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Supplementary Information for CGIAR Report: Plant Breeding Impacts, Non-monetary Benefit-sharing and contributions to Farmers' Rights

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I. Introduction

1. This Information Document is meant to be read together with Working Document IT/GB-7/17/24. This document provides information and case studies that complement and expand on issues addressed in the Working Document. More particularly, this Information Document presents complementary information concerning: 1) non-monetary benefits that are generated and shared by CGIAR Centers in the course of their research and development, 2) how CGIAR Centers recognize and promote Farmers' Rights as per Article 9 of the ITPGRFA, and 3) the impacts of CGIAR crop breeding programs.

II. Generating and sharing non-monetary benefits

A. Capacity development

2. CGIAR Research Programs have supported a number of students doing their BSc, MSc and PhD degrees. For examples, the CGIAR Research Program on Maize (MAIZE) co-supervised a total of 130 PhD, MSc, BSc students in 2015; in 2016, CGIAR Research Program on Roots, Tubers and Bananas (RTB) hosted and co-supervised 124 students; and the CGIAR Research Program on Dryland Cereals program 28 MSc students, and 24 PhD candidates from 2012 to 2016.

3. Various long-duration courses (more than 90 days) on crop improvement (including breeding, pathology and marker assisted selection) have been organized and supported by CGIAR Research Programs for advanced degree students and junior and mid-career scientists from all over the world. One example is the Basic Wheat Improvement Course which is organized annually under the CGIAR Research Program on wheat (WHEAT). CGIAR has supported various funding schemes for students in developing countries, like the Legume Scholars Program and the Dryland Cereals Scholarship Program.

4. Numerous additional short-term regional and national training courses have been organized through CGIAR Research Programs and projects. These have been oriented not only to scientists in research organizations, but also to officers and technicians working in governmental agencies and NGO staff.

5. Capacity development for farmers has covered a wide range of topics including sustainable intensification, postharvest practices, production using hybrid seed, produce processing and marketing, seed selection, seed multiplication, business model development, and gender awareness. Training events have taken place in the form of field days, farmer schools and travelling workshops. For example, under WHEAT, more than 18,425 farmers took part in 335 training events in 2016, in Afghanistan, Bangladesh, Ethiopia, India, Kenya, Mexico, Nepal, Pakistan and Turkey. In 2015, under RICE, IRRI and national partners provided training to 10,826 extension staff and lead farmers in Asia. In Bangladesh alone, 130,446 farmers were trained and 47,472 trials and demonstrations were conducted. Across Southeast Asia in 2015, 60,997 farmers were trained in different aspects of rice production. Box 1 presents a concrete case of capacity building under the Arab Food Security Project.

6. Hundreds of capacity-building materials have been made available by CGIAR Centers during the course of the first series of CGIAR Research Programs (2012-2016). Despite increasing efforts to publish these materials in other languages beyond English, language continues to be a limitation to their full accessibility.

Box 1: Impact story. Results of the capacity building efforts under the first phase of the Arab Food Security Project
The first phase of the Arab Food Security Project took place under WHEAT from 2011 and 2014. As part of this project, 25,700 farmers benefited from field days, farmer schools and travelling workshops where they learned about improved wheat varieties and agronomic practices. It is estimated that these efforts contributed to an average 28% increase in wheat yield across all countries. Mechanized raised-bed planting for smallholders led to an average 25% savings in irrigation water, a 30% increase in wheat yield and a 74% improvement in water-use efficiency on farmers' fields in Egypt. Substantial improvements in rainfed systems included a 45% gain in yields in Yemen and gains of 24% in Jordan and Tunisia. No-till systems increased wheat yields 16% in Syria, 20% in Jordan and 50% in Morocco. The project's Young Scientist Training Program mentored and trained 34 young scientists.

B. Information sharing

7. In the past decade, CGIAR Centers have explored innovative approaches to facilitate the generation and exchange of information among different actors, taking advantage of advances in information and communication technologies. The numerous open-access databases maintained by CGIAR Centers are used by thousands of scientists from almost all countries of the world each year. For example, the 19 open-access databases maintained by WHEAT received nearly 500,000 unique visits in the period 2011-2016. MAIZE's open-access databases were used by 383,032 unique users in the same period. IRRI's Rice SNP Seek database (which provides genotype, phenotype, and variety Information for rice) was accessed 74,121 times by 8,459 different users in 2015.

8. Many online platforms for knowledge sharing target extension agents and technicians. One example is the Rice Knowledge Bank, which showcases rice production techniques, agricultural technologies and best farming practices based on IRRI's pool of knowledge from research findings, media resources and in-country projects.

9. Innovation platforms and hubs have been set up and facilitated by various CGIAR programmes to enhance the quality of interaction, relationships, confidence, and trust among stakeholders involved in the research, development and market chains of target crops. MAIZE alone supports 168 innovation platforms and other multi-stakeholder interaction mechanisms across Africa, South Asia and Latin America.

C. Technology transfer

10. CGIAR Centers and partner organizations generate and share technologies and innovative practices for the conservation, characterization, evaluation and use of plant genetic resources for food and agriculture as part of their activities for efficient and rational conservation of germplasm, phenotyping, genotyping, phytosanitation and seed production. Global partnerships for large scale phenotyping and genotyping within CGIAR programs have facilitated the co-generation and sharing of innovative technologies and techniques.

11. CGIAR Centers have shared new technologies in the form of genetic material, as presented by the section on CGIAR Centers' transfers under the multilateral system of the CGIAR report included in **IT/GB-7/17/24**

III. Recognizing and implementing farmers' rights

A. Extracts from the Implementation Guidelines for the CGIAR Principles on the Management of Intellectual Assets

12. The text of Article 3 of the CGIAR Principles on the Management of Intellectual Assets (IA Principles) concerning Farmers Rights is set out in section 6 of Working Document IT/GB-7/17/24. After the IA Principles were adopted, CGIAR Centers developed guidelines for their implementation. With respect to Farmers Rights, the relevant portions of the Guidelines are reproduced in Box 2 below.

Box 2: Implementing Guidelines for the for the CGIAR IA Principles on the Management of Intellectual Assets: text regarding Farmers Rights

Article 3.2 [of the Implementation Guidelines for the CGIAR Principles on the Management of Intellectual Assets] provides that "CGIAR seeks to be respectful of national and international efforts to protect and promote farmers' rights as envisaged by the Treaty and support the development of appropriate policies and procedures for their recognition and promotion".

a) This means that CGIAR Centers ("Centers") should comply, in the countries where they work, with applicable national laws protecting and promoting farmers' rights. The most common examples are access and benefit sharing laws, which require collectors to obtain the prior informed consent on mutually agreed terms from providers of genetic resources and associated traditional knowledge, including, in some cases, from indigenous and local peoples or peasants, farmers, individuals, etc. Other examples of laws that may protect farmers' rights include plant variety protection laws, national seed regulations, laws concerning the land, resource and cultural rights of indigenous and or local peoples, and possibly even the national constitution. These national laws may be national initiatives or may implement international conventions to which the country is a party, such as the Convention on Biological Diversity ("CBD") and its Nagoya Protocol, the International Treaty on Plant Genetic Resources for Food and Agriculture ("Treaty") or the UPOV Conventions.

b) It also means that, whether or not there are national laws protecting and promoting farmers' rights in the countries where they work, Centers should, where possible, seek to work in ways that promote: the "protection of traditional knowledge relevant to PGRFA"; farmers' "right to equitably participate in sharing benefits arising from the utilization of PGRFA"; farmers' "right to participate in making decisions, at national level, on matters related to the conservation and sustainable use of PGRFA"; and farmers' right to "save, use exchange and sell farm-saved seed/propagating material, subject to national law and as appropriate" (as stipulated by Article 9 of the Treaty).

Below is a non-exhaustive list of practical actions that Centers could take, where appropriate, in this regard:

(i) When accessing Plant Genetic Resources for Food and Agriculture ("PGRFA") and/or associated traditional knowledge in the absence of access and benefit sharing laws, ensuring that the prior informed consent of farmers providing them has been given. This implies taking into account community protocols, if any, and proactively engaging the farmers to ensure that they understand the proposed uses of the PGRFA and/or the knowledge collected. This can be done with or through partners in the national agricultural research systems or other organizations with whom work is being carried out and, where possible,

(ii) Ensuring that research results (including characterized, evaluated and improved germplasm and useful information) are shared with farmers from whom PGRFA or associated information was accessed;

(iii) Ensuring that publications referring to traditional knowledge give all appropriate credits to the holders/providers of such knowledge and disclose the source of such knowledge;

(iv) Involving farmers as partners in research and development projects (which may include dedicating resources to strengthening the capacity of farmers to participate in such projects meaningfully);
(v) Building on and promoting farmers' local institutions and practices in research and development activities (e.g. by engaging in participatory breeding, supporting community-led initiatives in documenting their PGRFA and associated traditional knowledge in databases or registries, promoting local seed banks, working through and strengthening local seed systems);

(vi) Raising awareness among farmers' organizations about the availability of the PGRFA in genebanks and facilitate their access to such PGRFA through various outreach activities;

(vii) Involving farmer representatives in processes to determine research priorities and in the presentation of research outcomes in national fora;

(viii) Documenting efforts made by the Centers and partners to promote farmers' rights in the countries concerned, and sharing them to help inform farmers' rights-related policy development[1]

B. Case studies illustrating how CGIAR Centers contributed to recognition and implementation of Farmers' Rights

The Heirloom Rice Project in The Philippines

13. The Heirloom Rice Project, which started in 2014, is supported by the Department of Agriculture of The Philippines and IRRI with the aim of enhancing the productivity and enriching the legacy of heirloom or traditional rice through empowered communities in unfavorable rice-based ecosystems in the Philippines. Heirloom rice varieties, handed down for several generations through family members and grown by small landholders on their ancestral farms, have exceptional cooking quality, flavor, aroma, texture, color, and nutritional value. Hence, there is high demand for these varieties and they command higher prices in both domestic and international markets. These varieties are also resilient, showing high levels of resistance to diseases and tolerance of environmental stresses, thus helping farmers make a good income out of every crop. But the huge potential of heirloom rice as a lucrative livelihood is hindered by the inability of local farmers to produce these with higher seed quality and purity and in greater quantity. Moreover, certain heirloom varieties are gradually disappearing; some are even close to extinction. Market and product development, alongside maintaining biodiversity in the region, are crucial for farmers to continue growing these threatened rice varieties in the Cordillera Region and in the Arakan Valley Complex in Mindanao. The project focuses on the following actions: 1. Characterize existing heirloom or traditional varieties or landraces and modern climate resilient varieties in selected provinces; 2. Enhance local capacity and enterprise building in farming communities; 3. Identify opportunities for adding value and creating market linkages for heirloom or traditional rice varieties; 4. Document good management practices and disseminate through modern and traditional information, education and communication channels; and 5. Improve resistance to disease and tolerance of environmental stresses of selected heirloom varieties.

Collaboration with communities of the Parque de la Papa (the Potato Park), Peru

14. Since 2004, CIP has collaborated with farming communities within the Potato Park. As part of this collaboration and with the support and coordination of Asociación ANDES, CIP has repatriated more than 400 native potato varieties to Potato Park communities, in the form of disease-free seed. The project has also disseminated scientific knowledge among the communities and in the past few

[1] The Implementation Guidelines for the CGIAR IA Principles on the Management of Intellectual Assets are available at https://cgspace.cgiar.org/handle/10947/4487

years this collaboration has led to a number of joint experiments, notably regarding the effects of climate change and associated biotic and abiotic stresses.

Improving markets for local crops

15. Within the framework of its project "Agroforestry for Livelihoods of Smallholder Farmers in Northwest Vietnam" ICRAF and local communities have carried out collaborative research and development activities to add value to products of the indigenous fruit Son Tra (Docynia indica), with the overall aim of increasing the economic benefits of Son Tra to local people, especially H'mong farmers. The project has involved nutritional analyses and the development of processing techniques to make ready-to-use products, such as Son Tra extract and instant tea.

Monetary benefit-sharing with farmers in Peru

16. The Chirapaq Nan initiative links a Dutch seed potato company with the farmers who conserve potato genetic diversity in the Andes region. Several CIP scientists supported the establishment of AGUAPAN (Association of Potato Guardians) which unites farmers from different parts of Peru, all of whom maintain significant potato diversity in their fields. The association receives funds from the corporate social responsibility (CSR) budget of the potato seed company and this money is used by the farmers in accordance with their own decisions within AGUAPAN. The Chirapaq Nan project and the AGUAPAN model offer a complementary alternative to existing benefit sharing mechanisms.

Realizing farmers' rights through community-based agricultural biodiversity management

17. Bioversity International runs a number of projects that put into practice the farmers' rights as set out in the ITPGRFA.[2] Some of the measures included in these projects are: developing good practices; incentive mechanisms and policy and legal measures to recognize, reward and support custodian farmers and community seed banks; identifying and promoting the nutritional value of neglected and underutilized species; developing new methods to improve access, availability, quality and diversity of seeds; strengthening the technical and business knowhow of smallholder farmer seed producers; assessing the feasibility of payments for agrobiodiversity conservation services; identifying effective crop diversity mixes for pest and disease management; promoting the food and nutrition value of biodiversity in healthy diets; and designing new mechanisms for involving farmers in policy processes.

18. Bioversity and national partners in Bolivia, India, Mali, Nepal, Peru and South Africa, have trained farmers to document traditional knowledge of neglected and underutilized species in biodiversity registers and diversity catalogues. Some of these catalogues serve as local, provincial and national reference for agrobiodiversity registers.

19. In Brazil, based on evidence provided by the Biodiversity for Food and Nutrition project, 64 native food species of nutritional importance are now formally recognized in the 2016 Ordinance No.163, "Brazilian Native Socio-biodiversity Species of nutritional value". The ordinance, jointly signed by the Ministries of the Environment and Social Development and Fight Against Hunger, recognizes for the first time native species of economic and cultural importance for traditional communities such as quilombolas, extractivists, fisher folk and family farmers, among others.

20. In Uganda the new seed policy officially recognizes the informal seed system. This decision came about partlyas a result of an analysis of seed policies and through policy dialogues with

[2] Clancy, E et al. 2017. Realizing farmers' rights through community-based agricultural biodiversity management, Bioversity, Rome, (7 pp) provides further information about how various Bioversity International projects contribute to Farmers' Rights. Available at https://www.bioversityinternational.org/fileadmin/user_upload/Realizing_Farmers_Rights_Clancy.pdf

government institutions, under the Improving Seed Systems for Smallholder Farmers' Food Security project.

21. Under the Payments for Agrobiodiversity Conservation Services project, farming communities receive in-kind payments for growing different varieties of quinoa, an Andean grain (in Bolivia and Peru) and maize varieties (in Ecuador).

Promoting farmer inclusion in policy decision making processes in Peru

22. In 2015, Peruvian authorities launched a review of their existing potato seed regulations. CIP took an active part in this process and contributed scientific knowledge and international experience to the policy discussions. CIP organized decentralized meetings in potato growing communities to assist national authorities and farming communities to discuss and contribute to developing suitable legislation. In November 2015, during the one-month public consultation process of the final draft of the Potato Seed Regulations, CIP organized a workshop at its headquarters in Lima, Peru, with participation from farmers' organizations, civil society organizations, the national seed regulatory authority, agricultural extension services, representatives from the national Congress, and international experts. Participants reviewed the proposed regulations and prepared written submissions to the regulatory authority responsible for the draft. One of the major achievements of this participatory process will be official recognition of the existence and value of farmer selected varieties in the new national potato seed law. The introduction of sui-generis quality control mechanisms, such as the Quality Declared Planting Material (QDPM) system, will enable the multiplication and commercialization of seed of good quality at an affordable price.

IV. Results and impact of CGIAR breeding work

A. Summary of CGIAR Research Programs' results

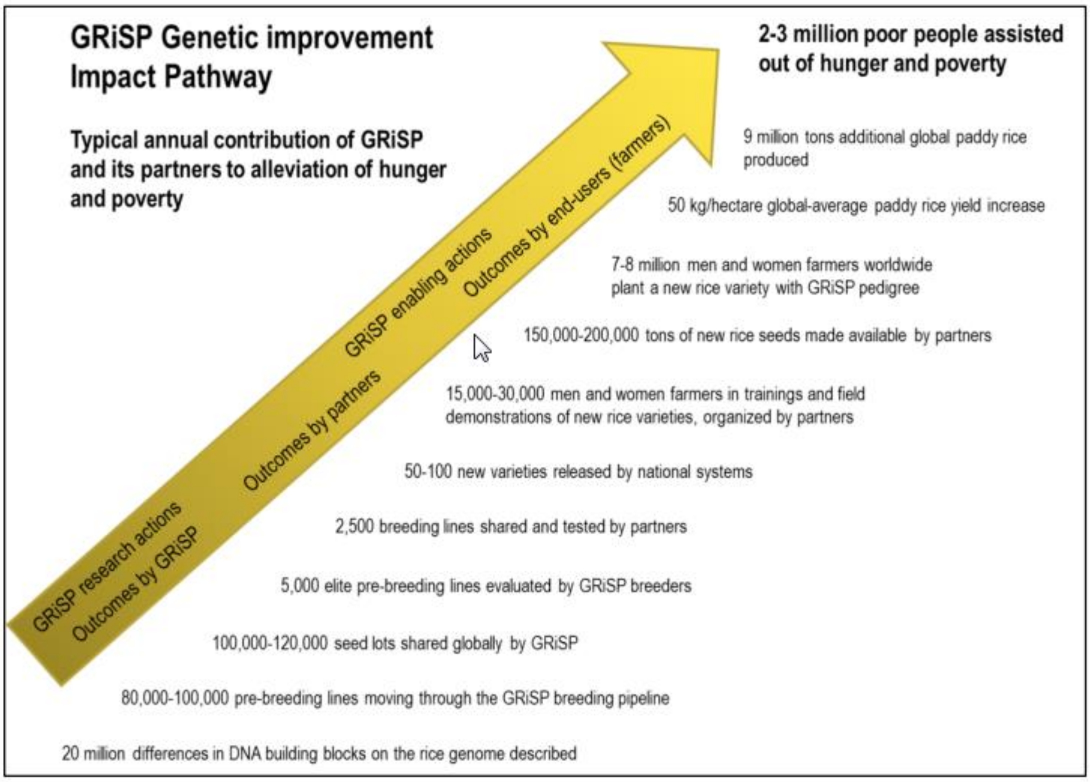
23. *MAIZE*: Since 2014, a total of 245 varieties developed through MAIZE have been released by MAIZE partners. These varieties possess key farmer-demanded traits such as higher and stable grain yield, tolerance to abiotic stresses (especially drought and heat), and tolerance or resistance to diseases such as maize lethal necrosis, maize streak virus, tar spot complex, Turcicum leaf blight, and Gray leaf spot. Several MAIZE varieties are nutritionally enhanced (e.g. Quality Protein Maize and pro-vitamin A maize). The number of hectares under improved MAIZE-derived technologies or management practices as a result of the research program have increased to over 5.5 million in 2016. The direct benefits of these technologies increased from 870,000 small-holder farmers in 2011 to 11,406,000 small-holder farmers in 2016. In 2016, over 78,245,000 people, including women and children members of farmer families, benefited from MAIZE-derived technologies and management practices.

24. *WHEAT*: Since 2014, partners in 65 countries released 233 new wheat varieties derived from WHEAT breeding research. It is estimated that well over 15 million hectares and more than 22 million resource-poor farmers are using improved technologies or management practices as a result. Cultivars derived from lines developed by CIMMYT and ICARDA are grown on more than 70% of the wheat area in South Asia, Sub-Saharan Africa, West Asia and North Africa. Almost two-thirds of all released wheat varieties globally are direct CGIAR selections or have a CGIAR immediate parent. A key mechanism for connecting developing country breeders with the Global Wheat Breeding Program is germplasm exchange through international wheat improvement networks. Wheat varieties from CIMMYT and ICARDA represent more than one-third of all international germplasm distributions under the ITPGRFA. In the twenty years 1994-2014, from annual funding of just USD30 million (excluding national program costs for wheat evaluation), yearly economic benefits of CGIAR wheat

breeding research have been estimated at between USD2.2 and USD3.1 billion (in 2010 dollars). This represents a benefit: cost ratio of between 73:1 and 103:1.[3]

25. RICE: In 2015 alone, around 70 new lines of rice derived from RICE (previously called the Global Rice Science Partnership -GRiSP) were released or approved for release by national systems. In South Asia, about 2.7 million ha are planted to submergence-tolerant rice varieties derived from IRRI breeding programs, involving about 5.5 million farmers; 0.83 million ha are under drought-tolerant varieties, benefitting 1.6 million farmers; and 0.32 million ha are under salt-tolerant varieties, covering 0.65 million farmers. About 70% of improved varieties released in Asia have IRRI germplasm in their pedigree. In 10 of the 18 countries of Latin America and the Caribbean, at least one variety resulting from the CIAT- Latin American Fund for Irrigated Rice (FLAR) is among the top three most planted in that country. In Sub-Saharan Africa, the actual adoption rate is 26% for NERICA improved varieties coming from AfricaRice. Over the period 2000-2014, adoption rates of NERICA varieties reached 75% in Gambia, 83% in Guinea, and 95% in Sierra Leone. Impact studies reveal that NERICA varieties on average have reduced the incidence of poverty by 21% in adopting farmers, and increased the food consumption score by 33–46% compared to nonadopters. The percentage of rice varieties released by national programs that incorporates improved germplasm from CGIAR Centers increased from 27% in the 1970s to 77% in the 2000s.

Figure 1 shows the volume and scale of operations of the RICE (GRiSP) annually.



Source: GRiSP Annual Report 2016

26. *CGIAR Program on Dryland Cereals and CGIAR Program on Grain Legumes*: As of October 2016, the program on Dryland Cereals delivered 85 new varieties and 34 new hybrids of barley, millets and sorghum in its target countries. By this date, almost 9 million ha was under improved

[3] Lantican, M.A., H.J. Braun, T.S. Payne, R.P. Singh, K. Sonder, M. Baum, M. van Ginkel, and O. Erenstein. 2016. *Impacts of International Wheat Improvement Research, 1994-2014.* Mexico, D.F.: CIMMYT. Available at: http://repository.cimmyt.org/xmlui/bitstream/handle/10883/4822/57826.pdf?sequence=4&isAllowed=y

varieties derived from the program. In India, the hybrid pearl millet HHB 67, developed through marker-assisted breeding, is being grown on more than 700,000 ha area, with significant bearing on the resilience and income of smallholder farmers. In 2015, 24 varieties of chickpea, common bean, faba bean, groundnut, lentil and pigeonpea were released as a result of breeding work under the program on Grain Legumes. Rapid adoption of the improved pigeonpea varieties resulted in 150,000 ha in India and 145,000 ha in Bangladesh planted to these varieties. Studies by IITA showed that farmers who adopted improved varieties of cowpea increased their productivity by 254% on 58% of cowpea farmlands cultivated in 2012. The same study found that almost 900,000 people had been lifted out of poverty between 1980 and 2015. It also established that the nutritional status of children below five years was higher among those who had adopted the technologies. The total net present value of investment in cowpea germplasm conservation and improvement efforts over 31 years was valued at $3.6 billion, while the cumulative future value in the next 35 years would be $39.1 billion. About 80% of the soybean varieties released in West and Central Africa (63 out of 79 varieties) are the direct result of IITA germplasm enhancement. Of the 1.3 million ha planted to soybean in Sub-Saharan Africa in 2009, just over half (52%) were planted to IITA-related varieties. The high relative importance of IITA-related varieties stems from their popularity in Nigeria, where 82% of the area was planted to IITA-related varieties. More than half of the soybean area in Uganda is planted to IITA-developed varieties.

27. *RTB (Roots, tubers and bananas)*: Recent studies on the level of adoption of tubers in Sub Saharan Africa show that from 1970 to 2010, IITA and NARS in 17 countries released 367 improved varieties of cassava (more than 80% were IITA-bred or had IITA-bred parents) accounting for 40% of the total cassava area. A baseline study on the adoption of improved cassava varieties introduced by IITA and partners in Zambia, DR Congo, Tanzania, and Sierra Leone showed that almost 195,000farmers were lifted out of poverty as a result of growing the new high-yielding varieties. Yam breeding at IITA has led to 13 varieties of Dioscorea rotundata and 10 of D. alata being released in Nigeria and Ghana. These varieties are characterized by higher yields, multiple pest and disease resistance, wide adaptability, and good tuber quality attributes.

28. CIP germplasm was involved in 42 of the 45 potato varieties released in Ethiopia, Kenya, Malawi, Rwanda, and Uganda over the past decade, covering about 35% of the cultivated area. Of the 60 new sweetpotato varieties released by the NARS in Burundi, Mozambique, Rwanda, Tanzania, and Uganda since 2000, 19 were CIP bred and 7 were from CIP parents. Adoption rate of improved varieties was 7% of the sweetpotato area, rising after sharply increased investment in sweetpotato breeding. CIP-related material is estimated at 30% of the improved potato and sweetpotato varieties (61 in total) adopted in the top nine producer countries in Asia. Approximately 25% of the potato growing area in China (1.2 million ha) is planted with varieties that were either developed by Chinese breeders using CIP progenitors (13%) or are CIP-bred (12%).

29. *LIVESTOCK*: Under the CGIAR Research Programme on Livestock and Fish, CIAT breeding work resulted in the first Urochloa hybrid released ever in 2003, characterized by high and durable spittlebug resistance and increased productivity and nutritional quality. Forage hybrids resulting from CIAT's Urochloa breeding work are currently sown on over 700,000 ha in over 30 countries, based on seed sales by private sector partners.

B. Impact case studies: CGIAR Centers’ breeding and capacity building

Impact of stress tolerant rice varieties in South Asia

30. The newly developed stress tolerant rice varieties developed by IRRI and disseminated with national partners in South Asia -- especially in India, Bangladesh and Nepal -- have been highly accepted by farmers. These new varieties possess high yield potential, good grain quality and offer a yield advantage of 0.5 to 1.5 t/ha over the previously grown stress-susceptible varieties in years with

flood, drought or salinity problems. The submergence-tolerant varieties with the introgressed sub1 gene in Swarna, Samba Mahsuri, BR 11 and other recipient backgrounds are being cultivated by around 1 million farmers on at least 1 million ha in South Asia. The drought-tolerant varieties (Sahbhagi dhan, DRR dhan 42, DRR dhan 44 in India, Sukha dhan 3, Sukha dhan 4, Sukha dhan 5, Sukha dhan 6 in Nepal, BRRI dhan 56, BRRI dhan 66 and BRRI dhan 71 in Bangladesh) are becoming popular among farmers. Salinity-tolerant rice varieties have been also disseminated. IRRI and public and private sector partners in South Asia, South East Asia and Eastern Africa has put in concentrated efforts to ensure the availability of high-quality seed to millions of farmers through training engaged agencies and farmers in seed production. In 2017, IRRI-developed lines combining tolerance to submergence and drought are released as varieties CR dhan 801 in India and Baghuguni dhan 1, Baghuguni dhan 2 in Nepal. These newly developed multi-stress tolerant varieties provide a kind of insurance to rice farmers to harvest a good yield irrespective of submergence or drought or both and will encourage farmers to increase their use of inputs to raise productivity even in normal years without any fear of losing their crop[4]

Improved Yield, Disease Resistant Narita Bananas

31. Millions of people in Sub-Saharan Africa depend on cooking bananas (Musa acuminata) as a year round staple crop that provides up to 30% of their caloric intake. To many smallholder farmers, a successful crop is the difference between having enough to feed their families and facing an uncertain and insecure future. These farmers face serious disease problems that limit production and they will soon encounter a new problem in the form of Fusarium oxysporium race 4, an extremely virulent pest introduced recently to Mozambique that threatens to spread to susceptible banana varieties throughout the continent. IITA breeding program has identified sources of resistance but bananas are extremely difficult to breed using conventional techniques.

32. The first improved yield, disease resistant hybrids are the result of over 20 years of joint breeding efforts between the National Agricultural Research Organization (NARO) of Uganda and IITA. Twenty-five of these so called NARITA hybrids have been evaluated over three crop cycles at the IITA Sendusu research station in Uganda and the performance of many was comparable to the local check variety, Mbwazirume. Their potential for adoption by farmers and consumers is currently being evaluated in a broader range of environments in Tanzania and Uganda as part of a participatory varietal selection approach incorporating input from farmers and consumers in five locations. These hybrids hold considerable promise for meeting the needs of small holder farmers in Uganda, Tanzania and throughout East Africa[5].

Cooperation-88, a very successful potato variety in China

33. Cooperation-88 (C88) is a late-blight resistant potato variety formally released in 2001 that has become popular in China, particularly in Yunnan Province. The International Potato Center (CIP) and Yunnan Normal University collaborated to produce the variety, which has been adopted by farmers since the first field trials in 1996. C88 is popular in domestic markets due to its high quality and taste for table consumption. Its processing attributes also make it a commonly used input in China's expanding potato chip industry; C88 represents 60-70% of the industry raw input[6]. C88 can also be stored for a relatively long time and can be shipped without incurring significant damage to the tuber, which makes it attractive for long distance trade between Provinces in China and across borders

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[4] More information at: http://strasa.irri.org/

[5] Tushemereirwe, W. et al. 2015. Performance of NARITA banana hybrids in the preliminary yield trial for three cycles in Uganda. http://www.musalit.org/seeMore.php?id=15482

[6] Li C., Wang J., Chien D.H. Chujoy E., Song B. and VanderZaag P. (2011) Cooperation - 88: A High Yielding, Multi-Purpose, Late Blight Resistant Cultivar Growing in Southwest China. American Journal of Potato Research: 1-5; Robinson J. and Srinivasan C.S. (2013) Case-Studies on the Impact of Germplasm Collection, Conservation, Characterization and Evaluation (GCCCE) in the CGIAR. CGIAR Standing Panel on Impact Assessment. http://ispc.cgiar.org/sites/default/files/images/GCCCE2013.pdf

with neighboring countries. After more than 20 years since its first use, C88 is still popular, covering more than 17% of Yunnan's potato area and near 165,000 hectares in other provinces where it is being adopted (Guizhou, Guangxi, Sichuan, Chongqing). An estimated yield advantage of more than 20% has generated significant aggregate economic impacts for producers and consumers, ranging from USD2-3 billion from 1996 to 2015 in Yunnan, with additional industry benefits for processors.[7] This is only one of several examples of CIP's impact in China, where other varieties generated from CIP germplasm have been widely adopted. Total area with CIP-related varieties in China amounts to 1.25 million hectares or near 25% of total potato area in the country (Gatto et al., 2017).[8]

Innovative seed systems to deliver improved varieties of tropical legumes for better livelihoods

34. Legumes represent the most affordable source of protein and micronutrients available to the rural and urban poor and are especially important for the hundreds of millions of women and children in Sub-Saharan Africa and South Asia. Improvements in their productivity is seen as a way of guaranteeing additional income while helping to diversify food production and income streams, mitigating the risk associated with staple crop price fluctuations. Legumes contribute significantly towards reducing poverty, improving food security, nutrition, health, empowerment of women and protection of the natural resource base.

35. A total of 163 new varieties of common bean, groundnuts, chickpea and cowpea were released through the project Tropical Legumes III, led by ICRISAT. The varieties are fast replacing the older dominant seed varieties in all target countries. Through a decentralized seed system and innovative partnerships with multiple stakeholders in the legume seed value chain, seed production and delivery significantly increased by 221% (from 139,048 t in 2010 to 446,359 t in 2015).

36. The project adopted an inclusive approach through farmers' participatory trials and promotion of innovative approaches, such as small seed packs, revolving seed funds, seed loans and decentralized production schemes. As a consequence, improved varieties were adopted on 2,008,000 ha, $513 million was realized by producers, and nearly USD2 billion were generated by from project and investment partners. For each dollar invested, USD9 was generated with direct project investment or USD20 with partnership investment and again $20 when using adoption rate based estimate.[9]

On-farm impact of pearl millet hybrids in India developed using ICRISAT-bred hybrid parents

37. Pearl millet is one of the important food crops in the low rainfall and shallow soil areas of Africa and Asia. In India, its area suffered from soil erosion, but production increased three to four times over the past six decades due to the development and wider use of hybrids. ICRISAT contributed to this change by generating diverse arrays of hybrid parents having high productivity and disease resistance and sharing them with public and private sector organizations. Two impact assessment exercises conducted in 2006 and 2010 determined that about 60-70% of hybrids cultivated in India are based on ICRISAT based breeding materials.

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[7] Myrick, Stephanie N.B. (2016). An Economic Impact Assessment of Cooperation-88 Potato Variety in the Yunnan Province of China. Master of Science thesis. Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University. Blacksburg, VA, USA. https://vtechworks.lib.vt.edu/handle/10919/74871.

[8] Gatto, M., G. Hareau, W. Pradel, V. Suarez and J. Qin (2017). Release and adoption of modern potato and sweet potato varieties in South, East and South East Asia. Paper presented at the 9th Asian Society of Agricultural Economists (ASAE) International Conference "Transformation in Agricultural and Food Economy in Asia", Bangkok, Thailand, January 11-13, 2017.

[9] More information at: http://tropicallegumes.icrisat.org/

38. It is estimated that the hybrids involving ICRISAT parents covered more than 50 per cent of the pearl millet areas in Rajasthan, Gujarat and Uttar Pradesh states during 2013-14. These varieties produced much higher grain and fodder yields than the varieties they replaced and much higher benefit cost ratios. Farmers reaped substantial private benefits by the adoption of ICRISAT based hybrids.

39. Besides the private benefits, the social benefits are also substantial. ICRISAT based hybrids succeeded in reducing the per ton unit cost of production to the farmers by USD34.5 in Gujarat, USD24.9 in Rajasthan and USD19.7 in Uttar Pradesh. The social benefits due to ICRISAT based hybrids were estimated at USD24.83 million in Gujarat, USD51.75 million in Rajasthan and USD40.47 million in Uttar Pradesh per year. The total benefits accrued to ICRISAT based hybrids could surpass USD150 million per year, if coverage with these varieties in other Indian states is also considered. These social benefits do not accrue to the farmers alone. Due to low income and price elasticity of demand, most of the social benefits accrue to the consumers. Some benefits accrue to the seed companies and seed dealers. Farmers may be able to access only a small part of the total social benefits estimated.[10]

Pigeonpea success story in Eastern and Southern Africa -- an effective use of local germplasm

40. Pigeonpea improvement in Eastern and Southern Africa (ESA) started in 1992, relying mostly on native germplasm. Thirty pigeonpea varieties were released using ICRISAT germplasm, with adoption of up to 40-50% that led to an expansion of the area planted (1.14 million ha) and production (1.047 million tons) with enhanced productivity (917 kg/ha). Since 2001, area, production and productivity have increased further, by 96%, 175% and 40%, respectively, contributing to 21% of global production. Pigeonpea production in ESA has increases at an annual growth rate of 13.5% over the past decade and shows huge promise. Farmers are getting remunerative prices of about USD1 per kg of grain.Production is expanding into non-traditional areas as a result of the release of photo-period insensitive and climate-resilient medium duration varieties that are easily integrated into existing cropping systems as an intercrop. Thanks to community based seed systems, 4250 tonnes of quality seed were produced and disseminated, leading to 0.5 million ha planted to the improved varieties in the past 8 years. This increase equals USD130 million of additional benefits to smallholder farmers alone.[11]

Increased wheat yield in Ethiopia

41. About 4.6 million rural households (36% of cereal farm households) in Ethiopia depend on wheat farming. Adoption of varieties resulting from WHEAT has helped Ethiopia's wheat production increase from 1.6 million tons in 2003-04 to more than 4 million tons by 2014 – the highest ever and more than doubling in a decade. This growth is equivalent to 6% average yield growth per year, 2% of which was driven by area expansion. Average wheat yields over the decade to 2014 rose from 1.47 to 2.37 tons per hectare and contributed to improved food security. Small-scale wheat farmers in high-potential areas who use improved wheat varieties and cropping practices routinely harvest 10 tons or

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[10] SK Gupta. 2016. Improving food security and incomes with productive, nutritious multi-purpose pearl millet hybrid production technologies for East Africa and South Asia. Review Meeting of the Program on Dryland Cereals

[11] Rao NVPRG, Manyasa EO, Ojulong H, Siambi M and Upadhyaya HD. 2016. Effective Utilization of Local Genetic Diversity of Pigeonpea, Sorghum and Finger Millet in Eastern and Southern Africa: Impacts and Prospects. In: IAC (2016) Abstracts Book. 1st International Agrobiodiversity Congress, November 6-9, 2016, New Delhi. Pp 114; Rao NVPRG, Siambi M, Silim SN, Lyimo SDN, Ubwe R, Makenge M, Kananji GAD, Yohane E, Amane MIV, Obong Y, Kimurto PK, Monyo ES, Kumar CVS, Mponda O, Kileo R, Kanenga K, Damaris OA, Okori P, Ojiewo CO, Upadhyaya HD, Harawa R, Saxena RK and Varshney RK. 2016. Pigeonpea success story in Eastern and Southern Africa: Achievements and prospects. In abstracts book of International Conference on Pulses for health, nutrition and sustainable agriculture in drylands. Marrakesh, Morocco, 18-20 April, 2016, pp 183.

more of grain per hectare — nearly equivalent to wheat yields in Western Europe. This is supported by seed systems that can respond quickly to rust disease epidemics. In 2010-11 around 70% of wheat area was sown to what became rust susceptible cultivars due to dramatic changes in virulence; by 2013-14 an estimated 80% of the wheat area was under cultivars that were resistant to yellow or stem rust, including Ug99 strains. CIMMYT and ICARDA's partnership since 1980 with the Ethiopian Institute of Agricultural Research (EIAR) has been crucial; research has shown that 80% of the wheat lines in Ethiopia's breeding programs are CIMMYT- or ICARDA-derived.[12]

Adoption of improved cassava varieties in South East Asia

42. CIAT's contributions to the development of the cassava sector in the main cassava producing countries of Southeast Asia are wide and significant. A recent study on the diffusion and adoption of improved cassava varieties in Cambodia, China, India, Indonesia, Laos, Myanmar, The Philippines, Thailand and Vietnam estimated that 65% of the 4.1 million ha of targeted cassava production in the nine countries are grown using CIAT related varieties.[13] CIAT started direct collaboration in cassava genetic improvement for Southeast Asia in 1983, in Thailand. Varieties such as Raygon 60 (released in 1987), Raygon 90 (in 1991), Kasetsart 50 (or KU50) released in 1992, Raygong 5 (in 1994) and Raygon 72 (in 1999), all had positive impacts on yield of cassava roots and starch. They were subsequently disseminated in neighboring countries.[14] KU50 has been identified as the most used cassava variety in Asia, with around 1.3 million ha of this variety growing in Cambodia, Laos, Myanmar, and the Philippines, besides Thailand and Vietnam. For the last 2 countries, the economic impact of this variety reached USD393.5 million between 1992 and 2010.[15] Besides improved varieties for starch production, local cultivars for direct consumption of cassava are very important in Laos, Indonesia and the Philippines and make up almost half of the cassava acreage grown in these countries.

Biofortified lentils for rice-based cropping systems in South Asia

43. Over 14 million ha of rice fields in South Asia are left fallow in the winter season. ICARDA and NARS partners in Bangladesh, Nepal and India have developed new short duration varieties and crop management methods for cultivating lentil in the fallow land. The approach has already proven its potential in Bangladesh and Nepal and is being scaled out in India. Bangladesh grows about 165,000 ha of lentil and has traditionally imported more than half of its consumption. One key scientific enabler in establishing a thriving rice-lentil system in Bangladesh is new higher-yielding varieties of lentils (BARIMasur4, BARIMasur5, BARIMasur6, BARIMasur7, BARIMasur8) tolerant to rust and stemphylium blight and with high iron content. Extensive training of farmers in managing these new lentil varieties has led to an increase in lentil production from 126,000 tonnes in 2001 to 210,000 tonnes at present, mainly because of the yield increase from 790 kg/ha in 2001 to 1270 kg/ha. Lentil cropping has spread to more than 85% in Bangladesh alone, bringing in an additional annual income of USD26.6 million for producers. For about a million small-scale farmers, obtaining a harvest of bio-fortified lentils from their existing land has improved not only their livelihood but also nutrition

[12] Shiferaw, B., Kassie, M., Jaleta, M. and Yirga, C. 2014. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. Food Policy, Vol. 44.

[13] Labarta, R., T. Wossen, and DP. Le (2017). The adoption of improved cassava varieties in South and Southeast Asia. Paper presented at the 9th Asian Society of Agricultural Economists (ASAE) International Conference "Transformation in Agricultural and Food Economy in Asia", held in Bangkok, Thailand, January 11-13, 2017

[14] Howeler, R. (2006). Cassava in Asia: Trends in Cassava Production, Processing and Marketing. Paper presented at Workshop on "Partnership in Modern Science to Develop a Strong Cassava Commercial Sector in Africa and Appropriate Varieties by 2020", held in Bellagio, Italy, May 2-6, 2006

[15] Robinson, J. and C. Srinivasan (2013). Case-Studies on the Impact of Germplasm Collection, Conservation, Characterization and Evaluation (GCCCE) in the CGIAR. CGIAR Standing Panel on Impact Assessment. Rome.

for their families. Identification of a new source of extra earliness (90 days to maturity) from a wild accession opens up the prospect of rice-lentil-boro rice system in South Asia.[16]

Seeds of Discovery: Harnessing crop genetic resources to meet present and future challenges

44. Beginning late in 2010, a 10-year investment by the Mexican government enabled CIMMYT's Seeds of Discovery (SeeD) initiative to assemble a platform of technologies that facilitate the effective use of maize and wheat genetic resources in breeding to address challenges of climate change and evolving needs of farmers and consumers. The platform consists of 1) high-density genotypic data and extensive phenotypic data characterizing maize and wheat germplasm bank accessions; 2) software tools to enable informatics analyses of these and relevant germplasm bank data; and 3) maize and wheat germplasm incorporating novel diversity for priority traits from exotic germplasm into farmer- and breeder-preferred genetic backgrounds. Each of these platform components was co-developed with partners who brought unique expertise and resources to the project.

45. Equitable access and sustained impact of the platform and the maize and wheat genetic resources it describes are pursued via multi-pronged capacity development and proactive intellectual property strategies. Capacity development efforts include farmer-participatory variety evaluation and improvement, technical workshops, visiting scientist, and student thesis projects. SeeD's intellectual property strategy includes access to all data under a "one click license" that permits use for research and development conditioned on not seeking intellectual property that could limit use by others. Germplasm developed by SeeD is available under the Standard Material Transfer Agreement (SMTA) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

46. The combined application of phenotyping with novel genotyping, analysis and informatics technologies has begun to impact smallholder farmers and both basic and applied research institutions. For example, the application of the technologies have helped in identifying germplasm bank accessions with superior resistance to tar spot complex (TSC) disease, a foliar disease of maize that is devastating crops in Guatemala and Mexico. Smallholder farmers in the Mexican State of Oaxaca are using this newly identified germplasm in participatory breeding to improve their preferred landraces or to develop new landraces. In Guatemala, researchers are evaluating SeeD-identified or SeeD-developed diverse germplasm for resistance to TSC, identifying options for use by farmers whose crops have been severely damaged by this disease in recent years.

47. Other indicators of early impacts include: 1) demand by 20 researchers of Mexican institutions to apply the approach and germplasm to enhance their own programs; 2) seven institutions, UNAM (Mexico), INIFAP-Sinaloa (Mexico), CNRG (the Mexican Genetic Resources Center), CATIE (Costa Rica), ICARDA (Morocco), IITA (Nigeria), and a Mexican private seed company, have availed themselves of the genotyping services of the SeeD project to enhance their own research; 3) more than 2,650 downloads of datasets and 724 downloads of training materials; and 4) a self-funded project from another crop (coffee) research institute to work with SeeD to replicate main elements of the SeeD initiative for their mandate crop. The social, economic and environmental value created by this project is potentially agriculture-sector-wide, increasingly benefitting farmers and consumers of a growing number of crops with a broad range of needs and preferences.[17]

[16] Jitendra Kumar, H. Dikshit, O. Ali, R. Nath, A. Sarker and Shiv Kumar. 2016. Lentil for Rice-based Cropping Systems in South Asia. CGIAR Research Programme on Grain Legumes. Poster. Available at http://grainlegumes.cgiar.org/wp-content/uploads/2016/10/GL-19_Lentil-for-rice-based-cropping-systems-in-South-Asia_Jitendra-Kumar.pdf; "Combating Micronutrient Malnutrition With Biofortified Lentils". Science Matters, October 2015. ICARDA

[17] More information available at: http://seedsofdiscovery.org/

Impact of early maturing chickpea varieties in Myanmar

48. Chickpea is an important legume crop in Myanmar, not only for local consumption but also for export. About 96% of the chickpea area is in the Central Dry Zone (CDZ) in Sagaing (47%), Mandalay (25%) and Magway (24%) regions. The CDZ is characterized by erratic and low (<750 mm) rainfall. Chickpea is grown after the rainy season on residual soil moisture, mostly without irrigation, and often experiences drought and heat stresses during the reproductive phase. Chickpea varieties with early maturity, resistance to Fusarium wilt and tolerance to drought and heat stresses are required for CDZ. Department of Agricultural Research (DAR) of Myanmar has worked closely with ICRISAT for the development of chickpea varieties suited to CDZ. Since 2000, seven early maturing (85 to 95 days) chickpea varieties, four of kabuli type (Yezin 3 (ICCV 2), Yezin 5 (ICCV 3), Yezin 8 (ICCV 97314) and Yezin 11 (ICCV 01309)) and three of desi type (Yezin 4 (ICCV 88202), Yezin 6 (ICCV 92944), and Yezin 12 (ICC 07118)) have been released in Myanmar from the breeding lines supplied by ICRISAT. Farmers have rapidly adopted these varieties. During 2014-15, 96% of the chickpea area was under five of these varieties (43% Yezin 3, 20% Yezin 4, 16% Yezin 6, 16% Yezin 8 and 1% Yezin 11). Adoption of these varieties along with improved crop production practices has given an impressive compound annual growth rate of 5.6% for chickpea yield during the past 15 years (2000-01 to 2015-16). Chickpea production increased 5-fold (117,000 to 581,000 tons) due to 3.3-fold increase in area (164,000 to 373,000 ha) and 2.2-fold increase in yield (712 to 1560 kg ha). Myanmar has emerged as an important chickpea exporting country from 2001 with an average annual export of 47,500 tons (valued at USD24 million).[18]

Development and deployment of drought tolerant MAIZE-derived germplasm

49. Driven by the need to adjust to climate change, it has been estimated that investments in the development of drought tolerant (DT) germplasm would generate between USD362 to USD590 million and possibly as high as USD880 million in cumulative benefits to both producers and consumers by 2016 in MAIZE project target countries, reducing poverty for more than 4 million producers and consumers. In response, MAIZE contributed to the development and deployment of more than 250 drought tolerant, nitrogen use efficient, and heat tolerant improved MAIZE varieties through a number of trail blazing projects. The average adoption rate of these varieties was 24.5%, and the average yield increase 23%. The amount of certified seed of DT maize varieties in sub-Saharan Africa (SSA) commercialized by seed company partners reached more than 60,000 t across 13 African countries: Angola, Benin, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Tanzania, Uganda, Zambia and Zimbabwe. This was achieved through a network of more than 100 small and medium scale seed producers and companies. In a study re-assessing impacts of DT maize in SSA (2007-2016), researchers found that DT maize varieties outperformed popular commercial maize varieties grown in SSA in terms of more stable yields (with an average yield advantage of 1-2 t/ha under severe drought stress), which, in turn, translated into more stable income for the maize-dependent smallholders. Evidence on productivity gains and welfare impacts of adoption in Nigeria indicate a 21% reduction in poverty, with about 370,000 households, equivalent to 2.7 million individuals moved out of poverty. Although DT maize adoption rates were variable across SSA, benefits throughout the study period were estimated to be USD395 million for producers and consumers. Ongoing projects aim to catalyze seed companies in SSA to produce an estimated 66,000 t of certified seed of DT maize to put into the hands of more than 7.9 million smallholder farmer households.[19]

[18] Mar Mar Win, Kyi Shwe, Thin Maw Oo and Pooran M Gaur. 2016. mpact of early maturing chickpea varieties in Myanmar. CGIAR Research Programme on Grain Legumes. Poster. Available at http://grainlegumes.cgiar.org/impact-of-early-maturing-chickpea-varieties-in-myanmar/

[19] More information available at: http://dtma.cimmyt.org/

Increasing nutrition through bio-fortified beans in Rwanda

50. High-iron bean (HIB) varieties are one result of CIAT's conventional breeding work done as part of HarvestPlus, a CGIAR-wide program coordinated by CIAT and IFPRI to develop and scale up the delivery of biofortified (i.e., increased vitamins and minerals) crops to reduce malnutrition around the world.

51. Taking advantage of Rwandans' high per-capita bean consumption rates (up to200g/day), the Rwanda Agricultural Board (RAB), CIAT and HarvestPlus joined efforts through collaborative research to combat iron deficiency-caused anemia, which affects 37% of children under 5 years of age and 20% of women of childbearing age in Rwanda. They released the first four HIB varieties in 2010, followed by six more in 2012. Seeds of the 10 HIB varieties, bush and climber types, have been intensively disseminated throughout the country by a wide range of partners including government agencies, schools, health centers, NGOs, agrodealers and direct marketing through local markets. Since 2014 the introduction of "payback" (farmers receive free HIB seed in return for giving back certain amount of harvested grain) and "seed swap" (farmers can trade their local bean varieties for HIB varieties)systems has helped to multiply HIB planting material and flush out less nutritious bean varieties, replacing them with iron-rich ones. After eight seasons of active dissemination, adoption and diffusion rates in Rwanda were estimated through enlisted households (a total of 19,575) and survey analyses across the country (120 randomly selected villages). Extrapolating from the 28% adoption rate (i.e., 28% of rural bean-growing households have grown at least 1 HIB variety) of the survey to the national rural bean-growing population, it is estimated that almost half a million Rwandan households have grown an HIB variety since 2010.[20] The study also found that by 2015, HIB adopters increased the proportion of their bean land area over time, using up to 70% of it by season 6, and using Their own saved seed in subsequent seasons. HIB varieties made up 12% of the national bean output among smallholder bean farmers in 2015. In addition, HIB varieties were found to be higher yielding (23% for bush and 16% for climber types) than non-HIB varieties. Important for arresting anemia, more than 80% of the HIB production is used for home consumption rather than sold for income even though they are perceived as fetching a higher market price. Finally, women have played a crucial role in the adoption of HIB varieties as the decision to grow an HIB variety for the first time was made by a woman in more than 60% of households.

[20] Asare-Marfo, D., C. Herrington, E. Birachi, E. Birol, K. Cook, et al. (2016). Assessing the Adoption of High Iron Bean Varieties and Their Impact on Iron Intakes and Other Livelihood Outcomes in Rwanda -Main Survey Report. December, Washington, DC: RAB, CIAT, VirginiaTech, HarvestPlus