PHOTO: CIAT

The contribution of the CIAT genebank to the development of iron-biofortified beans and well-being of farm households in Rwanda

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HIGHLIGHTS

- Around 29 kg of beans are consumed per person per year in Rwanda – the highest consumption in the world; about 21% of children between 0 and 5 years old and almost 16% of reproductive-aged women suffer from iron deficiency.
- Iron-biofortified beans are a way address this problem particularly among remote, farming households who grow and consume their harvest.
- CIAT's genebank contributed to the development of seven iron-biofortified climbing bean varieties introduced in Rwanda from 2010 (CAB2, RWV3316, RWV3317, RWV3006, RWV2887, MAC44, and MAC42).
- Compared to a similar study on bush bean varieties, the impact of iron-biofortified climbing varieties on the well-being of farm households appears limited, suggesting a need for further research.

Genebanks and nutrition quality of food crops

The common bean is a major staple in the diets of the people Latin America and Africa. Beans are a highly nutritious food that not only contains protein, fiber, and complex carbohydrates, but also the vitamins and micronutrients that are essential to overcome the problem of hidden hunger. Beans are an indispensable source of iron and provide income for millions of people, specifically in Africa and Latin America. About 400 million people in the tropics eat beans daily. Rwanda has the highest bean consumption per capita in the world.

In a number of countries, including Rwanda, anemia still represents an important public health problem. Where farm populations depend heavily on their harvests for the food they consume, biofortification is one of the nutritional strategies that has the potential to become a sustainable, inexpensive, and effective solution for iron deficiency.

In order to biofortify bean, breeders need to locate sources of genetic diversity. The genebank of the International Center for Tropical Agriculture (CIAT) began collecting beans in the early 1970s, in order to prevent the loss of crop diversity. Genebank accessions have been used extensively in research and as parents in breeding programs, but the relationship between the orig-

BOX 1 The International Center for Tropical Agriculture (CIAT) Genebank

CIAT's genebank, located in Palmira, Colombia, conserves large collections of beans and tropical forages as seed and whole plants, and cassava *in vitro* and as small plants.

CIAT started its bean collection in the 1970s and now conserves almost 38,000 accessions, which includes landraces, wild species and wild ancestors of cultivated crops. Most of the germplasm originates in the Neotropics where beans where domesticated thousand of years ago. Mexico, Peru, Colombia, and Guatemala are particularly well represented. The collection also contains important diversity from Europe and Africa and, to a lesser extent, Asia.

Dr. Daniel Debouck has been a key player and found 3,900 new varieties during 35 expeditions in 11 Latin American countries and conserved them in CIAT's bean collection.

Since its inception, the genebank has received materials from 144 countries and has distributed bean accessions to 110 countries for research, breeding or direct use by farmers. CIAT sends the backup of its bean collection to the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and to the Svalbard Global Seed Vault in Norway.

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Table 1. Pedigrees of the seven iron-biofortified varieties.

Bred variety	Main bean breeder	Pedigree	Countries of origin of CIAT's genebank varieties
CAB2	Julia Kornegay	G20557 x VCB81020	KENYA x BRED VARIETY
RWV3316	Louis Butare	CAB2 x LAS400	BOTH BRED VARIETIES
RWV3317	Louis Butare	NGWIN x CAB2	LOCAL (RWANDA) x BRED VARIETY
RWV3006	Louis Butare	CAB2 x BUBERUKA	BRED VARIETY x LOCAL (RWANDA)
RWV28887	Louis Butare	CAB2 x LAS400	BOTH BRED VARIETIES
MAC44 – MAC42	Matthew Blair	AND930 x G12722	BRED VARIETY x COLOMBIA

Source: elaboration of data from the *Catalogue of advanced bean lines from CIAT* (Rodriguez et al. 1994)

inal accessions and the improved varieties grown by farmers has not always been documented. Often, pedigrees of varieties bred with CIAT germplasm are not reported back to the genebank.

Our main objective in this study was to assess the contribution of the CIAT genebank to the development of biofortified bean varieties and their impact on the well-being of farm households in Rwanda. To understand the contribution of CIAT's genebank, we traced the journey of bean accessions from when they were collected and introduced into the genebank to their use in improved bean varieties grown by farmers in Rwanda.

Synopsis of methods

In the study's first phase, we linked seven iron-biofortified climbing varieties introduced in Rwanda directly to CIAT's genebank through pedigree analysis and informant interviews with the breeders who developed them. The seven varieties are: CAB2, RWV3316, RWV3317, RWV3006, RWV2887, MAC44, and MAC42 (Table 1).

The second part of the study links the genebank to farmers via the climbing varieties grown by farm households, drawing from nationally representative data on bean producers in Rwanda collected by HarvestPlus, in partnership with the Rwanda Agriculture Board (RAB) and CIAT. We applied various econometric models to test the impact of their adoption on the yield, consumption and purchase of beans by farming households in Rwanda. In this second step, we built upon previous research on bush beans by Vaiknoras and Larochelle (2018).

The survey followed the distribution of iron-biofortified varieties that started in 2010 for four varieties and continued in 2012 for the remaining climbing varieties studied here. The first round of data collection took place in May and June of 2015. In this round we interviewed 19,575 households from 120 randomly selected villages regarding their history of adoption of iron-biofortified bean varieties. In the second stage, which took place in September 2015, we randomly selected 1,397 households from the villages of the first round for a second interview.

Table 2. Impact of the adoption of iron-biofortified varieties

	OLS	IV	IV (ML)	CF OLS
On yield (N=813)	0.156 (0.084)	0.982 (0.612)	0.336 (0.225)	0.078* (0.033)

*: statistically significant at 10% significance level. Standard errors in parenthesis.
ML=Maximum Likelihood

To maintain comparability with previous research on iron-biofortified bush beans, we used the data from Vaiknoras and Larochelle (2018) and conducted similar analyses. We tested the impact on the well-being of farm households in Rwanda by applying various estimation methods: Ordinary Least Squares (OLS), Instrumental Variables (IV), Control Function Approach (CF) and Poisson model (Table 2).

Main findings

We found that iron-biofortified bean varieties are the result of a long process that began during the 1990s and involved several universities and international institutions, including CIAT's genebank. In particular, CIAT's genebank played an important role in the screening of its highly diverse collection in search of needed traits.

Through the pedigree analysis, we could confirm that each of the studied varieties is directly related to CIAT's genebank. The varieties MAC42 and MAC44 were developed in the early 2000s at CIAT with genebank materials. Overall, we identified 12 genebank accessions used by different breeders to generate bred lines that were incorporated into the MAC varieties. The 12 genebank accessions used are: G12722, G21720, G6616, G4523, G76, G6533, G14013, G11891, G4505, G5704, G4452, and G5709. Six of those accessions originated in Colombia, one in the Dominican Republic, two in the United States, and one each in Brazil, Mexico, and Peru.

The varieties RWV3316, RWV3317, RWV3006, and RWV2887 are the result of the combination of the variety CAB2, developed at CIAT by Julia Kornegay, with either a local Rwandan variety or another CIAT's bred variety. CAB2 was developed in the early 1990s and was a very important progenitor in the development of iron-biofortified varieties in Rwanda. It was the result of the breeding between the genebank accession G20557 and the improved variety VCB81010 of Jeremy H.C. Davis, whose progenitors were G3467 and G2540 from CIAT's genebank. G20557 is a bush variety from Kenya; G3497 is a climbing variety from Mexico; and G2540 a climbing variety from Congo. Finally, RWV3317 and RWV3006 are the result of crosses between CAB2 and local Rwandan landraces, NGWIN and BUBERUKA.

The econometric analysis extends research by Vaiknoras and Larochelle (2018) on the impact of the iron-biofortified bush bean variety RWR2245. We evaluated the impact of iron-bioforti-

BOX 2 The Genebank Impacts Fellowship

My experience as a research fellow for the Genebank Platform started before I was accepted to the program. I read about the fellowship and immediately felt very excited about it. I had previously worked at CIAT so I visited some former colleagues. I asked for information on CIAT's genebank and on improved bean varieties so that I could write a research proposal that was interesting, feasible and innovative.

The real adventure began in July 2018, with a four-day bootcamp in Bonn, Germany, organized by the Crop Trust. During the bootcamp, I met the other six fellows and learned from experienced researchers about crop diversity conservation, impact assessment methods, and breeding programs. The bootcamp was an extremely valuable learning experience and prepared me so I could improve my research proposal. It also provided me with general knowledge on the work conducted by genebanks worldwide.

From September until December 2018, I worked as a visiting researched at CIAT's genebank. During my first two weeks, I attended meetings with CIAT's main experts in bean, forages and cassava conservation and regeneration. I spoke with the leaders of CIAT's core programs and with CIAT's bean breeders and had the opportunity to visit CIAT's genebank and CIAT's stations in Palmira, Popayan, Tenerife and Carrizal. With the assistance of CIAT's staff and as a result of the above mentioned guided tours, I gained an understanding of how CIAT's genebank operates, how new varieties enter the genebank, how they are multiplicated, characterized, harvested, dried, packed and stored, as well as, how accessions were distributed worldwide.

Stefania with her CIAT mentor, Peter Wenzl

My research was conducted in cooperation with CIAT's Genetic Resources program and with the department of Decision and Policy Analysis (DAPA), whose help was essential for the impact assessment, which was the core of the second part of the study. Furthermore, the expertise of Melinda Smale and Nelissa Jamora was essential to the development of my work, as well as the contribution I received by Kate Vaiknoras and Catherine Larouchelle, who had previously worked on a study on bush iron-biofortified varieties.

Finally, Dr. Daniel Debouck, the principal scientist of the Genetic Resources program and its former leader, provided me with essential information on the work of CIAT's genebank and on its history. Through this fellowship, I had the opportunity to work with a scientist who is a legend in the field of bean collection and conservation.

fied climbing bean varieties on: yield; number of months consuming beans from own production; quantity of beans consumed per month; the quantity of beans purchased; and number of months purchasing beans the market.

Variates were comparable to those included in the modeling of Vaiknoras and Larochelle, but we focused on bean varieties with CIAT accessions in their ancestry. In contrast to their findings for bush beans, we found only a weakly significant effect of iron-bio-fortified climbing varieties on yield.

Conclusion and future considerations

"Do genebanks play a role in the improvement of nutrition quality of food crops?"

Our study answers "yes".

CIAT's genebank played an essential role in the long journey of bean genetic resources that led to the development of iron-biofortified varieties with the potential to improve nutrition in Rwanda.

High-iron climbing beans were developed and released in numerous countries including Rwanda. Photo: Neil Palmer/CIAT

Our research also revealed scope for improvement. Research during the first part of this study was impeded by the difficulty of locating relevant information. Much of the information about the breeding process that led to the development of iron-biofortified varieties has been lost.

During our data collection, we encountered the following limitations: (1) iron-biofortified varieties were developed during the time when recording of information was still paper-based and not easily available; (2) communication between CIAT's genebank and bean breeders is poor and breeders are not required to report back to the genebank about how they are using the varieties requested; (3) written documentation has not been standardized and much information is recorded only

PHOTO: NEIL PALMER/CIAT

in the memories of experts. This crucial problem of communication generates a misalignment of objectives between CIAT's genebank and bean breeders.

We believe that the breeding and development process of improved varieties could be accelerated with enhanced collaboration and more active exchange of information between breeders and genebanks.

In the second part of the study, we applied models and variates that were comparable to those used in the impact analysis for bush beans. Although estimated coefficients on bean consumption and purchase generally had the expected signs, only the effect of climbing beans on yield was statistically significant at 10%. Further analysis is required to understand the differential effects of bush and climbing bean varieties. Detailed information on farm inputs and risk preferences of farmers are also key to understanding yield effects since climbing beans, even though they have higher yield potential, require additional inputs. Moreover, some econometric issues could be investigated to advance this research, such as the use of different instrumental variables.

Agro-ecological factors may be important. Measurement challenges may also explain differences, such as those related to the frequency of harvest, production and adoption definitions.

Further reading

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Additional details can be found in the paper on which this brief is based: Sellitti, Stefania, Kate Vaiknoras, Melinda Smale, Nelissa Jamora, Robert Andrade, Peter Wenzl, and Ricardo Labarta. 2019. The contribution of the CIAT genebank to the development of iron- biofortified bean varieties and well-being of farm households in Rwanda. Genebank Working Paper No. 10. CGIAR Genebank Platform, CIAT and the Crop Trust.

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