.080	0.000	
	Total Restricted	0.536	0.000	0.000	
	Total Unrestricted + Center Income	13.459	14.307	16.393	
	Total	13.995	14.307	16.393	

7.0 LESSONS LEARNED

- **Multiple reporting requirements are costly**

Reporting requirements are considerable, more than originally anticipated and now includes annual reports, responses and revisions for the Gates Foundation (2 grants); annual report, response and revision to the Executive Committee (ExCo) of the CGIAR; annual reports to donors who give restricted funding (USAID and ADB), with associated response to comments and revisions. The development of Medium Term Plan for the CGIAR Science Council is an annual comprehensive reporting exercise that requires a response to reviewers' comments and revision. The Project Advisory Committee meetings require documentation for its semi-annual meetings including the development of agendas and background materials. Coordination, collation, and editing of inputs from the various components of the project takes up considerable time for each of these tasks.

- **Successful dissemination of orange-flesh sweetpotato, where consumers are accustomed to consuming white varieties**

There are two general strategies for dissemination of biofortified staple foods: (i) where nutrients are invisible to the consumer (iron and zinc), nutrient density is bred into the highest yielding, highest profit lines being released by agricultural researchers. Adoption is driven through farmer demand for these agronomically superior varieties which account for a high proportion of total supply of that food staple in a country, and (ii) where nutrients are visible (pro-vitamin A carotenoids), adoption is driven through demand creation and marketing – that is, delivering nutrition messages which explain how consumption of orange-colored varieties (which replace white varieties) can improve family nutrition.

In the latter case, a pilot study supported by HarvestPlus and conducted in Mozambique (results now published in the Journal of Nutrition) showed that farm households could: 1) be convinced to switch to production of orange-flesh sweetpotato (OFSP), 2) that intakes of OFSP by preschool children of these farm households increased, and 3) that the vitamin A status of these preschool children improved.

Based on that experience, a comparative study of larger-scale dissemination efforts in contrasting situations in Uganda and Mozambique has been initiated which is exploring alternative interventions to minimize the cost of effecting this same behavior change among rural households. A manual on “best practices/lesson learned” will be produced in 2009.

- **Compounds which can increase the bioavailability of trace minerals**

The importance of maximizing bioavailability of minerals, especially of iron, is a key component of nutrition research within HarvestPlus. A preliminary animal model demonstrated that lutein (a non-provitamin A carotenoid) may promote the bioavailability of iron, and further studies of the effect of carotenoids from food sources (maize and sweetpotato) on bioavailability of iron were established. Inulin, a non-digestible, probiotic carbohydrate, increase the bioavailability of dietary iron in pigs. Wheat has been bred to have increased levels of inulin. *In-vitro* screening revealed that components in some genotypes of potato and cassava can promote iron bioavailability. Results from HarvestPlus research trials currently underway will provide new insights into natural ways of overcoming the poor bioavailability of iron in plant-based diets.

- **Retention and bioavailability studies for several crops**

HarvestPlus nutrition teams are measuring the effects of processing, storage and cooking methods on nutrient retention for biofortified crops and determining retention-friendly practices that may be used by target populations. Recent research generated by HarvestPlus indicates that retention may also be genetically determined which then adds retention heritability to the plant breeding portfolio.

HarvestPlus has determined that the retention of pro-vitamin A in maize to be acceptably high across several important processing methods (e.g., milling, boiling of flour, fermentation, nixtamalization) while some cassava genotypes were better at retaining pro-vitamin A than others after boiling.

The extent to which added micronutrients are bioavailable and absorbed by the body must also be determined. Barriers to absorption are identified by HarvestPlus and strategies are then devised (potentially through breeding) to increase the bioavailability of the nutrients in HarvestPlus crops. As part of this research portfolio, HarvestPlus collaborators have determined the retinol equivalency (vitamin A activity) of pro-vitamin A in maize to be 2-4 times better than had been assumed, thus suggesting that maize is an excellent food source to deliver pro-vitamin A in the diet.

As precursor studies to the HarvestPlus Challenge Program, important proof-of-concept was established for the efficacy of orange fleshed sweet potato to improve vitamin A status in South African children, and for high iron rice to improve iron status among Filipino women. Comprehensive research programs that will lead to testing the efficacy of high iron beans in Central America, and high zinc rice in Bangladesh, and the effectiveness of orange fleshed sweet potato in Uganda and Mozambique, are underway.

Appendix 1

HarvestPlus Alliance Output 2007

Publications

HarvestPlus Abstract Series

Low J.W., Mary Arimond, Nadia Osman, Benedito Cunguara, Filipe Zano, and David Tschirley. 2007. A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Serum Retinol Concentrations in Young Children in Mozambique. HarvestPlus Abstract 3.

Working Papers

Meenakshi, J.V.; Johnson, Nancy; Manyong, Victor M.; De Groote, Hugo; Javelosa, Josyline; Yanggen, David; Naher, Firdousi; Gonzalez, Carolina; Garcia, James; Meng, Erika. 2007. How cost-effective is biofortification in combating micronutrient malnutrition? An *ex-ante* assessment. HarvestPlus Working Paper 2.

Potts, Michael J.; Nagujja, Stella. 2007. A Review of Agriculture and Health Policies in Uganda with Implications for the Dissemination of Biofortified Crops. HarvestPlus Working Paper 1.

Other

HarvestPlus Research and Implementation Brochure
HarvestPlus Display Panels

Journal Articles

Beiseigel Jeannemarie M., Janet R Hunt, Raymond P Glahn, Ross M Welch, Abebe Menkir and Bussie B Maziya-Dixon. 2007 Iron bioavailability from maize and beans: a comparison of human measurements with Caco-2 cell and algorithm predictions. *American Journal of Clinical Nutrition*, Vol. 86, No. 2, 388-396

Burgos, Gabriella, Walter Amoros, Maximo Morote, James Stangoulis and Meredith Bonierbale. 2007. Iron and zinc concentration of native Andean potato cultivars from a human nutrition perspective *Journal of Food Science and Agriculture* (online) 87(4): 668-675

Bouis, Howarth E. 2007. The potential of genetically modified food crops to improve human nutrition in developing countries *Journal of Development Studies* 43(1): 79-96 2007.

Chavez, A.L., T. Sanchez, H. Ceballos, D.B. Roderiguez-Amaya, Penelope Nestel, Joe Tohme and M. Ishitani. 2007. Retention of carotenoids in cassava roots submitted to different processing methods. *Journal of the Science of Food and Agriculture* 87(3): 388-393.

Choi, Eun Young, Robin Graham and James Stangoulis. 2007. Semi-quantitative analysis for selecting Iron- and Zn-dense genotypes of staple food crops. *Journal of Food Composition and Analysis* 20(6): 496-505

Diretto, Gianfranco, Salim Al-Babili, Raffaella Tavazza, Velia Papacchioli, Peter Beyer, Peter and Giovanni Giuliano. 2007. Metabolic engineering of potato carotenoid content through tuber-specific over expression of a bacterial mini-pathway *PLoS ONE* Apr 4(2): e350

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