DEVELOPMENT

Iron Common Bean (*Phaseolus vulgaris*)

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Target Micronutrient		Iron; secondary trait: zinc	
Target Countries		Rwanda, Democratic Republic of Congo, Uganda	
Baseline (parts per million, ppm)		50 ppm	
Target Increment		44 ppm	
Target Level in Crop		94 ppm	
Nutrition Factors		**Original Assumption**	**Measured/Revised[1]**
Bean Consumption, grams/day (dry weight)	Women	200 g/d	123 g/d
	Children	100 g/d	65 g/d
Iron Retention (%)		90%	98%
Iron Absorption (%)		5%	7%
Absorbed Iron as % of EAR		60%	60%

Releases		
1st Wave	70–77 ppm (50–60% target increment)	Released: Rwanda, 2010; DRC, 2011
2nd Wave	80–90 ppm (80–90% target increment)	Released: Rwanda, 2012; DRC, 2013
3rd Wave	>94 ppm (>100% target)	Planned: 2014–15

[1]Rwanda

Breeding to Date: Common bean is the most common food legume in Latin America and eastern and southern Africa and is cultivated as both bush and climbing growth habits. During an exploratory phase (1994–2002), initial screening of more than 1,000 bean germplasm accessions by the International Center for Tropical Agriculture (CIAT) found ranges of 30–110 ppm iron (and 25–60 ppm zinc) in common beans. During HarvestPlus Phase I, high-iron genotypes were used to initiate crosses to combine the high-mineral trait with acceptable grain types and agronomic characteristics (1). Genotype-by-environment (GxE) testing was used to verify that mineral accumulation was stable across sites and generations (2). In Phase II (Development, 2009–2013), a number of lines were identified that expressed more than 80% of the target level. Inductively-coupled plasma (ICP) was identified as the gold standard for high-precision mineral analysis capable of detecting soil contamination (3,4), and X-ray fluorescence (XRF) spectrometry calibrations and standards were developed for high-throughput screening (article in preparation). Breeding programs in target countries Rwanda (Rwanda Agriculture Board—RAB) and Democratic Republic of Congo (L'Institut National pour l'Etude et la Recherche Agronomique—INERA) have developed crosses locally and are assuming a greater portion of the selection work. A full breeding pipeline consists of both locally developed germplasm and CIAT introductions. Mainstreaming of the iron trait in breeding programs at both CIAT and RAB is estimated at 50%, and 30% for INERA.

So far, nine varieties have been released in Rwanda and ten in DRC. In Rwanda, four 1st-wave, fast-track varieties (2 bush, 2 climber) were released in 2010 and five 2nd-wave climbing bean varieties in 2012. In DRC, five 1st-wave, fast-track varieties (3 bush, 2 climber) were identified for release and dissemination in 2011 and five 2nd-wave varieties (3 bush, 2 climber) in 2013. Varieties with good yield and farmer-preferred end-use quality in major market classes are given in the table below.

Future Releases: Currently, about 100 climber and bush bean lines are in advanced line validation trials to identify agronomically competitive 3rd-wave varieties; leads have 90–100% target increment and release is projected for 2015. Future breeding efforts will focus on developing higher yielding, robust, high-iron varieties for a wider range of agroecological zones covering a broad range of market classes (grain color and size, cooking time, and taste).

Photo: N. Palmer (CIAT)

Capacity Building: In 2011, RAB's and INERA's analytical capacities were strengthened by installing and implementing x-ray fluorescence (XRF) machines for in-country mineral analysis of beans. The XRF at RAB serves as the mineral analytical hub for Africa; the second XRF installed nearby in Bukavu, DRC serves as back-up. To date, more than 4,000 bean samples from Rwanda, Uganda, DRC, and Burundi have been screened for iron and zinc.

Regional Testing: Since 2012, a 50-entry regional nursery comprised of released varieties and elite high-iron breeding leads from different countries has been deployed each crop season for GxE testing in Rwanda, DRC, Uganda, Burundi, and Malawi; testing will be expanded from 2014 onwards to Tanzania, Kenya, and South Africa. The regional nursery serves as a germplasm dissemination and testing tool. Agronomic and iron data from multiple sites per country allow high precision identification of fast-track candidates and parents for breeding, as well as higher effectiveness in targeted breeding for yield and iron stability based on adaptive pattern. Further, by substituting temporal-by-spatial environmental variation in large-scale regional GxE testing, testing steps can be eliminated and time-to-market shortened by 1–2 years.

Highlights:

- Competitive iron varieties approaching 90% of target increment and covering a wide range of market classes have been released in Rwanda and DRC.
- Many thousands of bean growers have been reached through intensive efforts at seed production and distribution (see delivery section).
- In-country capacity for mineral analysis has been established in Rwanda and DRC.
- A feeding trial with college-age women demonstrated positive health effects of iron beans (see nutrition section).

Challenges:

- Plant breeding may focus on reducing uptake inhibitors such as phytate, which can inhibit iron absorption from beans, but it is difficult to maintain acceptable yield with this trait.
- Efforts to improve yield will result in more productive varieties, and it will always be necessary to continue breeding to ensure that the better yield is accompanied by high iron.

1. Beebe, S.; Gonzalez, AV; Rengifo, J. 2000. Research on trace minerals in the common bean. *Food Nutr. Bull* 21:387–91.
2. Blair, MW; et al. 2010. Registration of high mineral common bean germplasm lines NUA35 and NUA56 from the red mottled seed class. *J. Plant Regul* 4:1–5.
3. Yasmin, Z; et al. 2014. Measuring genotypic variation in wheat seed iron first requires stringent protocols to minimize soil iron contamination. *Crop Science* 54:1–10.
4. Pfeiffer, WH; McClafferty, B. 2007. HarvestPlus: Breeding crops for better nutrition. *Crop Science* 47(Suppl. 3): S88–S105.

First- and Second-Wave Varieties Released in Rwanda and DRC

Variety Name	Release Year	Country	Iron Content* (% target)	Altitude Range; Color; Disease Reaction
First wave (fast-track): 50–60% target increment				
RWR 2245 (Bush)	2010 2011	Rwanda DRC	76 ppm (59%)	Low to mid altitude; color red mottled; AB, AC resistance; ALS, RR tolerance
RWR 2154 (Bush)	2010	Rwanda	71 ppm (47%)	Low to mid altitude; color sugar; AB, AC resistance; ALS tolerance
MAC 44 (Climber)	2010	Rwanda	78 ppm (64%)	Mid to high altitude; color red mottled; AC resistance; AB, ALS, RR tolerance
RWV 1129 (Climber)	2010	Rwanda	77 ppm (61%)	Mid to high altitude; color salmon; AC, RR resistance; AB, ALS tolerance
COD MLB 001 (Bush)	2008	DRC	64 ppm (32%)	Low to mid altitude; color red mottled; AB, AC resistance; ALS, RR, drought tolerance
Hm 21-7 (Bush)	2008	DRC	62 ppm (27%)	Low to mid altitude; color red mottled; AB, AC, RR resistance; ALS, drought tolerance
COD MLV 059 (Climber)	2012	DRC	84 ppm (77%)	Mid to high altitude; color red mottled; AC, CBB, RR resistance; ALS tolerance
VCB 81013 (Climber)	2008	DRC	69 ppm (43%)	Mid to high altitude; color white; AC, CBB, RR resistance; ALS tolerance
Second wave: 80–90% target increment				
RWV 3006 (Climber)	2012	Rwanda	78 ppm (64%)	Mid to high altitude; color white; AB, AC, ALS resistance
RWV 3316 (Climber)	2012	Rwanda	87 ppm (84%)	High altitude; color red; AC resistance; AB, ALS tolerance
RWV 3317 (Climber)	2012	Rwanda	74 ppm (54%)	High altitude; color sugar; AC resistance; AB, ALS tolerance
MAC 42 (Climber)	2012	Rwanda	91 ppm (94%)	High altitude; color sugar; AC resistance; AB, ALS tolerance
RWV 2887 (Climber)	2012	Rwanda	85 ppm (80%)	High altitude; color dark red; AC resistance; AB, ALS tolerance
PIGEON VERT (Bush)	2013	DRC	80 ppm (68%)	Low to mid altitude; color yellow; AC, BSM, CBB, RR resistance; LSF, drought tolerance
PVA 1438 (Bush)	2013	DRC	79 ppm (66%)	Mid to high altitude; color red kidney; CBB, RR resistance
COD MLB 032 (Bush)	2013	DRC	76 ppm (60%)	Mid to high altitude; color sugar; AB, AC resistance; ALS, RR, drought tolerance
CUARENTINO (Climber)	2013	DRC	100 ppm (114%)	Mid to high altitude; color white; AC, CBB resistance; RR tolerance
NAIN DE KYONDO (Climber)	2013	DRC	76 ppm (60%)	Mid to high altitude; color white; ALS, RR resistance; AB tolerance

*Average across four seasons, ICP and XRF data.
Notes: AB: Ascochyta blight; AC: Anthracnose; ALS: Angular leaf spot; BCMV: Bean common mosaic virus; RR: Root rot