High-Iron Beans

A Biofortified Solution for Iron Deficiency

Important!

- This module is designed to potentially serve a wide variety of audiences (nutritionists and agronomists, policymakers, extension workers, farmers)
- Not all of the material will be relevant to all audiences
- Please refer to the accompanying Facilitator's Guide for guidance on how to adapt these materials to your audience and facilitation best practices.

Legend

Icon	Description
Xm	Expected Duration, minutes
	Quick Review/Survey Questions
	Brainstorming Session
	Discussion Session
	Group Activity
	Animated Slide
	End of Animation

Unit 1

Introduction

Welcome

During this session, we will examine the potential of High-Iron Beans (HIBs) as a solution for iron deficiency and anemia in vulnerable populations.

Quick Survey

By show of hands:

- *How many of you are already familiar with biofortified high-iron beans?*
- *How many of you are familiar with biofortification, but not HIBs, specifically?*
- *How many of you have only a vague idea or no idea of what "biofortification" is and hope to learn more?*

Objectives

By the end of this session, you should be able to:

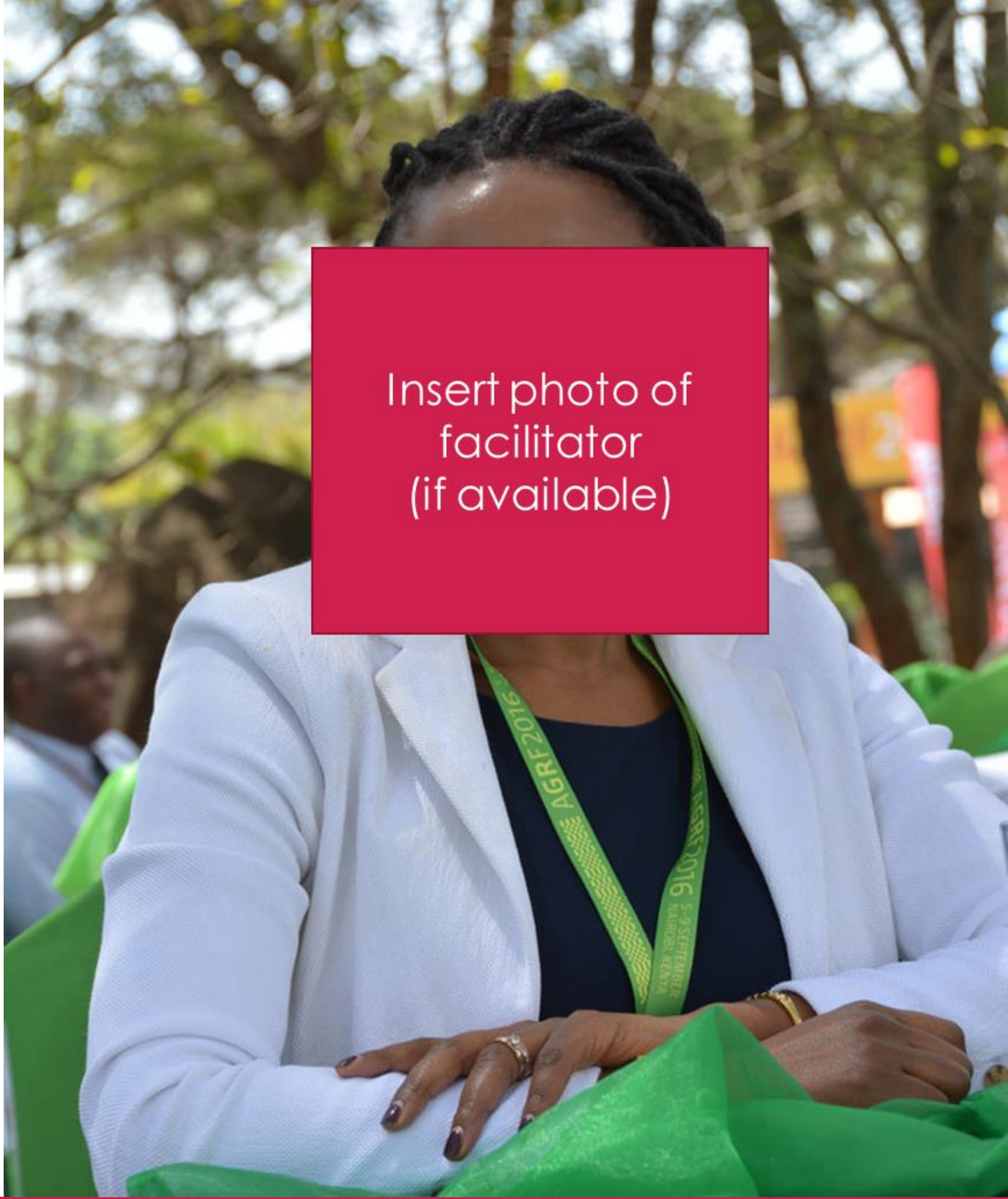
- Engage in discussions of micronutrient malnutrition with target groups, specifically about anemia/iron deficiency
- Describe how biofortified high-iron beans can address iron deficiency among vulnerable populations
- Summarize how breeders develop new HIB varieties
- Outline a strategy for promoting HIBs to farmers, consumers, partner organizations and the private sector
- Describe how HIBs can be integrated into a healthy diet
- Summarize key studies demonstrating the effectiveness of HIBs for addressing iron deficiency and anemia

Agenda

- Standard "housekeeping" items for session (break times, end time, facilities, meals)

Meet the Facilitator

- Name
- Role, Organization
- Credential(s)
- Fun biographical detail



Ground Rules

- Mobile phones off
- In addition to lecturing, there will be opportunities for discussions and asking questions.
  - To keep things moving, we might have to cut some conversations short and move on to the next topic
  - Not everyone will get to answer every question, but everyone will get multiple chances to speak and be heard throughout the session
  - If one or two people are answering every question, we will politely ask them to give someone else a chance to speak.

Ground Rules

As participants in this learning experience, we need to:

- Share our ideas without fear of criticism, and listen to the ideas of others without criticizing
- Engage in discussions without arguing
- Help other participants and accept help from others
- Create a safe, supportive environment for everyone to learn
- Have fun

Activity (Breakout Groups)

Meet Your Fellow Participants

- Pair off with another participant (ideally someone you don’t already know)
- Talk to each other and find out:
  - Their name
  - One interesting fact about their professional background
  - Something they enjoy outside of work, such as:
    - Hobbies
    - Favorite foods
    - Favorite holiday destination
- **You have 5 minutes**
- Reconvene and have each pair introduce each other to the rest of the class

20 m

Unit 2

Micronutrients and Biofortification

Unit Objectives

By the end of this unit, you should be able to:

- List and describe the three types of malnutrition
- Define ‘hidden hunger’ and explain the importance of micronutrients for good health
- Identify natural sources of micronutrients
- List and describe common interventions for micronutrient deficiency
- Define ‘biofortification’
- Compare biofortification to other interventions and summarize its major advantages and challenges
- Differentiate between biofortified crops produced through selective breeding and GMOs

The Problem of "Hidden Hunger"

Brainstorming

Malnutrition

What do we typically think of when we hear the term "malnutrition"?

2 m

Key Terminology

Malnutrition

Lack of proper nutrition, caused by

- Not having enough to eat
- Not eating enough of the right things
- The body not being unable to use the nutrients from food that a person does eat

The Problem of Malnutrition

- Serious public health issue in many parts of the world
- Major impediment to equitable economic growth
- In countries with persistently high levels of malnutrition, costs can rise to **16.5 percent of the economy (GDP)**

Women and Children

- Disproportionately impacts women and children
- Factor in 45% of all child deaths and 20% of maternal deaths (WHO)
- Causes 110,000 deaths during childbirth each year (WFP)
- Malnourished children lag **four years** behind peers in educational achievement

Quick Survey

*What are some of the **visible** symptoms of malnutrition? (What does a malnourished person look like?)*

2 m

Types of Malnutrition

- Because of past famines, many people associate “malnutrition” with:
  - Calorie Deprivation
  - Protein Deficiency
- In extreme cases, these result in visible “wasting” of the body

Photo: DFID

Quick Survey

How have governments, NGOs and other groups addressed calorie deprivation?

2 m

Responses to Malnutrition

- Historically, interventions have focused on providing high-calorie **staple foods** foods to avoid starvation
  - Direct distribution of staple foods during emergencies
  - Helping farmers increase production of staple crops

Brainstorming

Staples

What are "staple" foods? Can you give some examples?

2 m

Key Terminology

Staple

A staple food, or simply a “staple”, is a food that

- Is eaten routinely in such quantities that it constitutes a dominant portion of a standard diet for a given people
- Supplies a large fraction of energy needs and generally forms a significant proportion of total nutrient intake.

Staples Around the World

- Popularity of different staples varies around the world
- Depends on availability, traditional preferences, etc.

Brainstorming

Staple Crops

Based on consumption, which crops would be considered the most important staples in:

- *Africa*
- *Latin America & The Caribbean*
- *Asia*

7 m

Calories by Staple Crop

Asia	Africa	Latin America and the Caribbean	World
Rice 55%	Wheat 33%	Maize 35%	Rice 47%
Wheat 35%	Maize 32%	Wheat 32%	Wheat 34%
Maize 5%	Rice 19%	Rice 23%	Maize 12%
Potato 4%	Cassava13%	Cassava 5%	Potato 4%
Cassava 1%	Potato 3%	Potato 4%	Cassava 3%

"Green Revolution"

- Improvements in farming have helped
- Increased production of **staple crops** has reduced incidence of famine
- Global rate of calorie deprivation decreased from 18.6% in 1992 to 10.9% in 2016 (FAO)
  - 1 in 4 people in Sub-Saharan Africa still calorie-deprived

Discussion

What types of nutrients do staples provide?

What types of nutrients do staples generally ***not*** *provide?*

5 m

Types of Nutrients

Macronutrients

- Carbohydrates, fats and protein
- Need to consume in large amounts to provide energy, build muscle and fat
- Staples contain large amounts carbohydrates, which can help keep people alive

Photo: Martin Karimi, WFP

Types of Nutrients

Micronutrients

- Vitamins and minerals
- Needed in small amounts for body to function properly.
- Most staple foods do not provide sufficient micronutrients for good health

Photo: Martin Karimi, WFP

Brainstorming

Micronutrients

Can you name some important vitamins and minerals? Can you describe how they are important for human health?

5 m

Micronutrients and Health

- **Vitamin A (beta-carotenoids)** - Eyesight and immune system
- **Vitamins B1, B2, B3, B6, B12** - Help turn food into energy, produce red blood cells, nervous system function
- **Vitamin C** – Immune system, brain
- **Vitamin D** – Bones, immune system
- **Vitamin E** – Prevents cell damage
- **Folate (Folic Acid)** – Heart health, prevents birth defects, produce new cells (esp. red blood cells)
- **Vitamin K –** Bones, blood clotting
- **Calcium** – Bones, muscle development, cell function
- **Chromium** – Regulates sugar
- **Copper** – Blood cells, bone health
- **Fluoride** – Bone health, dental health
- **Iodine** – Regulates hormones
- **Iron** - Carries oxygen through the body in red blood cells
- **Magnesium** – Muscles, nervous system, bones, heart health
- **Manganese** – Bone health, wound healing, process food
- **Molybdenum** – Processes protein
- **Phosphorus** - Cell function, bones
- **Potassium** – Nervous system, muscles, regulates water
- **Selenium** – Prevents cell damage
- **Zinc** – Immune system, reproductive health, nervous system

Three Types of Malnutrition

When we think of "malnutrition", we need to account for:

- Calorie Deprivation
- Protein Deficiency
- ***Micronutrient Deficiency***

Brainstorming

Symptoms of malnutrition

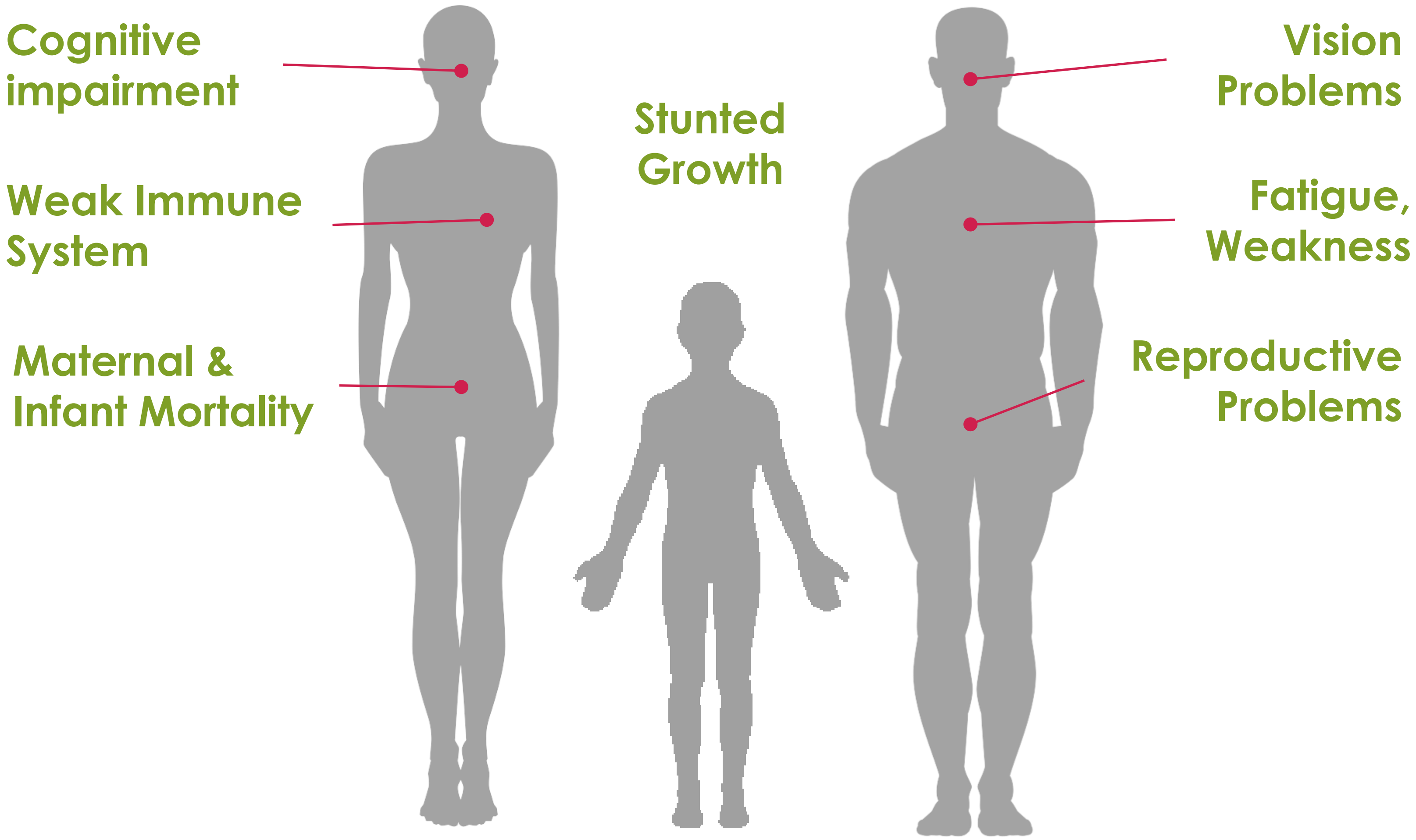
*What are the **visible** symptoms of micronutrient (vitamin/mineral) deficiency?*

3 m

"Hidden Hunger"

- Because micronutrient deficiency symptoms are less visible/obvious than macronutrient deficiency symptoms, micronutrient deficiency is called the **"Hidden Hunger"**
- Far more prevalent than calorie deprivation or protein
- Even mild deficiency, can have serious consequences:

Effects of Micronutrient Deficiency



Quick Survey

What percentage of the world's population are affected by micronutrient deficiencies?

2 m

Quick Survey

What percentage of the world's population are affected by micronutrient deficiencies?

Micronutrient deficiencies afflict more than **two billion individuals**, or **one in three people**, globally (FAO et al., 2015).

15 m

Economic Impact

Annual losses from micronutrient malnutrition (World Bank)

Country	Losses in GDP
Bangladesh	$700M
DRC	$100M
India	$12B
Nigeria	$1.5B
Pakistan	$3B
Rwanda	$50M
Tanzania	$289M
Uganda	$145M
Zambia	$186M

Brainstorming

Vulnerable Groups

What groups of people are most vulnerable to micronutrient malnutrition?

3 m

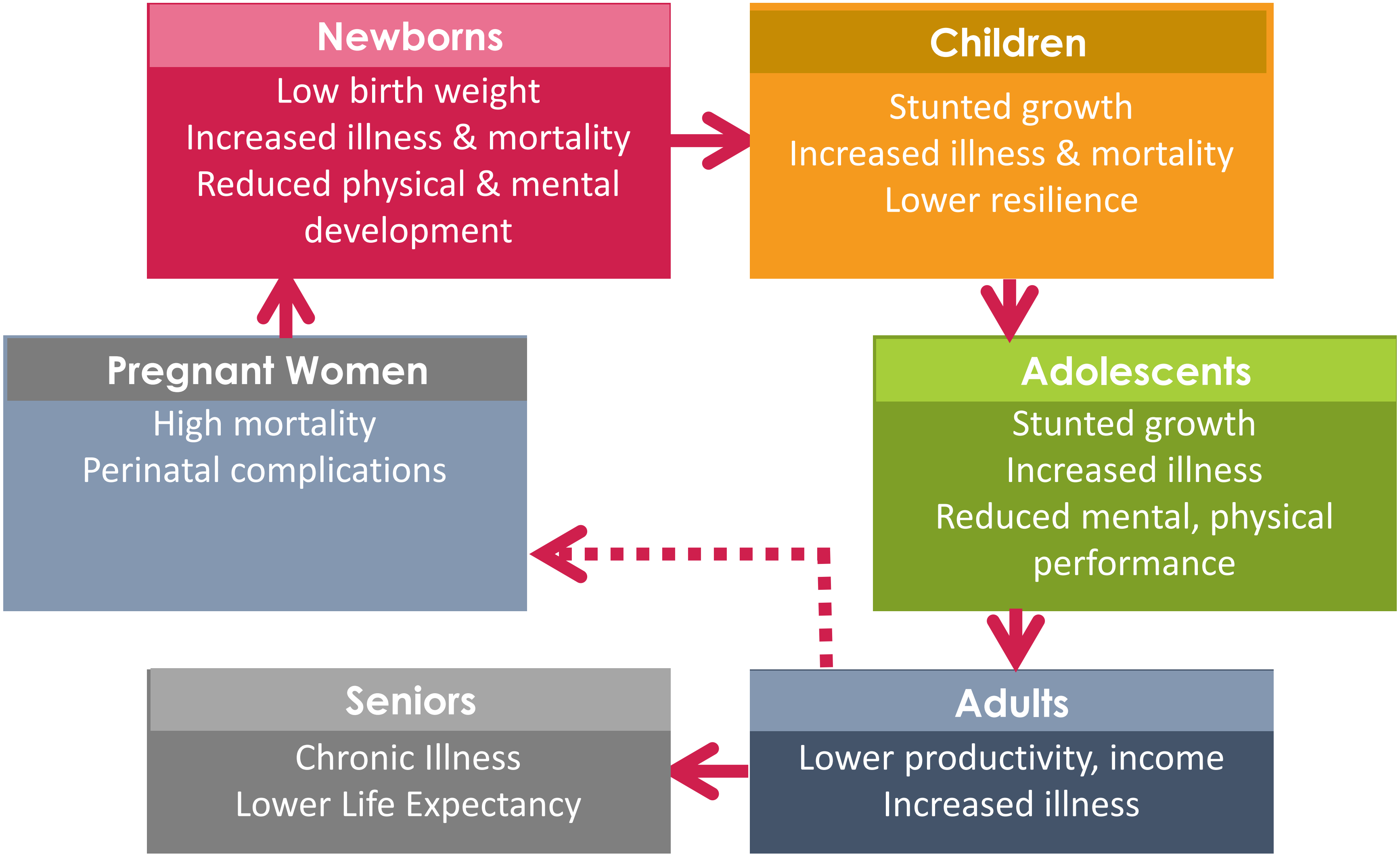
Vulnerable Groups

- Micronutrient deficiency is a health issue for everyone, but disproportionately affects
  - Low-income populations
  - Women of reproductive age
  - Infants and young children

Vulnerable Groups

- Micronutrient deficiencies in the early years of life can stunt growth and cause irreversible damage
- Pregnant and lactating women have much higher micro-nutrient needs than non-pregnant, non-lactating women and men

Hidden Hunger Across the Life Cycle



Quick Survey

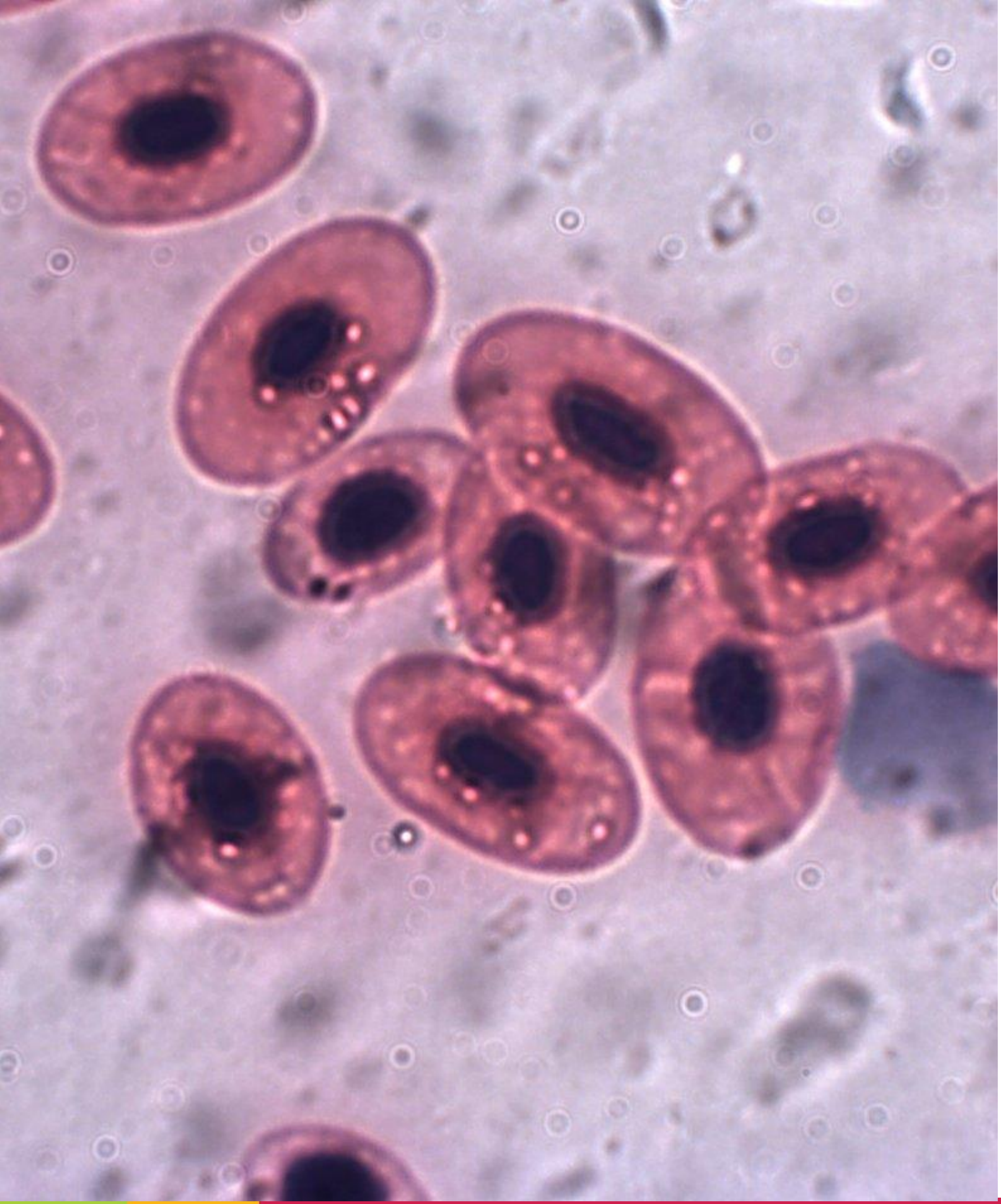
Which 4 micronutrients does the WHO consider to be of the highest public health importance?

2 m

Critical Micronutrients

The WHO considers four specific micronutrients as being of the highest public health importance:

- Iron
- Vitamin A
- Zinc
- Iodine



Iron

- Used throughout body, most critically in blood cells
- Without iron, blood cannot carry oxygen from lungs to other parts of the body
- Deficiency can result in fatigue and even death

Vitamin A

- Among other things, is used in various parts of the eye
- Without Vitamin A, eyes can become clouded, damaged
- Deficiency can result in poor night vision or even blindness

Zinc

- Used primarily by the body's immune and reproductive systems
- Deficiency results in stunted growth, hair loss, skin rashes, vulnerability to infections

Photo: Wikimedia / GNU

Iodine

- Used in body to regulate production of hormones
- Deficiency can result in enlarged thyroid gland (hyperthyroidism / goiter), cognitive impairment, birth defects

Photo: Superdove CC BY-NC-ND 2.0

Micronutrients and Public Health

The WHO has defined thresholds for when micronutrient deficiency becomes a major problem in a population

Micronutrient	Benefits	Threshold
Vitamin A (beta-carotenoids)	Eyesight and immune system	15%
Iron	Carries oxygen through body in red blood cells	20%
Zinc	Immune system, reproductive health, nervous system	25%
Iodine	Regulates hormones	20-50%

Discussion

Are you aware of any specific micronutrient deficiencies that impact public health among the communities you work with?

7 m

Quick Review

"Micronutrient deficiency" refers to a lack of:

A. Calories

B. Vitamins and minerals

C. Protein

D. Beneficial microbes in the digestive system

1 m

Quick Review

Micronutrient malnutrition is often called "hidden hunger" because...

A. Lack of micronutrients can cause people to lose their appetite
B. Many governments deny its existence
C. It is less prevalent, globally, than macronutrient malnutrition
D. Its symptoms are less obvious than those of macronutrient malnutrition

1 m

Quick Review

A healthy diet should include as many calories from ___________ as possible.

A. Whole-grain carbohydrates

B. Healthy fats and proteins

C. Vegetables

D. Sugar and honey

1 m

Quick Review

What are the four micronutrients that the WHO considers to be of the greatest public health importance?

A. Vitamin A, Iron, Zinc, Iodine
B. Vitamin A, Vitamin C, Iron, Zinc
C. Vitamin C, Zinc, Calcium, Iodine
D. Vitamin C, Calcium, Magnesium, Iodine

1 m

Quick Review

Alternate

- *What is the difference between "macronutrient" versus "micronutrient" malnutrition?*
- *Why is micronutrient malnutrition called "hidden hunger"?*
- *What micronutrients does the WHO consider most critical for human health?*
- *What are some of the consequences of hidden hunger?*

5 m

Biofortification: An Intervention for "Hidden Hunger"

Staples and Nutrition

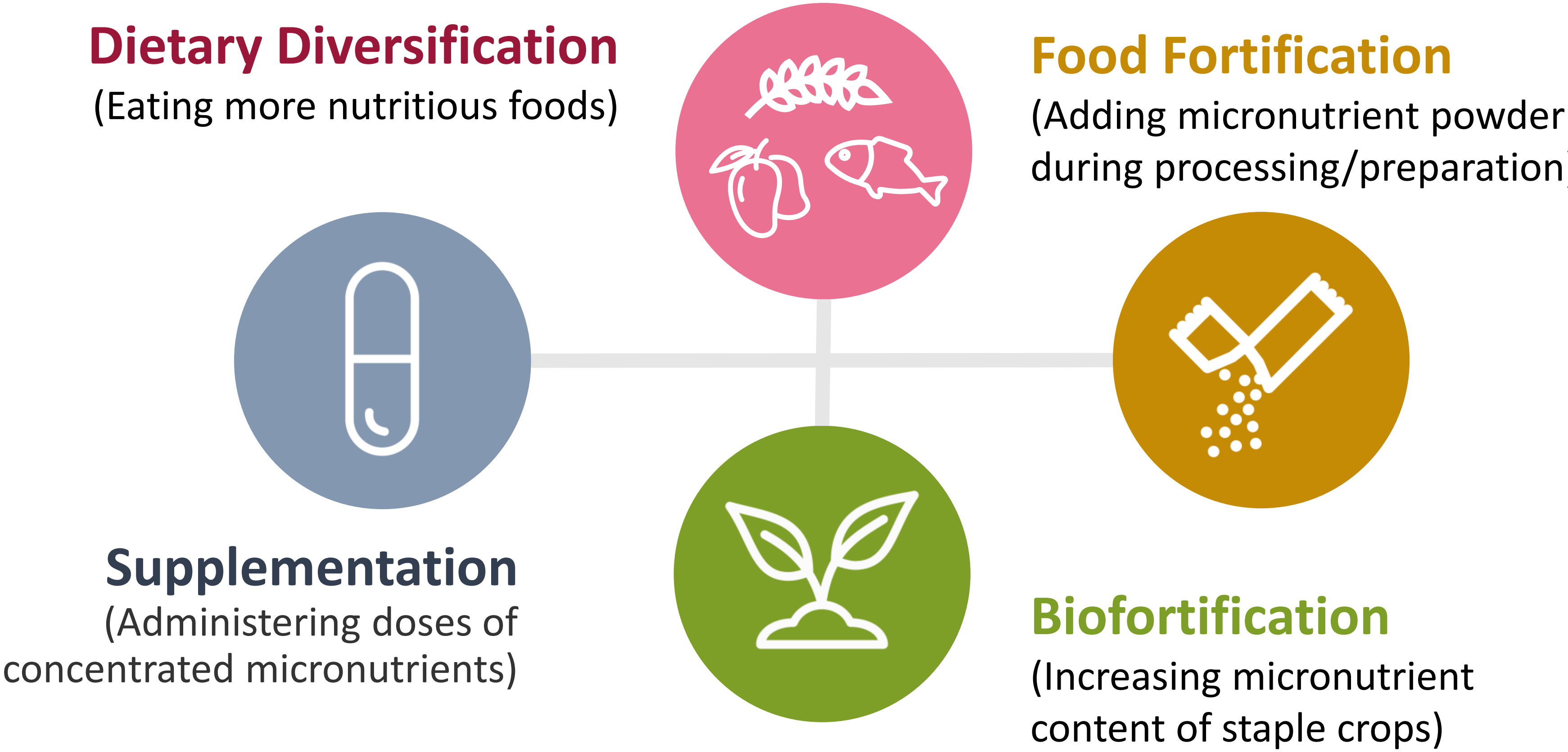
- Vulnerable populations get 60-70% of calories from staple crops
- Staples tend to be grains, high in carbohydrates / calories but lacking in important micronutrients

Discussion

What are some things that could be done to help vulnerable populations get more micronutrients?

5 m

Micronutrient Interventions



These interventions are most effective when used <u>together</u>

Dietary Diversification

- Natural sources of micronutrients are always ideal
- In some areas, nutritious foods available seasonally
- Education can raise awareness, consumption

Brainstorming

Sources of Micronutrients

What are some natural sources of micronutrients?

3 m

Sources of Micronutrients

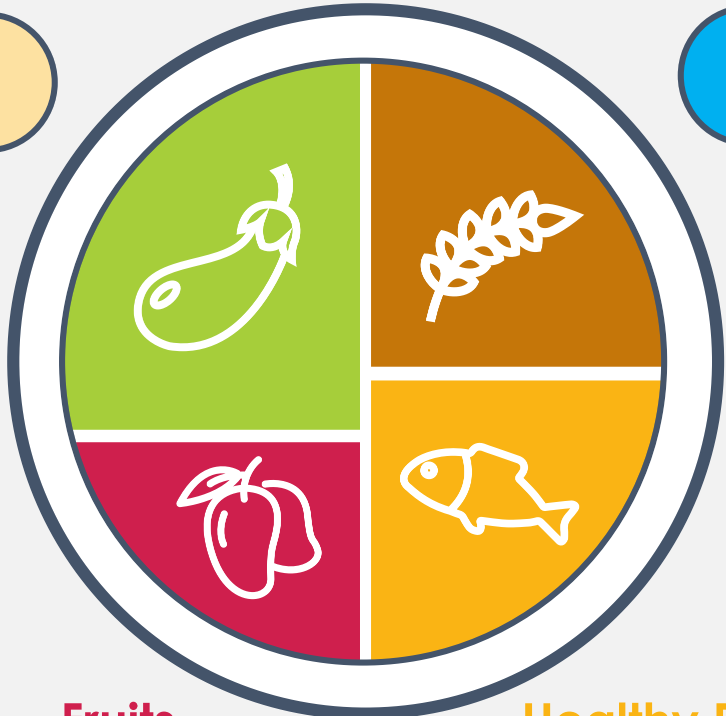
Major sources of micronutrients include:

- Animal products (meat, fish, dairy, eggs, liver and oil)
- Fruits & vegetables (esp. dark color)
- Nuts
- Legumes (beans, cowpea, pigeon pea, etc.)

What a Healthy Diet Looks Like

Use **HEALTHY OILS** (like olive and canola oil) for cooking, on salad, and at the table. Limit butter. Avoid trans fat.

Drink **WATER**, tea, or coffee (with little or no sugar). Limit milk/dairy (1-2z servings/day) and juice (1 small glass/day). Avoid sugary drinks.



Vegetables

The more veggies – and the greater the variety – the better. Potatoes and French fries don't count.

Whole Grains

Eat a variety of whole grains(like whole-wheat bread, whole-grain pasta, and brown rice). Limit refined grains (like white rice and white bread).

Fruits

Eat plenty of fruits of all colors.

Healthy Proteins

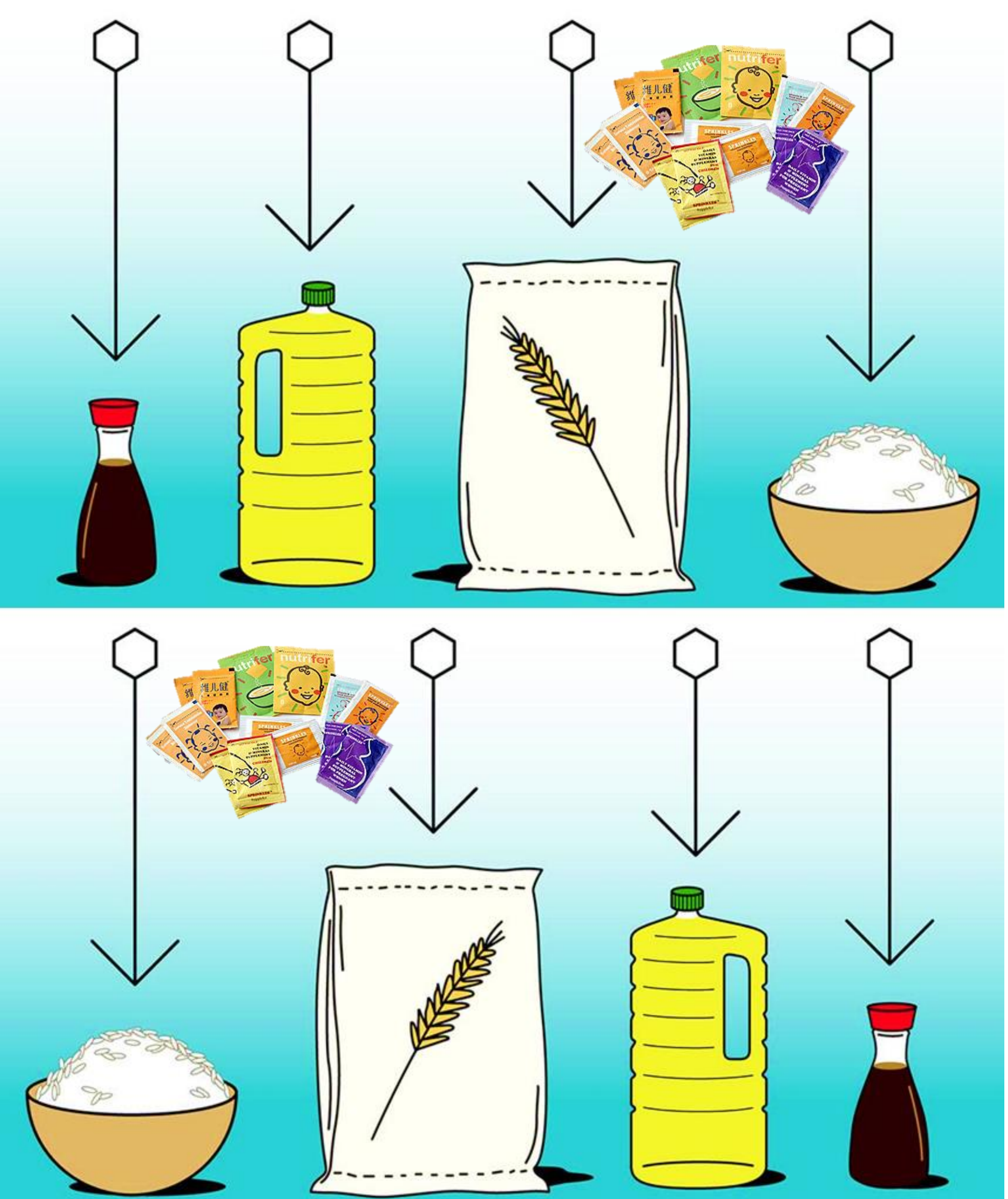
Eat fish, poultry, beans, and nuts; limit red meat and cheese; avoid bacon, cold cuts, and other processed meats.

Micronutrient Malnutrition

- Availability of nutritious non-staple foods (vegetables, pulses, meat, dairy) has not increased as much as staples
- Prices have increased significantly
- Availability often seasonal
- Rural, low-income populations often lack access

Supplementation

- Provide doses of highly concentrated vitamins and minerals
  - Capsules, tablets or injections
- Effective for young children esp. in first 2 years of life.
- Requires regular supply of supplements, which often cannot be sourced locally



Fortification

- Micronutrients added to food during processing (e.g., flour, rice, oils) or sprinkled on food before eating
- Micronutrient powders and oils sold at local markets, esp. in urban areas
- Vulnerable populations often lack access to processed foods, additives

The Challenge

- Staple crops are widely available, but deficient in micronutrients
- Supplements, additives, processed foods and nutritious non-staples are not available to many vulnerable populations

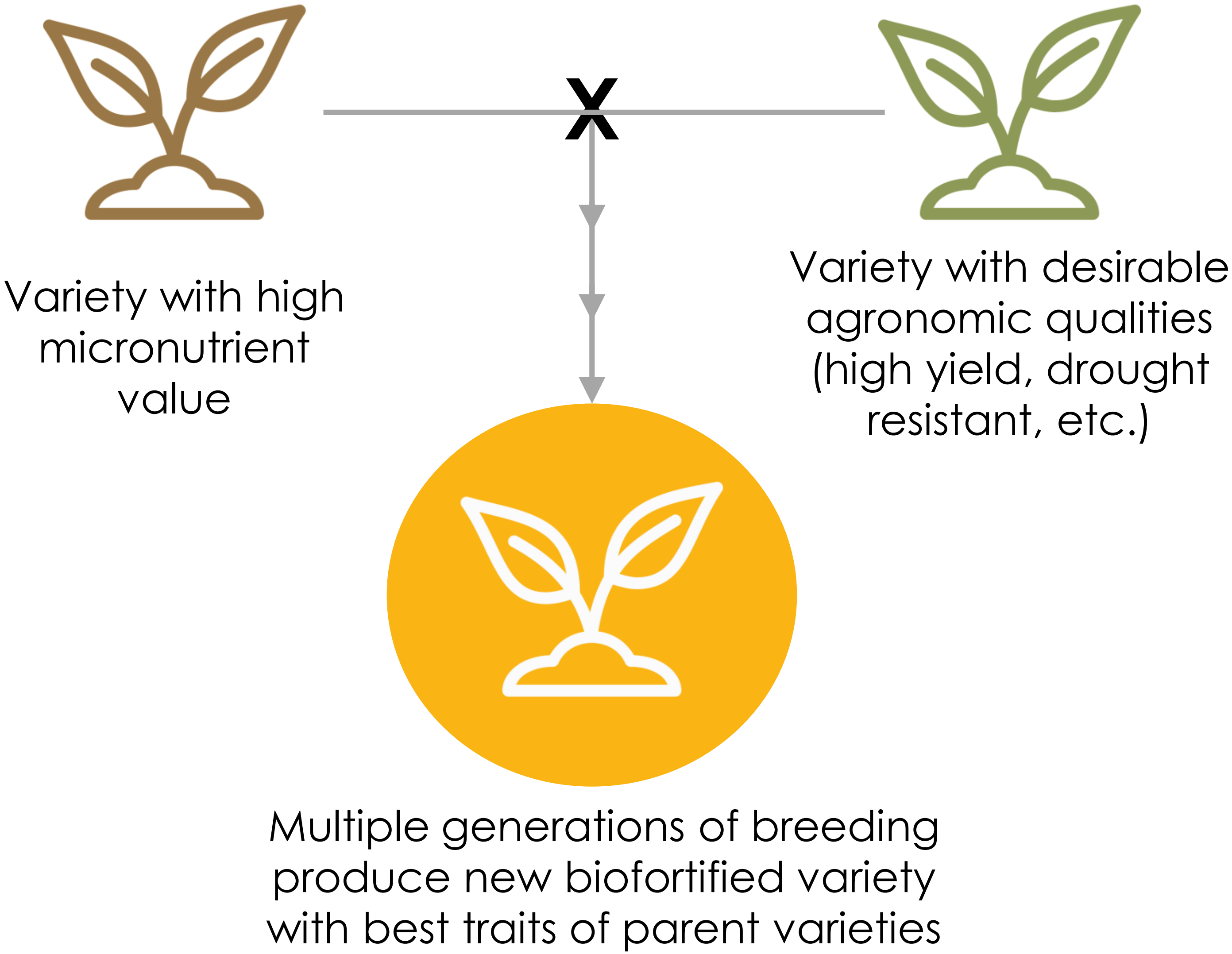
So…

- **Is it possible to make the staple crops that people *do* eat more nutritious?**

Biofortification

- Biofortification involves breeding new varieties of staple crops with higher micronutrient content
- Some traditional and wild varieties of certain staples have slightly higher micronutrient content
- **Selective breeding** can produce new varieties with **significantly** higher micronutrient content

Selective Breeding



Are Biofortified Crops GMOs?

Selective Breeding

- Plants allowed to reproduce naturally
- Traits are passed naturally from "parent" plants to offspring
- Breeders control which types of plants cross-breed with each other

GMO

- The DNA of a plant is modified artificially
- New traits are artificially added to plants, without any natural precedent

*All crops discussed in this course have been produced through **selective breeding** and are **not** GMOs.*

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Major Biofortified Crops

Zinc Rice
Up to 60% of daily zinc

Yellow Cassava
Up to 40% of daily vitamin A beta-carotenoids

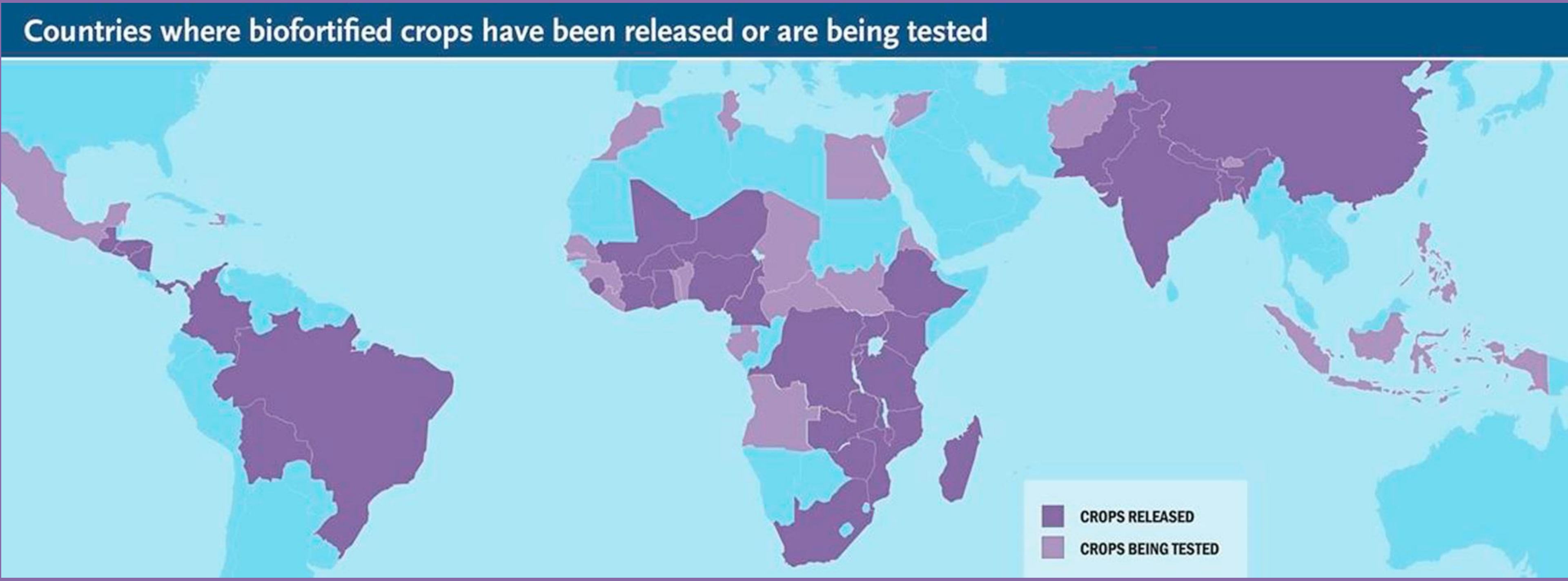
Iron Pearl Millet
Up to 80% of daily iron

High-Iron Beans
Up to 50% of daily iron

Orange-Fleshed Sweetpotato
Up to 100% of daily vitamin A (beta-carotenoids)

Zinc Wheat
Up to 50% of daily zinc

Pro-Vitamin A Maize
Up to 25% of daily vitamin A (beta-carotenoids)



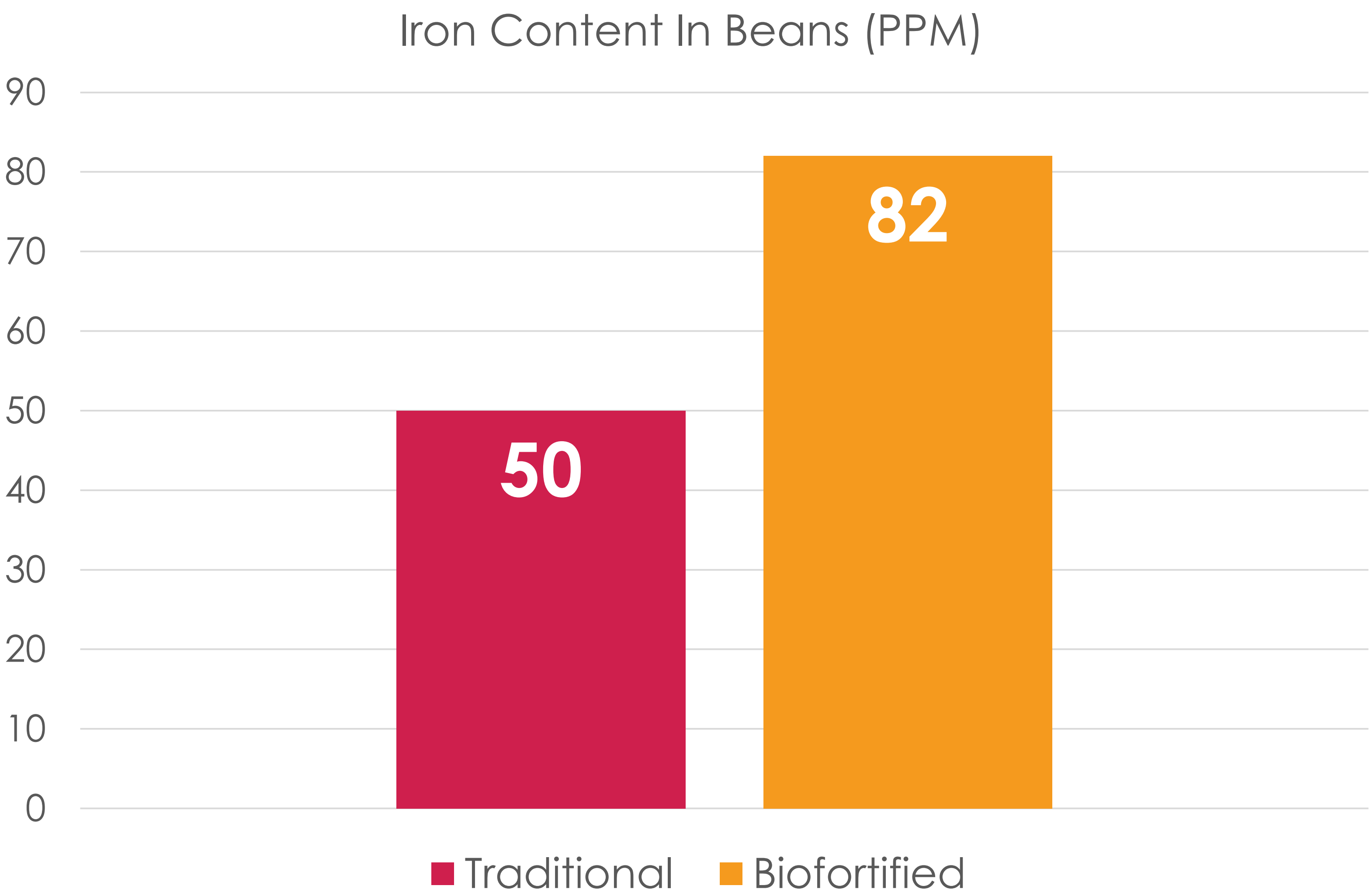
Biofortified Crop Distribution

Biofortified crops released in 30+ countries and currently being tested in 40+ countries

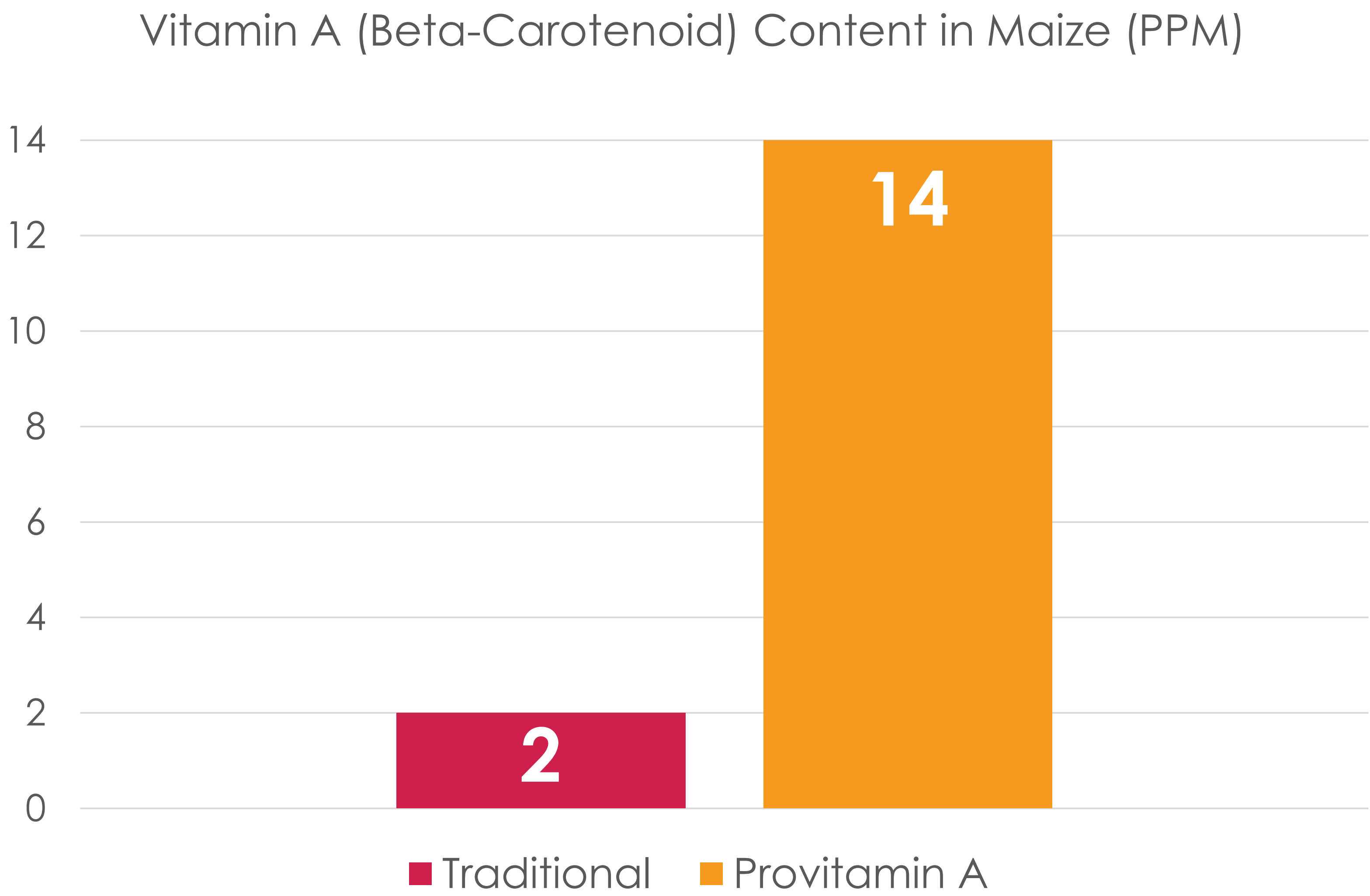
Biofortified Crop Distribution

	Hi-Iron Beans	Yellow Cassava	PVA Maize	Iron Millet	OFSP	Zinc Rice	Zinc Wheat
Bangladesh							
DRC							
India							
Latin America & Carribean							
Nigeria							
Pakistan							
Rwanda							
Tanzania							
Uganda							
Zambia							

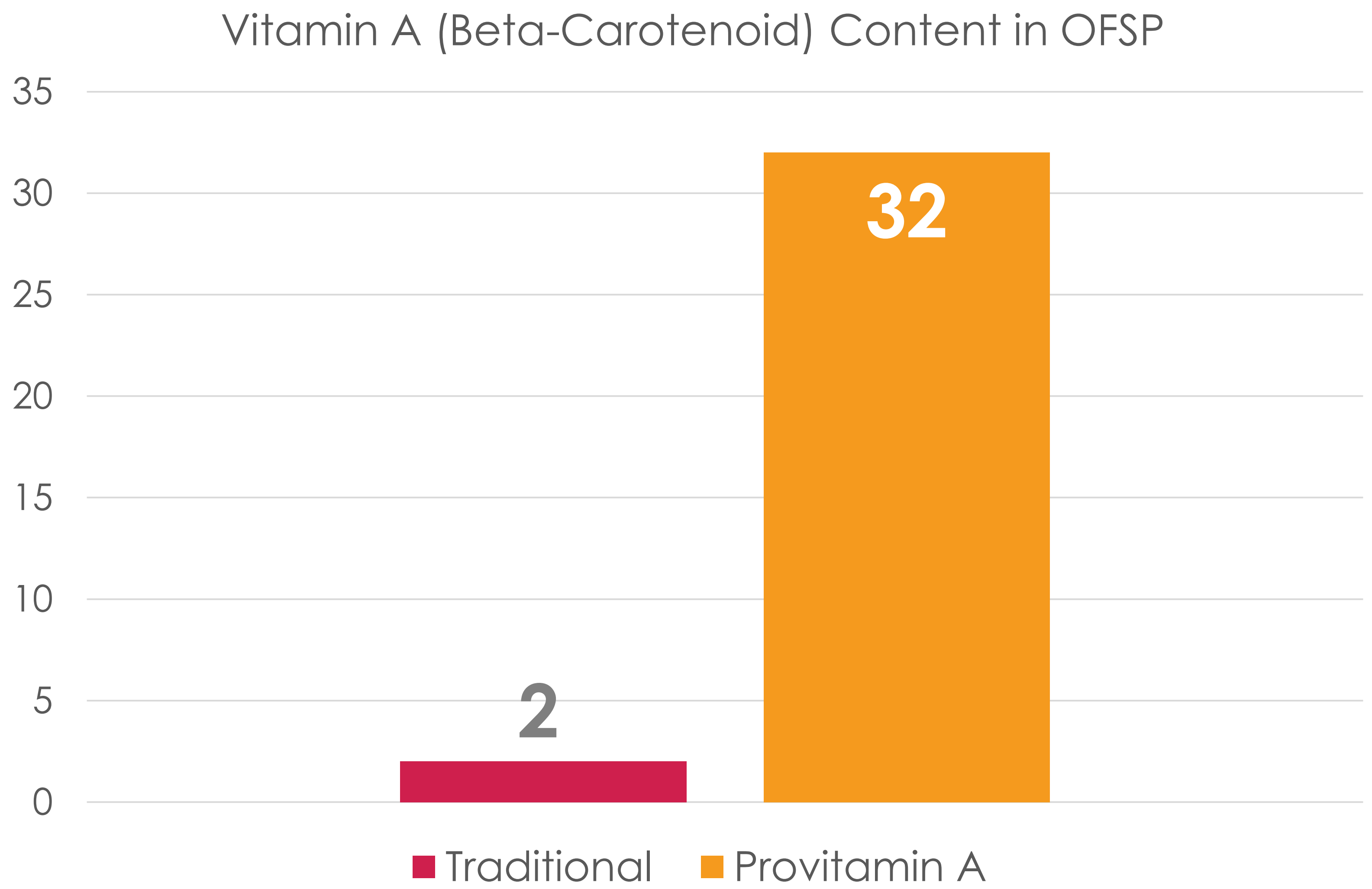
How much more nutrition?



How much more nutrition?

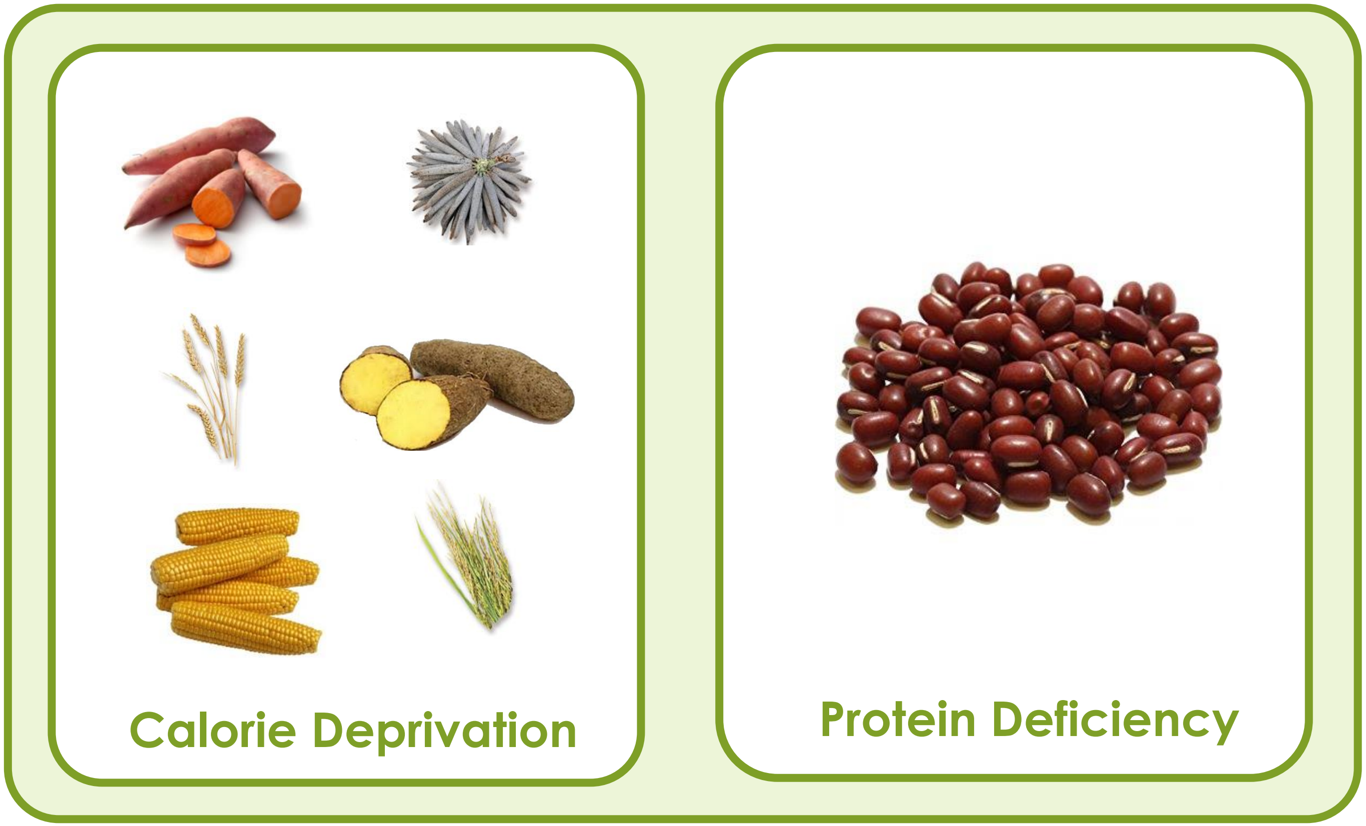


How much more nutrition?



“Food Basket” Approach

In combination, biofortified crops can address all dimensions of malnutrition.



Micronutrient Deficiency

Sustainability

- Once a biofortified staple is made available, farmers can cultivate it year over year at almost zero marginal cost.
- Goal is for biofortified crops to become fully integrated into food system and simply taken for granted
  - "Just crops"

Brainstorming

Comparing strategies

How is biofortification different from food fortification and supplementation?

How is biofortification different from dietary diversification?

What are some unique advantages of biofortification compared to other strategies?

7 m

Advantages of Biofortification

Biofortification’s primary advantages include:

- Focus on **staple crops** that poor people already cultivate and consume
- **Sustainability** and cost

Case Studies

- **Orange-Fleshed Sweetpotato** - Randomized controlled trial of 24,000 households in **Uganda** and **Mozambique** from 2006 to 2009
  - In Uganda, introduction of biofortified OFSP over four growing seasons resulted in significantly increased vitamin A (serum retinol) for children with low vitamin A at the beginning of the study
  - In Mozambique, consumption of biofortified OFSP by children under five significantly reduced likelihood of diarrhea, the second leading cause of death in this age group, by 39% and duration of diarrhea episodes reduced by more than 10%

Case Studies

- Study of **Provitamin A Maize** conducted in **Zambia** with 5–7-year-old children
  - After three months of consumption, total body stores of vitamin A increased significantly compared with those in the control group
  - Consumption of orange maize has been demonstrated to improve total body vitamin A stores as effectively as supplementation
  - Significantly improved visual function in marginally vitamin A deficient children

Case Studies

- **Iron pearl millet** proved effective in six-month study of adolescent children in rural Maharashtra, **India**.
  - For secondary school children who consumed iron pearl millet flat bread twice daily, iron deficiency was significantly reduced and serum ferritin and total body iron were significantly improved after only four months.
  - Children who were iron deficient at beginning were 64% more likely to resolve their deficiency by six months.
  - Improved cognitive performance and levels of physical activity

Return on Investment

- Development and distribution of orange-fleshed sweet potato in Uganda cost **$15-$20 USD per Disability Adjusted Life Year (DALY)** saved
  - This is considered highly cost-effective by World Bank standards

Return on Investment

- For every dollar invested in biofortification, up to **$17 USD** of benefits may be gained (from increased productivity, reduced illness, etc.)

COPENHAGEN CONSENSUS CENTER

Recognition for Biofortification

- Copenhagen Consensus, a panel of economists including multiple Nobel laureates, prioritized public health interventions
- For overall impact, biofortification ranked #5 out of 30 initiatives surveyed

Recognition for Biofortification

- 2016 World Food Prize awarded to developers of biofortified Orange-Fleshed Sweetpotato

- Howarth Bouls (IFPRI/HarvestPlus)
- Dr. Maria Andrade (CIP)
- Dr. Robert Mwanga (CIP)
- Dr. Jan Low (CIP)

Micronutrient Interventions

Supplementation
(Administering doses of concentrated micronutrients)

Food Fortification
(Adding micronutrient powder during processing/preparation)

Dietary Diversification
(eating more nutritious foods)

Biofortification
(increasing micronutrient content of staple crops)

These interventions are most effective when used <u>together</u>

Quick Review

Which of the following is NOT a common intervention for micronutrient malnutrition:

A. Supplementation
B. Food fortification
C. Nutrient substitution
D. Dietary diversification
E. Biofortification

1 m

Quick Review

Biofortification focuses on:

A. Eating a greater variety of nutritious foods, including animal products and non-staple crops
B. Giving concentrated doses of micronutrients in capsule or injection form
C. Adding micronutrient powders or liquids during processing/preparation
D. Breeding varieties of staple crops with higher micronutrient content
E. All of the above

1 m

Quick Review

The biofortified crops that we are studying in this course were produced by:

A. Genetic modification

B. Selective breeding

C. Adding special fertilizers to soil

D. All of the above

1 m

Quick Review

Which of these is **not** an actual biofortified crop?

A. Pro-vitamin A maize

B. Calcium wheat

C. High iron beans

D. Zinc rice

1 m

Quick Review

Alternate

- What are some common interventions for micronutrient malnutrition?
- What is biofortification?
- How is “biofortification” different from “food fortification”?
- Name some major crops for which biofortified varieties have been bred
- Are biofortified crops GMOs?

5 m

Discussion

We discussed the advantages… what challenges might we anticipate for popularizing biofortified crops as a solution for "hidden hunger" (micronutrient malnutrition)?

7 m

Major Questions

- Will a biofortified crop make an appreciable difference in a target population's health?
- Can we breed sufficiently micronutrient-rich varieties?
- Will local partners (governments, private companies) approve and support the crop?
- Will farmers grow the crop?
- Will consumers purchase and eat the crop?
- Can we achieve the necessary scale for a biofortified crop to become self-sustaining within local economies / food systems?
- How can we support biofortification through policy, business models, etc.?

Unit Objectives - Review

You should now be able to:

- List and describe the three types of malnutrition
- Define ‘hidden hunger’ and explain the importance of micronutrients for good health
- Identify natural sources of micronutrients
- List and describe common interventions for micronutrient deficiency
- Define ‘biofortification’
- Compare biofortification to other interventions and summarize its major advantages and challenges
- Differentiate between biofortified crops produced through selective breeding and GMOs

Unit 3

Iron Deficiency and High-Iron Beans

Unit Objectives

By the end of this unit, you should be able to:

- Summarise the effects of iron deficiency on human body
- Identify populations particularly vulnerable to iron deficiency
- Describe nutritional and agronomic characteristics of iron beans
- Distinguish between climbing and bush beans
- Explain key benefits of High Iron Beans
- Summarise key challenges with High Iron Beans adoption
- Define Biofortification Priority Index

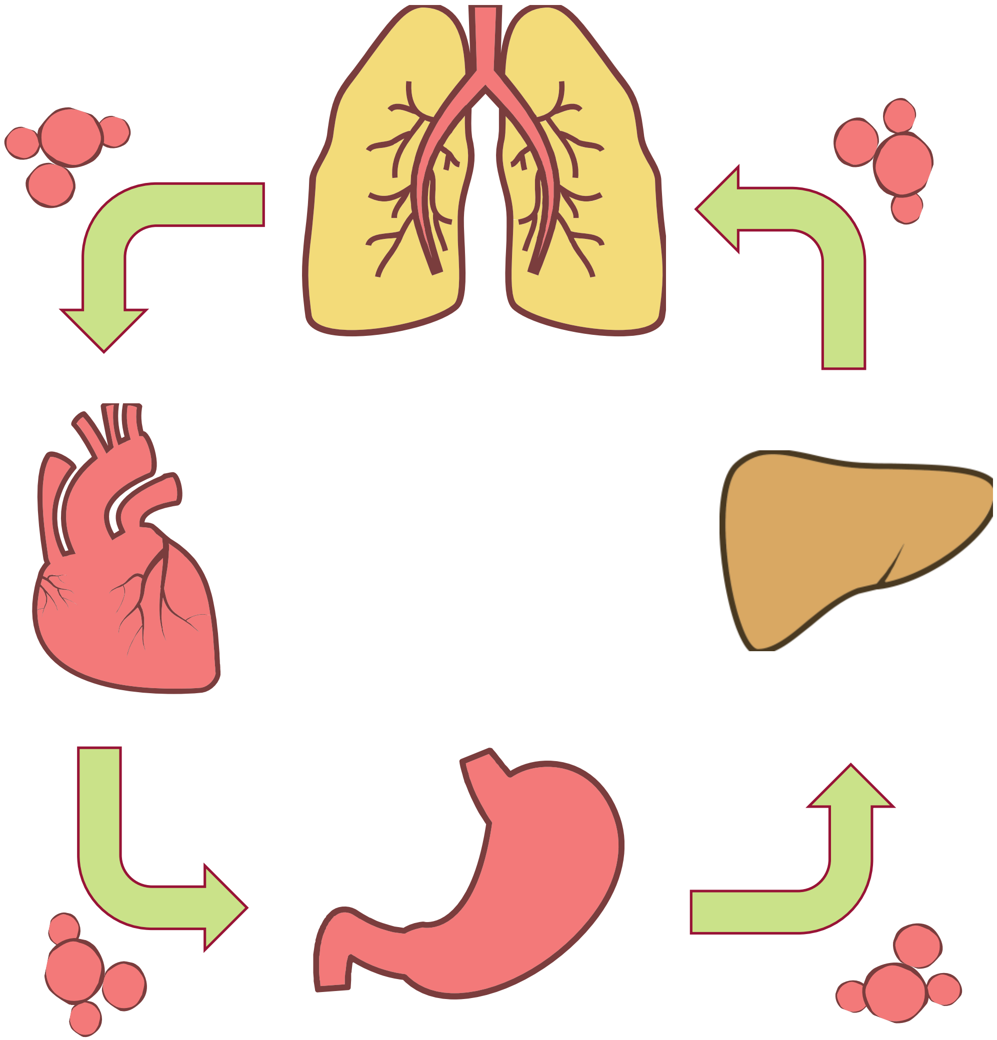
Iron Deficiency and Anemia

Iron Deficiency

- **Iron deficiency** is one of the most common micronutrient deficiencies in the world, affecting women, children, and infants most severely.
- Iron deficiency can cause **anemia**, where the body lacks red blood cells to carry oxygen from the lungs to other parts of the body

Iron, Oxygen and Anemia

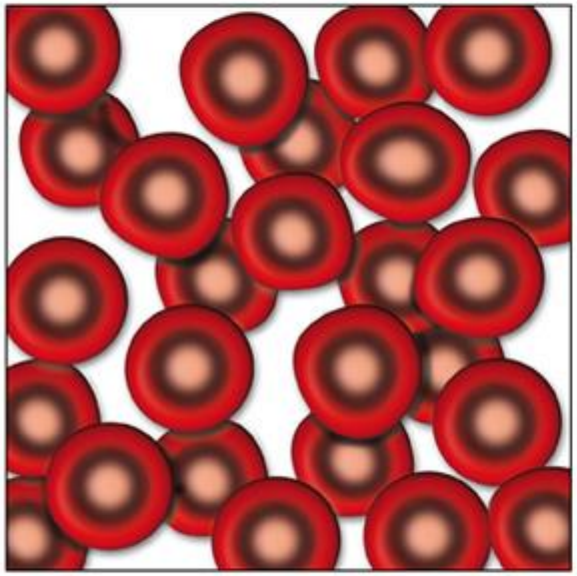
- Red cells (hemoglobin) in human blood carry oxygen from the lungs to other parts of the body that need oxygen to function
- Iron is a major component of hemoglobin



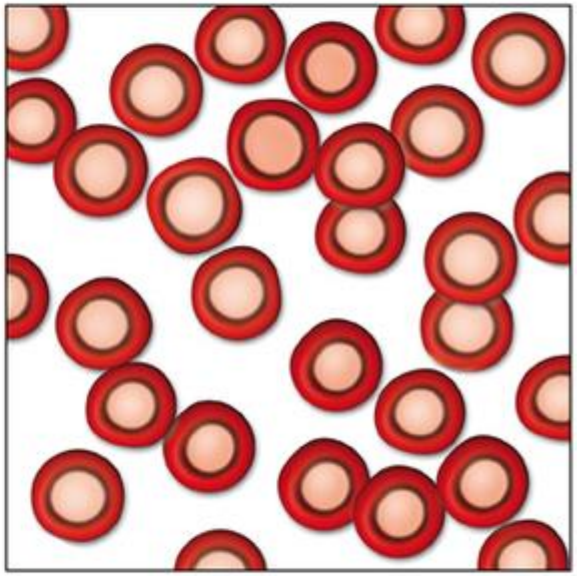
Iron, Oxygen and Anemia

- Without iron, fewer red blood cells are produced and those that exist have lower oxygen-carrying capacity
- For women, anemia is defined as <120g of hemoglobin per liter of blood

Healthy
(High Hemoglobin)



Anemic
(Low Hemoglobin)



Women and Children

- Anemia prevalent for women due to blood loss during childbirth, menstruation and generally increased requirement for iron
- Each year, **17,000 deaths** in women of reproductive age attributed to iron deficiency anemia
  - 70% occur in Africa

Women and Children

- Iron deficiency among children and women of child-bearing age is a public health problem in many countries
- In Tanzania, 58% of children under five and 40% of women of childbearing age suffer from anemia

Effects of Iron Deficiency

Common effects of iron deficiency include

- Decreased physical performance and physical activity,
- Decreased cognitive performance
- Depression
- Fatigue

"Pica" and Iron Deficiency

- Iron deficiency can cause abnormally strong cravings for specific foods or non-food items
- Likely cause of pregnancy-related food cravings
- Disorder of craving non-food items (clay, dirt, ice, paint, laundry starch) is known as "**pica**"

Discussion

Are iron deficiency and anemia a problem among the communities you work with?

Do people in these communities have traditional approaches to diagnosing and/or treating iron deficiency?

5 m

Quick Review

Iron is important to human health because:

A. It enables red blood cells to carry oxygen from the lungs to other organs in the body

B. Human bones consist primarily of iron

C. The majority of a person's daily calories should come from iron

D. A massive dose of iron can immunize a person against blood-borne diseases such as HIV

1 m

Quick Review

Women are especially vulnerable to anemia because…

A. It is caused by an excess of estrogen
B. Women tend not to like iron-rich foods, such as red meat
C. On average, a woman's body holds fewer liters of blood than a man's
D. They lose blood from menstruation and have increased iron requirements during pregnancy

1 m

Quick Review

Possible effects of iron deficiency include:

A. Increased risk of death (for women of reproductive age)
B. Decreased physical and cognitive performance
C. Depression and fatigue
D. Abnormal cravings
E. All of the above

1 m

Quick Review

Alternate

- *Why is iron so important for human health?*
- *Who is most affected by iron deficiency and why?*
- *What are some common effects/symptoms of iron deficiency?*

3 m

High Iron Beans (HIBs)

Beans and Biofortification

- **High Iron Beans** are a biofortified crop, which have been bred for higher iron content than traditional bean varieties
- Cheap, readily available source of iron
- Beans are traditionally eaten by many populations affected by iron deficiency, anemia

Why Beans?

- 400 million people eat beans as part of their regular diet
- Common bean is the most common food legume in Latin America and eastern and southern Africa
  - Per capita bean consumption in Tanzania is 19.3kg, contributing 16.9% of protein and 7.3% of calories

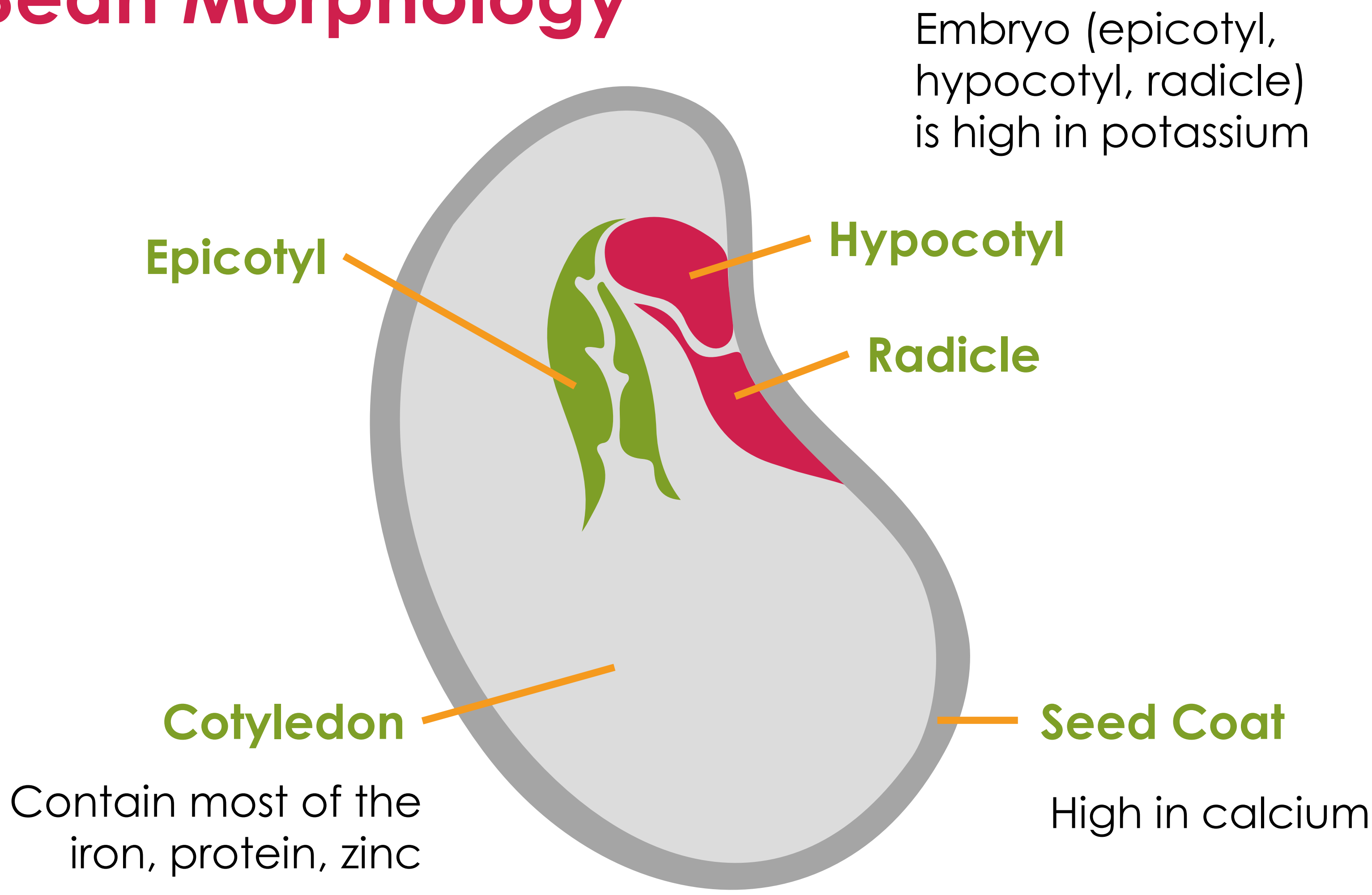
Bean Production in Africa

- Approx. 4,025,000 ha of beans planted annually in Africa
  - Eastern Africa accounts for 39% Southern Africa accounts for 32%.
- Production is primarily small scale, with little use of input (fertilizer, etc.)

Color and Appearance

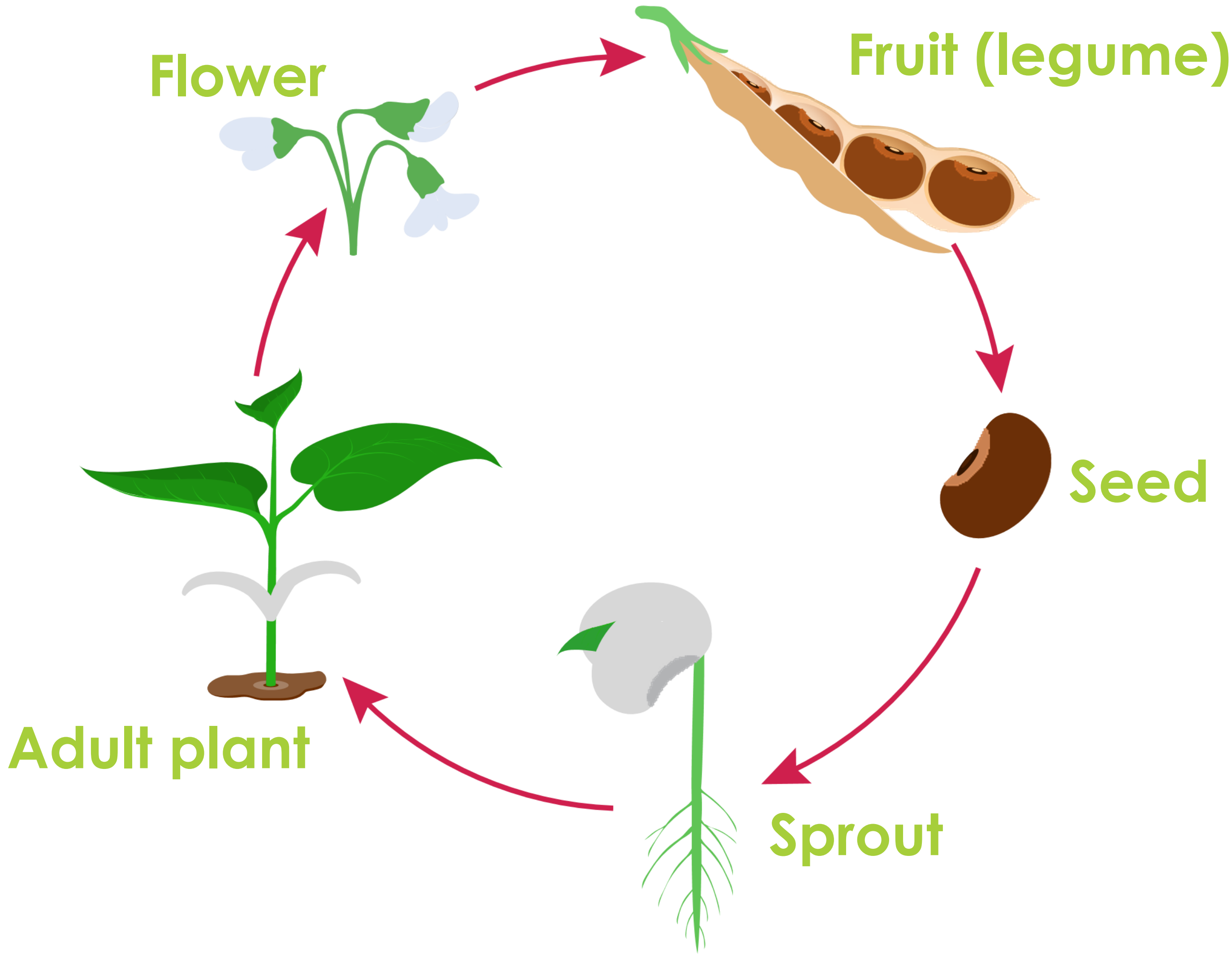
- Beans can be of various colors depending on the variety and the environment.

Bean Morphology



Bean seed (dicot)

Stages of Development



Nutritional Characteristics

- Natural source of protein, iron, and zinc, making it easier to breed varieties with even higher levels of these nutrients
- Iron from beans is easily absorbed by the body

Photo: Neil Palmer CIAT

Agronomic Characteristics

- Pest/disease/ drought resistant
- Can be rotated or inter-cropped with other crops
- Source of food, farmer income year-round
- High yield (1 to 2 t/ha)
- Requires little fertilizer

Bean Cultivation

- Beans perform well in various ecologies.
- Well adapted to intensification of land use through double cropping (often with maize)
- Can grow during dry season in low-lying areas with moisture
- Can grow in heavy soils in valley bottoms
  - Important as easier-worked soils on hill slopes become fully cultivated or decline in fertility
- HIBs bred to have superior agronomic qualities, but otherwise cultivation is no different than traditional bean varieties
- Visit Pan-African Bean Research Alliance (PABRA) website for information on agronomic best practices www.pabra-africa.org

Types of Beans

Two major types of beans:

- Bush beans
- Climbing beans

Bush Beans

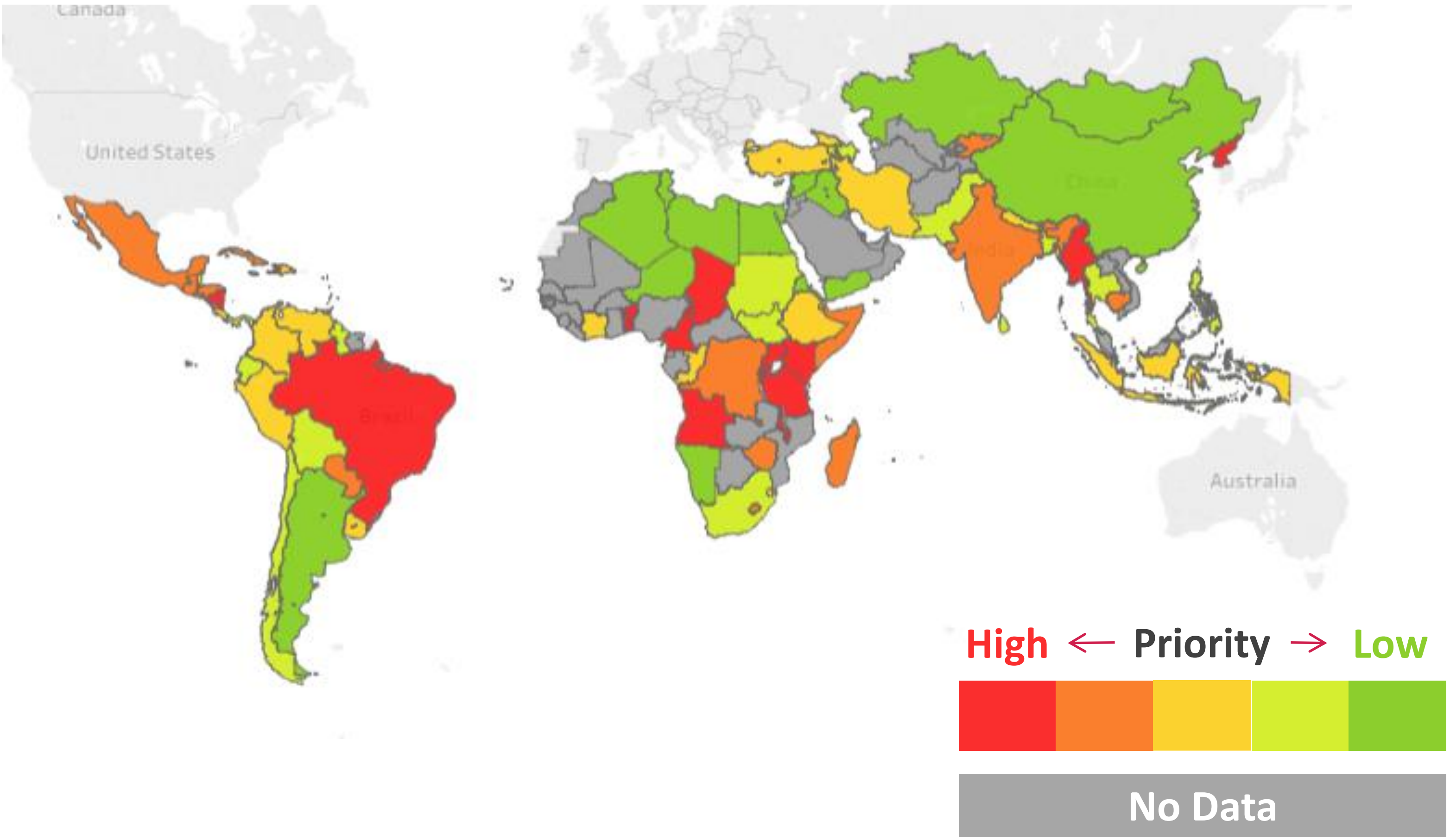
- Adapted for low to mid altitudes
- Each plant grows 1 to 2 feet in height
- Planted in rows

Climbing Beans

- Adapted to mid- to high-altitude areas
- Grows vertically on vine, higher yield with same acreage
- Increasingly popular due to land pressure
- Breeding of more biofortified climbing beans adapted to lower altitude / higher temperature is a priority

The Biofortification Priority Index (BPI)

Iron Beans



Live link: http://www.harvestplus.org/knowledge-market/BPI

Distribution of High-Iron Beans

High-Iron Bean varieties have been released in:

- Africa
  - DRC
  - Rwanda
  - Tanzania
  - Uganda
- Latin America & Caribbean
  - Bolivia
  - Brazil
  - Colombia
  - El Salvador
  - Guatemala
  - Haiti
  - Honduras
  - Nicaragua
  - Panama

Return on Investment

- HIBs are a highly cost-effective intervention for iron deficiency and anemia
  - Impact study in Rwanda found total cost of providing HIBs to a household (including development) is **$3**

Organizations Involved with HIBs

- Ministry of Agriculture
- Ministry of Health
- TFDA
- TNFC
- Tanzania Institute of Agricultural Research
- Selian Agricultural Research Insitute
- ARI-Uyole
- ARI-Maruku
- Local government Authorities
- CIAT
- Pan African Bean Research Alliance (PABRA),

Case Studies

- In Rwanda, iron-depleted university women showed significant increase in hemoglobin and total body iron after consuming biofortified beans for 4.5 months
  - Will review in detail later

Case Studies

- In Mexico, primary school children's iron status, cognitive performance, physical activity improved after consuming biofortified black beans for 3.5 months

Discussion

Are beans a common food staple for the populations you work with?

Do you see any particular opportunities or challenges for addressing iron deficiency and related public health issues with HIBs?

5 m

Major Questions

- Can High Iron Beans make an appreciable difference for populations affected by iron deficiency and anemia?
- Can we breed HIBs with sufficiently high iron content?
- Will local partners (governments, private companies) approve and support HIBs?
- Will farmers grow HIBs?
- Will consumers purchase and eat HIBs?
- Can we achieve the necessary scale for HIBs to become self-sustaining within local economies / food systems?
- How can we support the adoption of HIBs through policy, business models, etc.?

Quick Review

All of the following factors make High-Iron Beans an excellent crop for biofortification, except:

A. High yield
B. Naturally high levels of iron, zinc and other micronutrients
C. High cost
D. High per-capita consumption in many countries impacted by iron deficiency

1 m

Quick Review

The "Biofortification Priority Index" is a system for rating:

A. The suitability of certain crops for biofortification initiatives in certain countries
B. The levels of different vitamins and minerals in a biofortified crop
C. The amount of funding that local governments give to biofortification versus other interventions
D. The prevalence of biofortified crops as a percentage of all crops grown in a country

1 m

Quick Review

Cultivation of HIBs…

A. Requires more fertilizer than conventional varieties
B. Requires more land than conventional varieties
C. Is generally the same as cultivation of non-HIBs in terms of agronomic practices
D. Involves a completely different set of agronomic practices than cultivation of conventional varieties
E. Is only possible at lower altitudes

1 m

Quick Review

Alternate

- *What factors make beans a good crop for biofortification interventions?*
- *What is the "Biofortification Priority Index"?*
- *Name some of the countries where HIBs have already been released.*
- *How does cultivation of HIBs differ from cultivation of conventional bean varieties?*

5 m

Unit Objectives - Review

You should now be able to:

- Summarise the effects of iron deficiency on human body
- Identify populations particularly vulnerable to iron deficiency
- Describe nutritional and agronomic characteristics of iron beans
- Distinguish between climbing and bush beans
- Explain key benefits of High Iron Beans
- Summarise key challenges with High Iron Beans adoption
- Define Biofortification Priority Index

Unit 4

Breeding High-Iron Beans

Unit Objectives

By the end of this unit, you should be able to:

- List the factors nutritionists consider while setting micronutrient targets for biofortified crops
- Identify causes of micronutrient loss
- List the characteristics that farmers and consumers find desirable in bean varieties
- Outline the key steps of the breeding process and summarize what happens at each step

Breeding High-Iron Bean Varieties

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Discussion

What factors must nutritionists consider when they set micronutrient targets?

3 m

Setting Micronutrient Targets

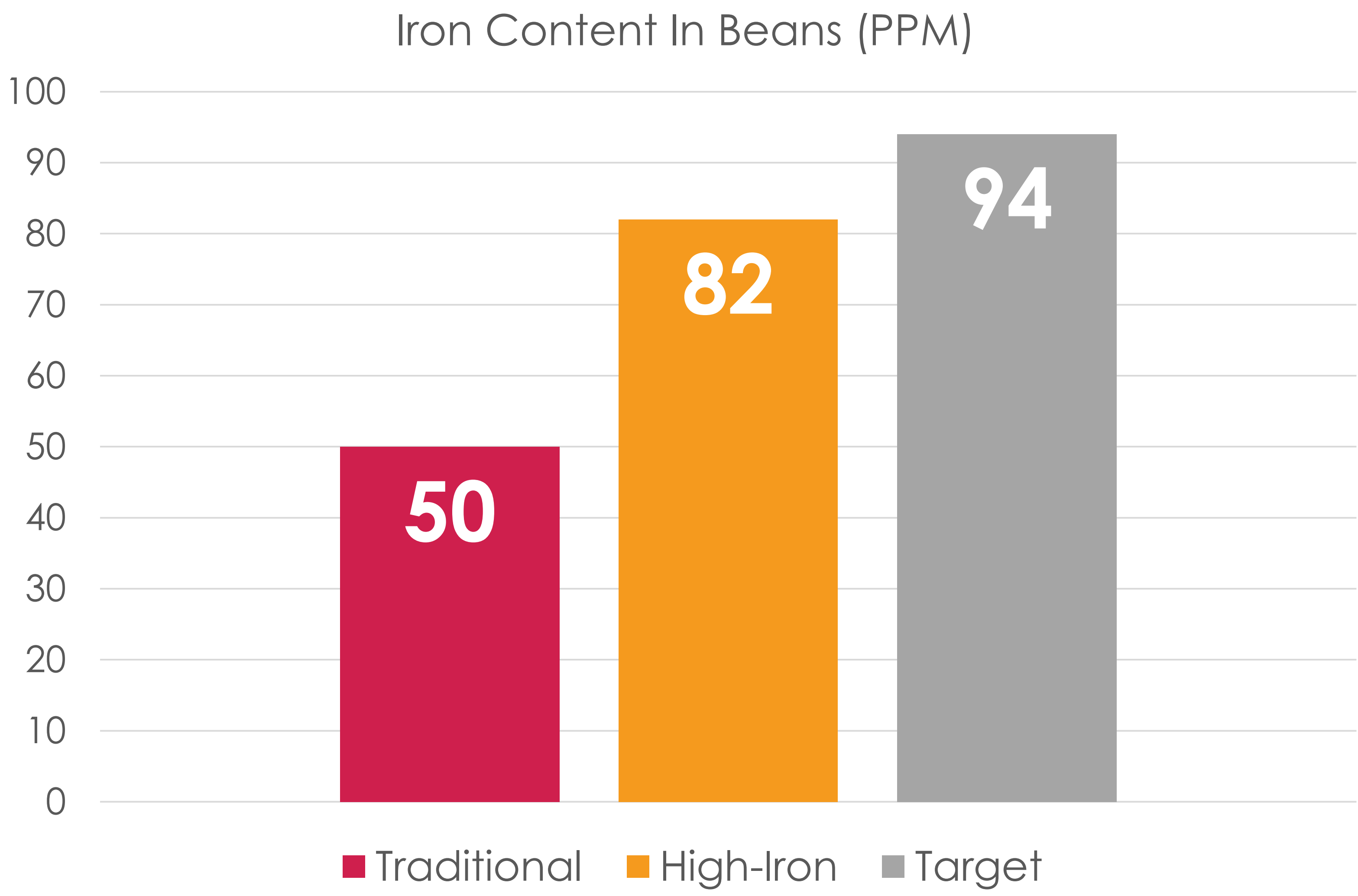
Nutritionists evaluate numerous factors

- Requirements for good health
- Ability of body to absorb ingested nutrients (bioconversion and bioavailability)
- Quantities of crop consumption by the target population

Targets by Population

- Target for iron beans set as **60% of Estimated Average Requirement (EAR)**
- Based on needs of preschool children 4–6 years old and non-pregnant, non-lactating women of reproductive age

How much more nutrition?



Discussion

Targets must also account for micronutrient losses over time. What might cause crops to lose their nutritional value?

7 m

Accounting for Losses

Targets must account for:

- Losses during storage and processing
- Losses from common methods of preparation

Quick Survey

Of the following methods for preparing beans, which do you imagine would retain the most iron?

- *Pressure-cooking w/o soaking in water*
- *Pan-frying w/o soaking in water*
- *Pressure-cooking after soaking*
- *Pan-frying after soaking*

2 m

Quick Survey

Of the following methods for preparing beans, which do you imagine would retain the most iron?

- *Pan-frying after soaking* ***98.2%***
- *Pan-frying w/o soaking in water* ***93.8%***
- *Pressure-cooking w/o soaking in water* ***92.3%***
- *Pressure-cooking after soaking* ***91.6%***

Discussion

Besides nutrition, what qualities of a crop might be important to farmers?

What qualities might be important to consumers?

5 m

Other Desirable Traits

Farmers

- High yield
- Early maturity
- Tolerance to pests and diseases
- Marketability
- Storage durability

Other Desirable Traits

Consumers

- Taste
- Texture
- Color/appearance
- Ease of preparation (cooking, peeling)
- Low flatulence
- Price

Photo: Neil Palmer CIAT CC BY-NC-SA 2.0

Discussion

Does it seem reasonable to expect breeders to produce bean varieties that meet nutritional targets while satisfying the demands of farmers and consumers? Do you expect there will be some compromise / trade-offs?

5 m

Quick Review

Nutritional targets for biofortified crops must account for:

A. Nutrients gained during processing and preparation
B. Supplementation and food fortification
C. Tolerance to pests and diseases
D. Nutrients lost during processing and preparation

1 m

Quick Review

Which of the following is true of “climbing” beans?

A. They require more land to produce the same yield as “bush” bean varieties

B. They are naturally adapted to higher altitudes, but are being bred for mid and low altitudes

C. They produce fewer beans per plant than bush bean varieties

D. They are declining in popularity as newer bush bean varieties are introduced

1 m

Quick Survey

Which agronomic quality do you think farmers in the communities you work with would find most important?

A. Yield
B. Disease/Pest Resistance
C. Storage Durability
D. Early Maturity

1 m

Quick Survey

Which quality do you think consumers in the communities you work with would find most important?

A. Taste
B. Cooking Time
C. Price
D. Nutrient Content

1 m

Quick Review

Alternate

- *What factors must nutritionists consider when they set micronutrient targets?*
- *What traits do farmers find desirable? Consumers?*
- *What differentiates "climbing" beans from "bush" beans?*

3 m

The Breeding Process

Breeding Biofortified Crops

Steps in process include:

1. **Screening existing varieties** for micronutrient content and agronomic traits
2. **Breeding new varieties** (crosses, selection) with best traits of "parent" varieties
3. **Laboratory testing** to measure micronutrient levels
4. At least 3 years of **field testing** to verify crop performance in the target environment
5. Submitting promising lines to **national partners** for further testing and release to farmers

Screening

- Researchers at CIAT screened samples of 36,000+ bean varieties from over 110 countries
- Initial screening found ranges of 30–110 ppm iron, with many exceeding the target level of 94 ppm
- Highest levels found in wild strains not immediately suitable for cultivation

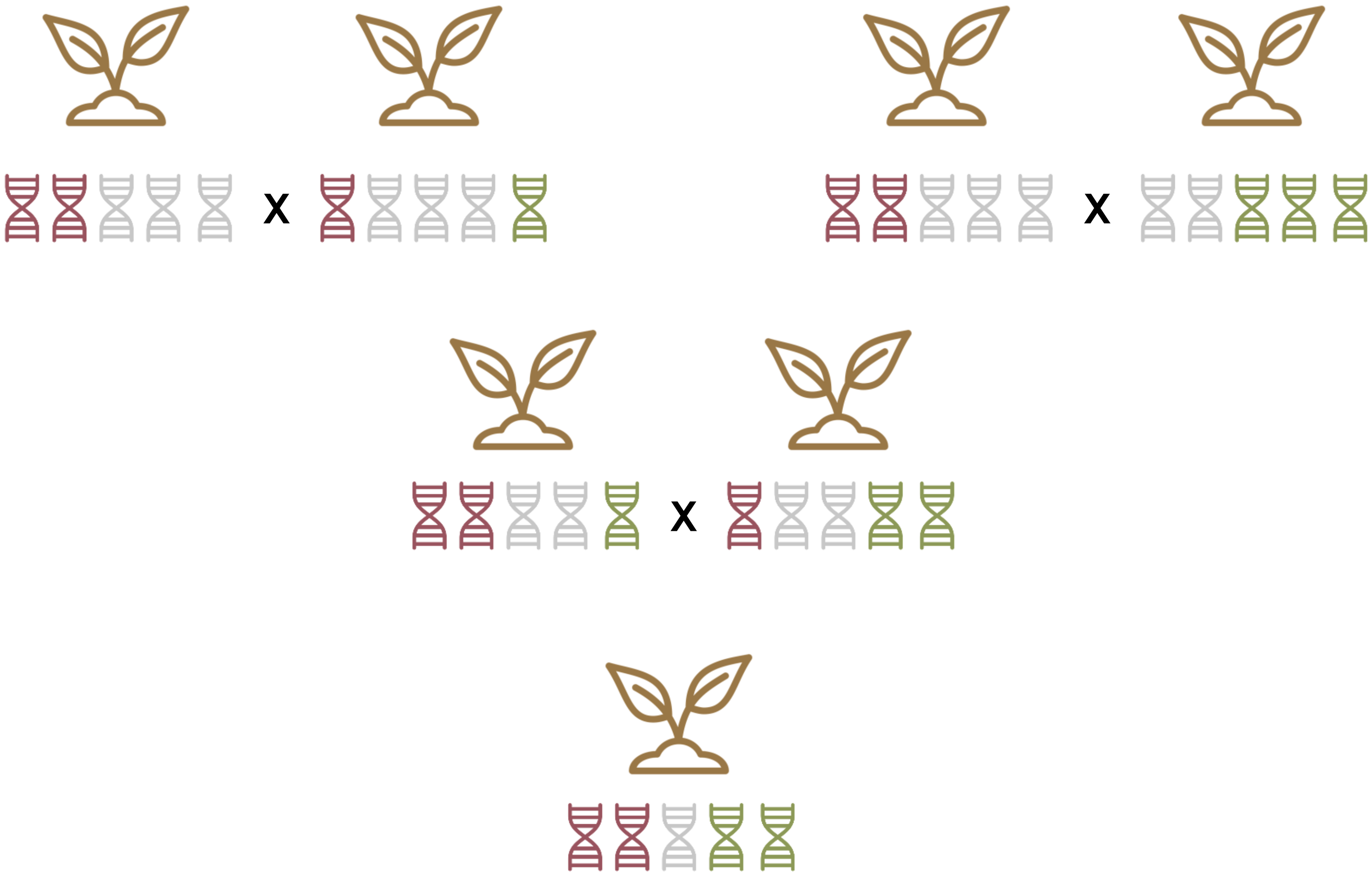
Case Study: CIAT Gene Bank

- CIAT gene bank in Colombia holds 37,987 bean samples as well as cassava and other legumes from 141 countries
- Provides seeds or plantlets free of charge to any individual or organization anywhere in the world for research or breeding

Breeding Parent Lines

- High-iron varieties are crossed with other bean varieties that have qualities desired by farmers and consumers
- Eventually, this produces "parent" lines that meet both agronomic and nutritional targets

Breeding for Desired Traits



Testing

- Developing biofortified crops requires many generations of cross-breeding
- Each generation must be tested to determine presence of desired traits, progress to nutritional goals

Laboratory Testing

- Thousands of samples tested each season to measure iron content of new varieties
- Breeders continually developing faster, more precise, higher-throughput tests to reduce time and cost of development

Field Testing

- Iron content of beans influenced by environmental factors such as soil and precipitation.
- New varieties tested in local farmers' fields

Field Testing

- Evaluated for yield, tolerance to pests and diseases, nutritional content, etc.
- Tested with/without fertilizer, irrigation
- Compared to the best local varieties

Participatory Appraisal

- During field testing, breeders consult farmers to confirm that crops meet agronomic needs
- Ideally, biofortified varieties perform as well or better than popular varieties, providing farmers incentive beyond nutritional value

Approval by National Partners

- Seeds of the best-performing varieties multiplied and offered to national governments
- Governments, private sector partners test varieties and, upon approval, make them available to farmers

Approval by National Partners

- New HIB varieties developed by CIAT, Selian Agricultural Research Institute being evaluated in several African and Latin American countries
- Rwanda Agriculture Board, DRC national agricultural institute (INERA) have developed varieties for local conditions

Brainstorming

National Partners

What are some concerns that national partners might have about biofortified crops like High-Iron Beans?

5 m

New Varieties for Tanzania

KATB9 / SELIAN 12

- Bush bean
- Qualities
  - Early maturing
  - Fast cooking
- Grows best at 1000m+ a.s.l

New Varieties for Tanzania

KATB1 / SELIAN 13

- Bush bean
- Early maturing
- Fast cooking
- Grows best at 1000m+ a.s.l

New Varieties for Tanzania

MAC44 / SELIAN 14

- Climbing bean
- Qualities
  - Resistant to Anthracnose and Bean Common Mosaic Virus
  - Yield >2t/ha
  - Fast cooking
  - High Iron and Zinc levels
- Grows best at 1300m+ a.s.l

New Varieties for Tanzania

RWV1129 / SELIAN 15

- Climbing bean
- Qualities
  - Resistant to Anthracnose and Bean Common Mosaic Virus
  - Yield >2t/ha
  - Fast cooking
  - High Iron and Zinc levels
- Grows best at 1300m+ a.s.l

Activity (Whole Class)

HIB Releases

- Review the sample release documents in your participant guide
- Based on what you read, which varieties do you think would be most appealing to the populations you work with? Might certain varieties be more appealing to different groups of farmers/consumers?
- Did any of the criteria covered in the release documents surprise you?
- Discuss as a class

30 m

Quick Survey

How long would you imagine it takes to develop a biofortified crop then get it out to the public?

2 m

Quick Survey

How long would you imagine it takes to develop a biofortified crop then get it out to the public?

Breeding process alone can take **3 to 8 years**, while overall process of breeding, testing and approval can take **6 to 10 years**

“Fast Tracking” Crops

During breeding process, varieties are developed that might not meet target, yet provided enough benefits versus traditional varieties to justify “fast-tracking” release to the public

HIB Releases

(Percent of target iron level)

1st Wave	2nd Wave	3rd Wave

60%	80%	100%
Rwanda 2010 – 4 releases DRC 2011 – 5 releases	Rwanda 2012 – 5 releases DRC 2013 – 5 releases Uganda 2016 – 5 releases	Releases in advance trials in multiple countries

Activity (Breakout Groups)

Explaining Biofortification

- Divide into groups
- As a group, decide how you would explain the biofortification process to a typical smallholder farmer or policymaker who might not be familiar with the strategy or the underlying science.
- The explanation must be less than 1 minute
- Be prepared to share your explanation with the class

You have 5 min to discuss in your groups

30 m

Quick Review

Which of the following steps in the breeding process happens first?

A. Screening Seeds

B. Field Testing

C. Laboratory Testing

D. Release to Partners

1 m

Quick Review

How long does it usually take to get a newly developed biofortified crop variety to market?

A. 6 months to a year

B. 1 to 3 years

C. 6 to 10 years

D. 10 to 15 years

1 m

Quick Review

"First wave" HIB varieties contained what percentage of the target iron levels?

A. 25%

B. 60%

C. 80%

D. 100%

1 m

Quick Review

Alternate

- *What are the steps in the breeding process?*
- *How long does it take for a biofortified crop variety to reach the market?*
- *What could be done to fast track biofortified crop varieties to market?*

3 m

Unit Objectives - Review

You should now be able to:

- List the factors nutritionists consider while setting micronutrient targets for biofortified crops
- Identify causes of micronutrient loss
- List the characteristics that farmers and consumers find desirable in bean varieties
- Outline the key steps of the breeding process and summarize what happens at each step

Unit 5

Fostering Demand for High-Iron Beans

Unit Objectives

By the end of this unit, you should be able to:

- Outline the steps for “scaling” and “anchoring” HIBs in local food systems
- List key activities for introducing a new crop
- Differentiate between different seed systems
- Explain advantages and disadvantages of self-pollinated crops (as they relate to biofortification)
- Summarise advantages of HIB for the farmers
- Summarise advantages of HIB for the consumers
- List some of challenges for HIB introduction and adoption

Steps to Achieve Scale

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Achieving Scale

- Once a biofortified crop becomes a regular part of local food system, supply will be self-sustaining
- This requires acceptance among farmers and consumers, support of private and public sector partners

Introducing Biofortified Crops

1. Variety release
2. Seed production and dissemination
3. Direct promotion to farmers, consumers
4. Farmer and consumer education
5. Engaging partners
6. Technical support and research

Variety Release

Variety Release

- Researchers work with governments, other stakeholders to breed biofortified staples for specific populations
- After breeders meet goals, government conducts additional review/testing
- Government manages release to public
- Researchers provide technical support

Seed Systems

Seed Systems

- **Seed systems** and strategies for introducing/scaling biofortified varieties vary by the type of crop
- Types of crops:
  - Vegetatively propagated
  - **Self-Pollinated**
  - Hybrid

Self-Pollinated

- Beans are a **self-pollinated** crop
- Seeds of self-pollinated crops usually have same traits as parent, and can be replanted year after year
- Farmers need to periodically replace seed to maintain quality, however replanting limits incentives for private sector seed companies

Self-Pollinated

- In many countries, absent commercial suppliers, public sector multiplies and distributes self-pollinated seed
- Informal farmer-to-farmer dissemination also common
- If sufficient demand is created, might spur private sector interest

Discussion

What are some of the advantages of self-pollinated crops?

What could be some of the disadvantages?

5 m

Self-Pollinated Crops

Advantages

- Farmers can replant seeds and share with one another
- Replanted HIB seeds will usually have the same high-iron trait as parents
- Cross-contamination of different varieties unlikely even when planted near each other (only 5% cross-pollination, mainly by insects)

Disadvantages

- Informal seed systems can lead to irregular supply
- Lack visible differences in seeds or mature plants can lead to misidentification between HIB and non-HIB seeds/crops
- In times of hardship or poor supply, farmers might compromise and plant low-quality seed
- Limited private sector interest

Strengthening Seed Systems

- Multiplication of sufficient, quality seed is first step
  - Without planting material, there will be no biofortified crops.
- Proponents help public sector and farmer networks to produce and distribute high quality seed

Discussion

Given all we have reviewed, what are some ways that our organization, partner organizations or farmers themselves could ensure access to high-quality bean seed?

5 m

Direct Promotion

- Integration into seed systems takes years
- Necessary to establish demand to attract public/private sector investment
- Biofortification proponents and partners promote crops directly to farmers and consumers during early stages of introduction

Discussion

During the initial introduction, what could be some of the ways to disseminate seeds?

What are the places/ channels we could use?

What would be the most effective in your area?

5 m

Dissemination of Seed

During initial introduction, seeds disseminated directly to farmers via:

- Local markets
- Schools
- Places of worship
- Health centers
- Extension workers

Case Study: High Iron Beans in Rwanda

Innovative programs for dissemination:

- "Payback system"
  - Farmers given free HIB seed on condition that they give back portion of grain after harvest
  - Helped to multiply planting material

Case Study: High Iron Beans in Rwanda

- "Seed swap"
  - Farmers trade in local seeds for iron rich HIB varieties
  - Gradually 'flush out' less nutritious varieties and replacing with iron rich ones.

Results

- Expectation is that, over time, high percentage of local beans supply will contain the biofortified trait
- Five years after the first release of HIBs in Rwanda, HIBs already made up >10% of bean production

Quick Review

In terms of reproduction/seed systems, beans can be described as what type of crop?

A. Vegetatively Propagated

B. Self-Pollinated

C. Hybrid

D. Bioengineered

1 m

Quick Review

Which of the following statements is true of self-pollinated crops?

A. Seeds can be replanted with little risk of losing desirable traits

B. Seeds must be purchased from suppliers every year

C. They are the most attractive crop type for private sector investment

D. All of the above

1 m

Quick Review

In the early stages of release, the most reliable strategy for driving farmer adoption of biofortified crops is:

A. Waiting for private sector companies to get involved

B. Allowing the government to take the lead

C. Developing consumer demand before engaging farmers

D. Promoting directly to farmers

1 m

Quick Review

Alternate

- *For biofortification to work as an intervention we need to obtain the buy-in/support of what groups?*
- *Are HIB self-pollinated, vegetatively propagated or hybrid crops?*
- *What are some advantages of self-pollinated crops?*
- *What are some of the channels for disseminating seeds?*

5 m

Promoting Farmer Adoption

Promotion to Farmers

- Farmers are key to biofortification
  - Often part of target population
  - After fulfilling household food needs, sell surplus to larger population via rural and urban retail outlets
- May hesitate to plant crop for which market has not been tested

Farmer Demand for HIBs

- Beans are already appreciated by farmers for a number of reasons
- Unique, desirable agronomic qualities
- Important source of income

Agronomic Characteristics

- Beans are resilient, high-yield crop
  - Resistant to pests and diseases
  - Tolerant to drought
  - High-yield (1 to 2 t/ha)
- Rotated with other crops to replenish soil
  - Beans replace nitrogen in soil that other crops consume, reducing need for fertilizers

Beans & Population

- Beans are important in places with high population density with tiny farms and few sources of dietary protein
- Produce high yields without requiring much land
- Good for intercropping, double cropping

“Bean Revolution”

- For 20+ years population has risen faster than bean production
- As farmers adopt new technology and better methods, bean production expected to increase to meet demand

Case Studies

- In the eastern African highlands, farm sizes have declined dramatically as population growth rates increased 2.5%-4% annually.
- In Rwanda, population density reaches 700 persons per cultivated km2
- 99% of Rwandan rural households grow beans, yet most are net purchasers
  - Only 22% of farms producing a surplus

Promotion to Farmers

- Nutritional benefits add additional value:
  - Benefits to farmer’s household from eating HIBs
  - Potential to use nutritional benefits to drive consumer demand for HIBs

Demonstrations

Demonstration trials have been key to adoption:

- Local field demonstrations allow farmers to study crops firsthand
- Small promotional seed packs allow farmers to try new variety with minimal risk

Beans and Livelihoods

- Important source of income for smallholder farmers
  - 12 million metric tons of beans produced globally each year
  - Bean sales exceed US$500 million a year
  - US$110 million a year export trade
  - Beans have generated US$200 million for more than 5.3 million rural households over 17 years
- Provides marketable product at critical times when farmers have nothing else to sell such as before the maize crop is harvested

Private Sector Demand

- HIBS can be used in various commercial products:
  - Canned beans
  - Pre-cooked beans
  - Bean flour
  - Other processed foods products
- Generating demand among processors ensures robust market for surplus grown by farmers

Photo: PABRA

Activity (Breakout Groups)

Promoting to Farmers

- Divide into groups
- Each group is to prepare a 2-min presentation to a group of farmers to explain the advantages of planting biofortified crop (can be any biofortified crop – we are just talking about generalities, not specifics of any one crop)
- **You have 10 minutes**
- Once complete, groups will deliver their explanation. Facilitator will play the role of a farmer, and group should be ready to address the farmer's concerns.

40 m

Case Study: Rwanda Impact Assessment

HIBs in Rwanda

- HIBs introduced in Rwanda between 2010 and 2012.
- A 2015 impact assessment of 20,000 farm households found:
  - 93% were bean growers
  - 65% were aware of HIBs
  - 29% had planted HIBs

HIBs in Rwanda

- 41% of adopters obtained first HIB planting material from the local market
  - Includes direct marketing efforts during initial introduction
- 33% obtained from social networks (incl. farmers' groups)
- 7% obtained from the Ministry of Agriculture or an extension agent

HIB Adoption

- Extrapolating results of survey to entire population of Rwanda, an estimated 500,000 households obtained HIB planting material through “official” delivery channels.
- Substantial unrecorded informal diffusion is also believed to have taken place (estimated at another 200,000 households)

Farmer Survey

2012 survey of first HIB adopters found:

- Farmers liked the agronomic and consumption qualities of HIBs as much or more than popular varieties.
- Primary reason for adopting HIBs was the improved yield potential of HIB varieties

Farmer Survey

- 80% planned to plant HIBs again
  - 85% of those planned to allocate larger area to HIBs
- 50%+ recommended HIBs to others
- 25% had given HIB grains to others
- 80% of beans produced were consumed within household

Coverage

- On average, farmers allocated less than half (**48%**) of their bean area to HIBs in their first season
- Average HIB coverage increased to **70%** by the sixth season

Discussion

What conclusions might we draw from the Rwanda impact assessment and farmer feedback survey?

5 m

Quick Review

For farmers, desirable qualities of beans include:

A. Good for intercropping

B. Replace nitrogen in soil

C. High yield per hectare

D. All of the above

E. B and C

1 m

Quick Review

Beans are an important crop in areas with:

A. High population density
B. Seed systems dominated by private-sector companies
C. High average income
D. Large farm sizes

1 m

Quick Review

According to the impact study, the majority of HIBs grown in Rwanda were:

A. Exported to other countries

B. Eaten by farmers and their families

C. Fed to livestock

D. Sold to local processing plants

1 m

Quick Review

Alternate

- *Why could farmers be hesitant to plant biofortified crops?*
- *What are the advantages of HIB from the farmers perspective?*
- *Are beans typically a cash crop for smallholder farmers in countries like Rwanda and Tanzania?*

3 m

Promoting Consumer Demand

Consumer Demand

- Biofortification cannot counter deficiencies unless consumers regularly purchase and eat biofortified foods
- Consumer acceptance research focuses on:
  - Sensory evaluation
  - Willingness to pay

Market for HIBs

- Status of beans as market vs. subsistence crop varies regionally:
  - In densely populated areas of Rwanda, Burundi <20% marketed
  - In the Rift Valley of Ethiopia, over 90% marketed
  - Even in areas with low market %, farmers still care about consumer preferences

Photo: Neil Palmer CIAT CC BY-NC-SA 2.0

Discussion

When consumers go to the market, how do they select beans?

What kind of characteristics or qualities are they looking for when evaluating beans?

3 m

Sensory Evaluation

- Testing is done with consumers to ensure new varieties are marketable
- Evaluate
  - Raw bean dryness
  - Color
  - Raw & cooked bean size
  - Taste
  - Ease of breaking

Activity (Whole Class)

HIB Sensory Test

- Participants should examine the samples of biofortified and conventional bean varieties
- Could you detect any obvious differences?

15 m

“Invisible” Minerals

- Where other biofortified crops might be visibly distinct from conventional varieties, HIBs look and taste the same as conventional varieties
- Lack of visible differences presents challenge for fostering consumer appreciation and demand for HIBs

Driving Demand

- While high-iron quality is not detectable, most HIB varieties bred for superior sensory qualities
- Labeling and education on nutritional benefit can boost demand

Case Study: Willingness to Pay

- Study in Tanzania gauged consumers willingness to pay a premium for beans with higher iron levels
- 93% willing to pay 40% more
- 60% willing to pay 66% more
- 26% willing to over 100% more

Quick Survey

How much more (as a percentage) were consumers in the Tanzania survey willing to pay for HIBs versus conventional varieties?

2 m

Quick Survey

How much more (as a percentage) were consumers in the Tanzania survey willing to pay for HIBs versus conventional varieties?

On average, survey participants were willing to pay up to **25% more** for high-iron beans. In most countries where they have been released, the actual cost of HIB varieties is typically only 10% higher than conventional varieties.

15 m

Activity (Whole Class)

Tanzania Consumer Survey

- Review the data from the Tanzania consumer survey n your participant guide
- What were some of the key findings/trends related to:
  - Purchasing/consumption habits
  - Preferences
  - Beliefs about beans and nutrition
  - Willingness to pay
- Did any of the feedback surprise you?
- Discuss as a class

20 m

Case Study: Rwanda Survey

- Survey of 1150 rural and 659 urban consumers in Rwanda showed, even without nutritional information, consumers preferred HIB varieties over popular local varieties
- Rural consumers also appreciated reduced cooking time, improved overnight keeping quality

Case Study: : Rwanda Survey

- Providing nutrition information had positive effect on consumers' willingness to pay a premium for HIBs
- Similar research in Guatemala with 360 rural consumers also found preference for HIBs based on sensory attributes

Brainstorming

Nutrition Messaging

What do you think might be some effective methods for delivering nutrition information about biofortified crops?

Which members of a community should we target, specifically?

How much of an impact would you expect nutrition messaging to make on farmer adoption and consumer acceptance?

5 m

Media

Nutrition information can be delivered via:

- TV
- Radio
- Social marketing
- Public media
- Newspapers
- Face-to-face promotion

Women as Farmers & Consumers

- Women primarily responsible for decisions and labour in smallholder bean production in most sub-Saharan countries
- Women in Tanzania consistently more involved in bean production and marketing than with maize

Women and Agronomy

- Male heads of households tend to allocate fertilizer to other crops, leaving women with less fertilizer for bean production
- Women prioritize varieties with low fertilizer requirements

Women as Consumers

- Beans have a long cooking time (up to 3 hours)
- 1 kg of beans requires 7 kg of firewood, which women are responsible for gathering
- Women prefer varieties with short cooking times and long retention of flavour after cooking

Activity (Breakout Groups)

Developing Messages

- Divide into groups
- Design one of the following for HIB for a specific audience (farmers, consumers, women, families):
  - 30 to 60-second “radio” message
  - One-page pamphlet
  - Series of three SMS messages
- **You have 10 minutes**
- Share your message with the class

30 m

Challenges

Labeling and Misidentification

- Package labeling critical as HIBs visually identical to conventional varieties
- Misidentification is a problem, since HIBs look same as traditional varieties
- 19% of farmers surveyed in Rwanda misidentified traditional varieties as HIBs

Labeling and Misidentification

- HIB varieties are often called by names different from their official designation
- Rwandan study found an average of 48 different names for each of the ten HIB varieties, with 136 names for the most popular HIB, RWR2245

Activity (Breakout Groups)

Labeling

- Divide into groups
- Each group should design a label for HIB
  - Convey essential information for consumers as succinctly as possible
  - Give sense of benefits
  - Include an appropriate, distinctive symbol
- **You have 10 minutes**
- Share your results with the group

30 m

Quick Review

All of the following can help drive consumer demand for HIBs except:

A. Breeding HIBs for superior taste and sensory qualities
B. Educating consumers on the nutritional benefits of HIBs
C. Training consumers to distinguish HIB varieties from conventional varieties
D. Clearly labeling HIBs

1 m

Quick Review

Women are an important market for HIBs because:

A. Women typically control bean production in Sub-Saharan Africa

B. They are responsible for cooking and appreciate the reduced cooking time of most HIB varieties

C. They have access to large quantities of fertilizer

D. They are better able to identify HIBs

E. Both A and B

1 m

Quick Review

In general, smallholder farmers:

A. Do not care about the marketability of HIBs since they tend to consume most HIBs within their own household

B. Care greatly about the marketability of HIBs as they are primarily sold as a cash crop

C. Care somewhat about the marketability of HIBs as selling beans can provide extra income
year-round

D. Do not care about the marketability of HIBs since consumers only tend to purchase beans grown on large-scale farms

1 m

Quick Review

Alternate

- *What characteristics do consumers consider when they select beans?*
- *What can we do to generate consumer demand for HIBs?*
- *Why are women are an important demographic for HIB promotion?*
- *Why is labeling important for HIBs?*

3 m

Unit Objectives - Review

You should now be able to:

- Outline the steps for “scaling” and “anchoring” HIBs in local food systems
- List key activities for introducing a new crop
- Differentiate between different seed systems
- Explain advantages and disadvantages of self-pollinated crops (as they relate to biofortification)
- Summarise advantages of HIB for the farmers
- Summarise advantages of HIB for the consumers
- List some of challenges for HIB introduction and adoption

Unit 6

Scaling HIBs

Unit Objectives

By the end of this unit, you should be able to:

- Outline the strategic goals of biofortification interventions
- Identify potential partner organizations for supporting HIBs over the long term
- Recognize the potential impact of policies, regulations and trade on biofortification initiatives
- Explain the importance of integrating biofortification into international standards

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Implementation

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

Achieving Scale

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

Discussion

We have discussed how proponents can directly support biofortified crops during the initial introduction, but how could they become self-sustaining over the long term?

5 m

Scaling Up Operations

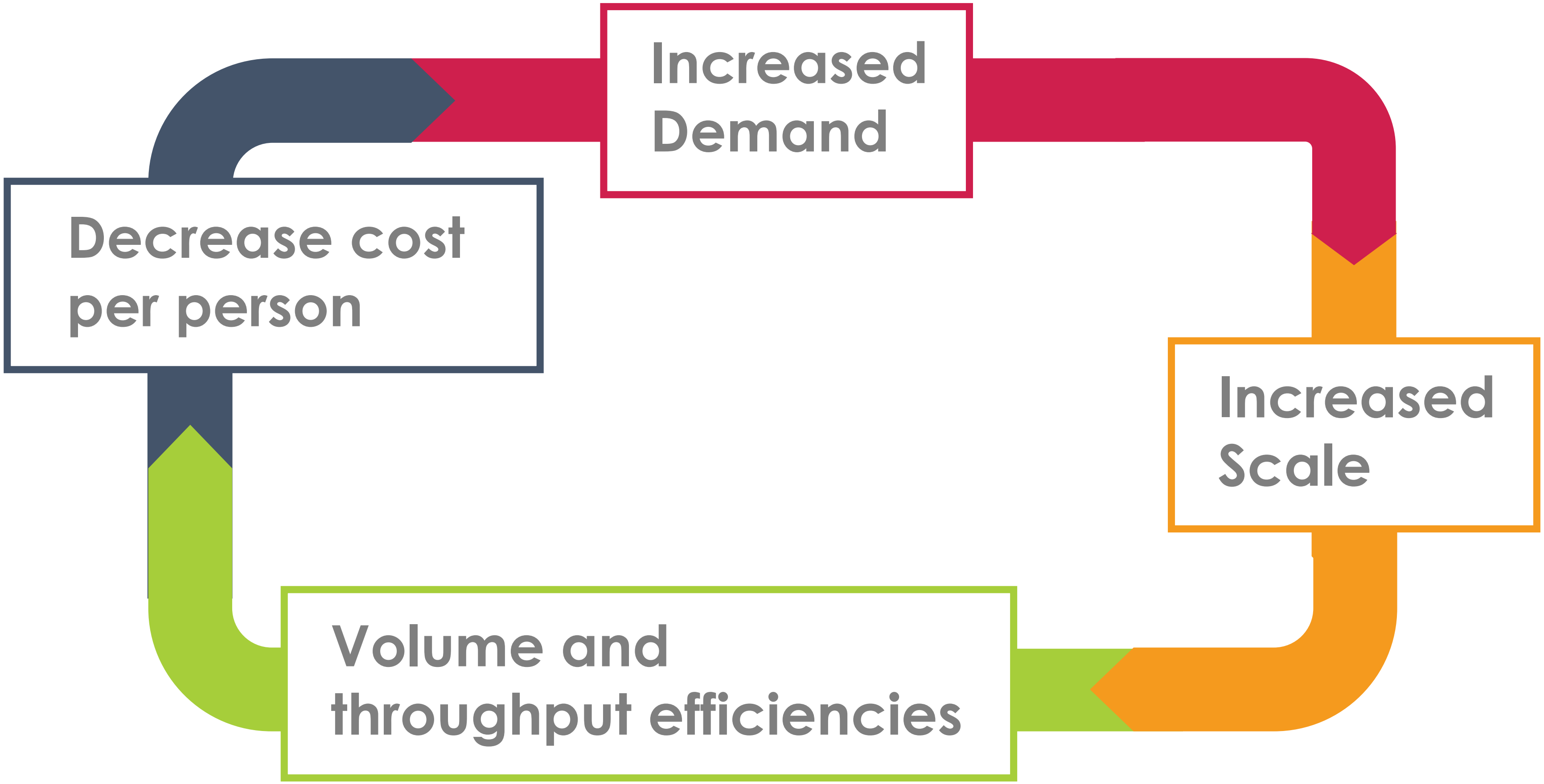
- Goal is for biofortified crops to reach sustainable market share in order to ensure long-term supply
- Scale back direct support/financing, allow demand among farmers and public to sustain biofortification

Strategic Goals

- Mainstream biofortified varieties into crop pipeline
- Achieve critical level of demand / market share
- Transfer ownership to public and private sector partners
- Reduce need for specific funding for biofortified crop development

Virtuous Cycle

Demand drives **scale**, which can make biofortification more **cost-effective** and **sustainable**



Expanding Partnerships

- Cooperating with partner organizations and forming multi-stakeholder platforms can accelerate introduction and scaling of biofortified crops
  - e.g., NGOs can integrate into existing food programs

Using HIBs and other biofortified crops in processed foods can increase nutritional value

Commerical Food Processors

- Using HIBs and other biofortified crops in processed foods can increase nutritional value
- Developing interest in HIBs among commercial food processors can ensure market for surplus HIBs

Discussion

Who could we partner with generally to help scale biofortified crops?

How could each of the following groups support HIB adoption?

- *Private Companies*
- *National governments*
- *Regional/Multilateral institutions*
- *NGOs*

5 m

Capacity Building

- Proponents and researchers need to provide capacity building to enable partners to better support biofortification

- Seed companies
- NGOs
- Retailers

- Community Organizations
- Extension agents
- Policymakers

Technical Support and Research

- Breeders and proponents can advise & assist farmers, partner organizations
- Collect feedback from local stakeholders
- Conduct research, gather data to refine strategy, guide next wave of crop development

Brainstorming

Technical Support and Research

What types of information can we provide to other stakeholders?

What types of information might we want to collect?

7 m

Discussion

In your own experience, how long does it take for new crops and agricultural practices to go from new/novel to mainstream?

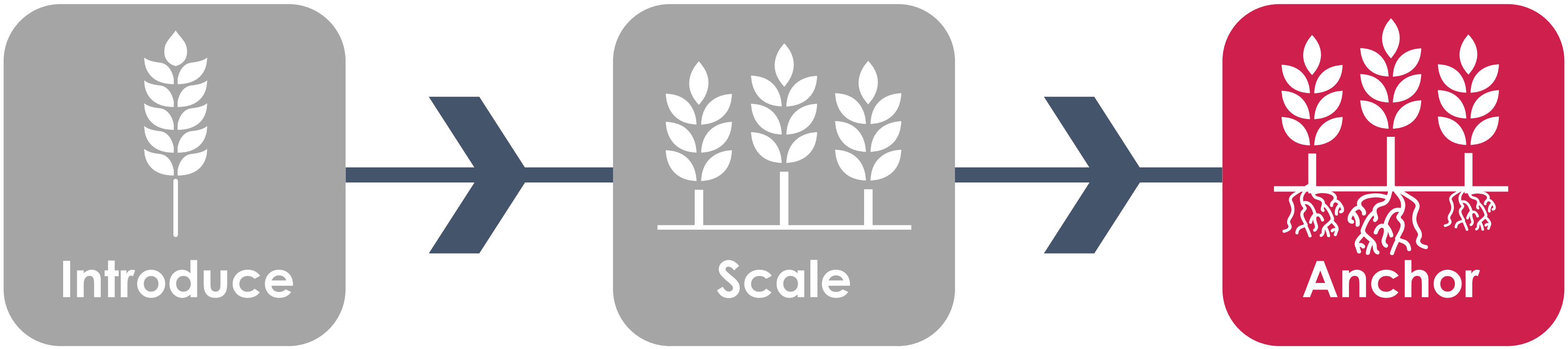
What could we do to accelerate mainstreaming of biofortification?

How long do you imagine it might take in the communities where you work?

10 m

Anchoring

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain



Ensuring Sustainability

Once scale is achieved, need strategic-level support to ensure sustainability

- Policy
- Regulation
- Trade

Activity (Breakout Groups)

Explaining HIB Benefits

In less than a minute, how might you explain the benefits of HIB adoption to a typical policymaker / local government representative who might not be familiar with the strategy?

You have 5 min to discuss in your groups

30 m

Discussion

What could a local government do to support adoption of HIB?

What kind of policies and regulations could be introduced / modified to help adoption of HIB?

10 m

Policy

- Help local and national government to enact policies and support mechanisms for continued engagement in biofortification as a solution for malnutrition
- Incorporate biofortification into regional, global initiatives
  - African Union’s Comprehensive Africa Development Programme and the Scaling Up Nutrition movement
  - HarvestPlus Latin American and Caribbean (LAC) program led by the Brazilian Ministry of Agriculture's Research Corporation (EMBRAPA)

Policy

- Add biofortification as a requirement for future variety releases by private suppliers, other research organizations
  - Tanzania National Agricultural Policy (2013) Promotes production and utilization of crops with high nutrient contents in areas experiencing nutritional problems
  - National nutrition strategy (2011/2012 2015/2016) promotes increased vitamin and mineral intake through supplementation, fortification and dietary improvement as well as biofortification.
  - “Building Nutritious Food Baskets (BNFB)” which is a three-year project implemented in Nigeria and Tanzania to accelerate and support scaling up of biofortified crops for food and nutrition security

Regulation

- Food labeling
  - Standardize labeling, health claims
  - Reduce false claims
- Develop official standards
  - Add minimum micronutrient levels to agronomic requirements for new crop release
- Proponents, breeders can assist certification authorities

Codex Alimentarius

- Efforts underway to integrate biofortification standards into “Codex Alimentarius”

- Food standards maintained jointly by WHO and FAO
- Recognized by World Trade Organization (WTO) as its reference organization

Trade

- Supporting viable business models for HIBs within bean value chain will ensure sustainability
- Incorporating biofortification in national, regional and international agreements can facilitate cross-border marketing, reduce barriers

Trade

- Most beans grown for domestic markets, but considerable informal trade also takes place across borders, for instance:.
  - Bunia and Goma in eastern DR Congo to Kisangani and down the Zaire River to Kinshasa;
  - From the Kasai and Shaba areas to Lubumbashi, also within DR Congo;
  - From the Southern Highlands of Tanzania to Dar es Salaam; From western and eastern Kenya to Nairobi.
- Cross-border trade, though significant, is often localized:

Discussion

How amenable do you think the governments that you work with would be to adopting and enforcing biofortification standards?

What opportunities are there for trade in the regions where you work?

10 m

Implementation

- 3-stage approach (introduce/scale/anchor) is not a "master plan"
  - Not everything can be figured out before starting delivery operations
  - Continue to adapt approach while learning more about farmer and consumer preferences, market conditions, etc.
- Stages build on each other
  - Successful introduction of biofortified varieties necessary condition for scaling up / reaching market penetration
  - Successful scaling / achieving market penetration lays foundation for incorporation of biofortification into policy, regulatory and business frameworks

Quick Review

An effective, sustainable way for policymakers to support HIBs would be to:

A. Implement minimum nutrition standards for future bean releases

B. Ban the cultivation and marketing of non-HIB varieties

C. Subsidize exports on a large scale

D. Implement fines for mislabeling beans as HIBs

1 m

Quick Review

Breeders and advocates can help to "anchor" biofortified crops by:

A. Providing direct, permanent subsidies to farmers over the long term

B. Offering technical assistance as local stakeholders assume greater responsibility

C. Demanding that national partners and regional institutions impose tariffs on non-HIB varieties

D. Setting a specific date for withdrawing support, to ensure local stakeholders take responsibility

1 m

Quick Review

Alternate

- *What are some of the strategic goals for biofortified crops?*
- *Who could we partner with to help promote HIB adoption?*
- *What could local and national governments do to support biofortified crops adoption?*
- *Is export trade a major factor for anchoring HIBs?*

5 m

Unit Objectives - Review

You should now be able to:

- Outline the strategic goals of biofortification interventions
- Identify potential partner organizations for supporting HIBs over the long term
- Recognize the potential impact of policies, regulations and trade on biofortification initiatives
- Explain the importance of integrating biofortification into international standards

Unit 7

Integrating HIBs into a Healthy diet

Unit Objectives

By the end of this unit, you should be able to:

- Review the nutritional benefits of eating HIBs
- Compare different methods of preparing HIBs in terms of nutrition
- Summarize the findings of the Rwandan study of HIBs

Activity (Breakout Groups)

Cooking with HIBs

- Divide into groups
- Each group will prepare a different recipe from the participant guide using HIBs
- Share with the class and discuss the results

90 m

Beans as Food

- Available year-round
- Can be consumed fresh, canned or dried
  - Dried beans most common
  - Iron levels higher in dried beans vs. canned
- In addition to the beans themselves, the leaves and pods can also be consumed

Methods of Preparation

- Pressure cooking and soaking in water diminish iron retention
- To get the most iron, should consume both cooked grains and broth
- HIBs bred to be faster-cooking
  - Appeals to women in households

Case Study: Mexican Schoolchildren

- Mexican primary school children's iron status improved after consuming biofortified black beans for 3.5 months
- Accompanied by improved physical and cognitive performance

Case Study: Rwandan Women and HIB Consumption

Case Study: Rwandan Women

- Double-blind randomized control trial was conducted with Rwandan women to determine the efficacy of iron-biofortified beans
- First efficacy trial for effect of iron-biofortified beans on an at-risk population
- 195 university students in Huye, Rwanda
- Aged 18–27
- Selected individuals with low levels of iron in blood
  - Serum ferritin <20 mg/L

Exclusion Criteria

Selection process excluded women who:

- Took iron supplements
- Had a major medical condition
- Used medications that could interfere with dietary iron absorption
- Use psychoactive drugs
- Were pregnant or lactating
- Had body mass index (kg/m2) <16
- Were severely anemic (hemoglobin <90 g/L)
  - Applicants with severe anemia were given supplements and referred to the university hospital for follow-up

Test & Control Groups

- Participants randomly assigned to receive either
  - HIBs (86 mg Fe/kg)
  - Conventional beans (50 mg Fe/kg)
- Consumed twice daily for 128 days
- Beans were carioca (cream- and brown-striped) variety grown at CIAT campus in Colombia and shipped to Rwanda specifically for trial
  - HIBs and “Control” beans produced under similar soil and climate conditions

Conditions

- Participants ate only from specially-equipped cafeteria, separate from main university facilities
  - Portions weighed by staff
  - Limited menu rotated every two weeks
  - 100% vegetarian, no meat
  - Bottled water only beverage
  - All other side dishes were the same

Bean/Iron Consumption

- Both groups consumed an average of 336 g wet beans/day
  - HIB group consumed 14.5 mg iron per day
  - Control group consumed 8.6 mg iron per day
- Daily amount of absorbed iron from beans was 1.06 mg/d and 0.79 mg/d, respectively.
  - This represents 75% and 56% of the daily iron requirement for women of this age group

Results

- At baseline,
  - 86% of subjects were iron-deficient (serum ferritin <15 mg/L)
  - 37% were anemic (hemoglobin <120 g/L).
- Blood samples collected at prescreening, baseline, random midpoint, and end line.
- After 128 days, HIB group had significantly greater increases in hemoglobin (3.8 g/L), serum ferritin (0.1 log mg/L), and body iron (0.5 mg/kg) than control group
- For every 1 g iron consumed from beans during study, there was a significant 4.2-g/L increase in hemoglobin.

Conclusion

- Consumption of iron-biofortified beans significantly improved iron status of participants
- Consistent with previously published studies of consumption of iron-biofortified rice in Filipino women and iron-biofortified pearl millet in iron-deficient Indian schoolchildren
- Results suggest that consumption of HIBs has potential to improve functional consequences of iron deficiency (physical work capacity, cognitive performance, etc.)
- Further planned trials will focus on pregnant, lactating women

Quick Review

In the study of Rwandan women, significantly improved iron status has been achieved after:

A. 10 days

B. 4 months

C. 2 years

D. 7 years

1 m

Quick Review

Alternate

- *What are some of the nutritional benefits of HIBs?*
- *What methods of preparation deliver the most iron?*
- *How long (approx.) did it take for the study participants to show some significant improvement in their iron status? Days? Months? Years?*

5 m

Unit Objectives - Review

You should now be able to:

- Review the nutritional benefits of eating HIBs
- Compare different methods of preparing HIBs in terms of nutrition
- Summarize the findings of the Rwandan study of HIBs

Unit 8

Conclusion

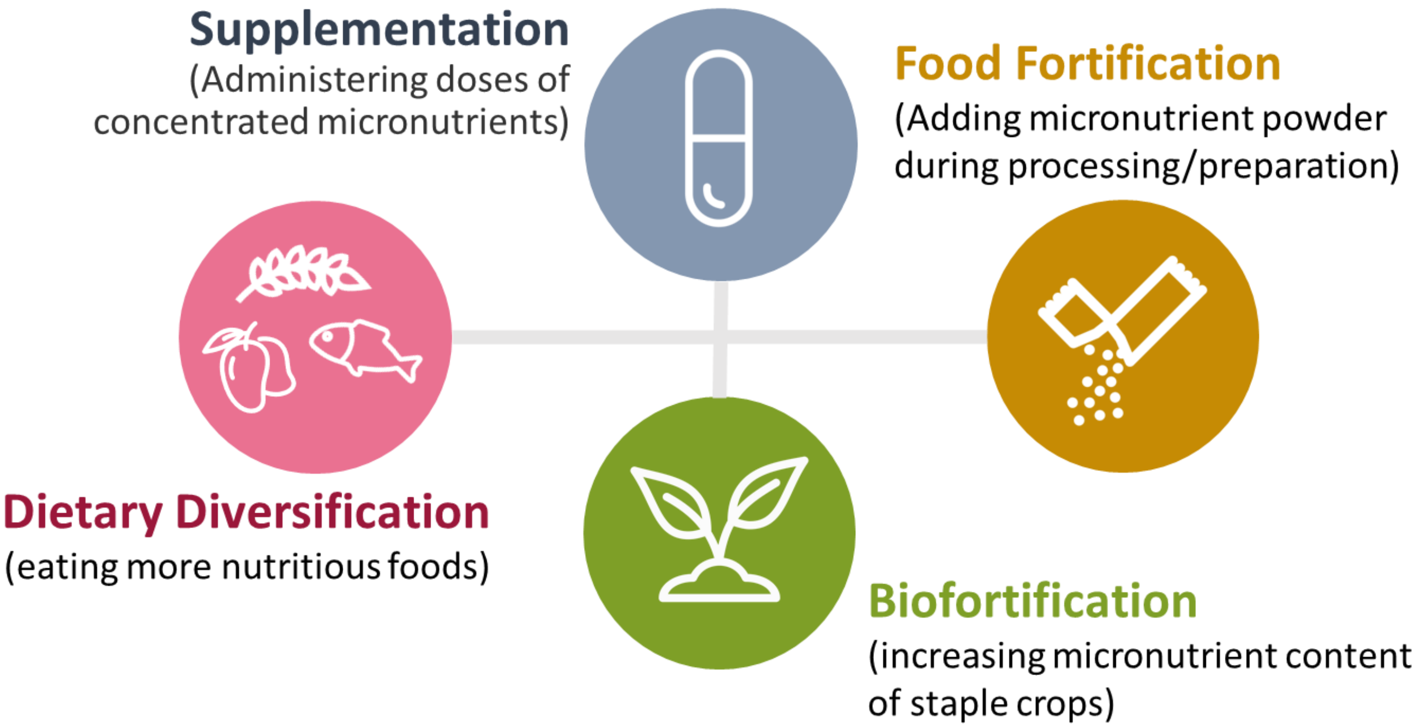
Biofortification: Results

15 years of studies confirm:

- Increasing nutrients in staple crops through biofortification can alleviate micronutrient deficiencies in real-world (non-experimental) conditions
- Crop breeding can increase nutrient levels enough to improve human nutrition without reducing yield
- Farmers are willing to grow biofortified crops and consumers are willing to eat them, as much or more than conventional popular varieties
- Biofortified crops can reach rural populations with limited access to diverse diets or other micronutrient interventions
- Biofortification is cost-effective per World Bank standards

Future Development

- Current breeding efforts focus on developing climate-smart iron beans that are high iron, higher yielding, and tolerant to drought and heat.
- Additional crop improvement research is underway to combine a Low Phytic Acid (lpa) mutation with the iron trait, which increases the bioavailability of iron when beans are consumed



Key Takeaways

- Biofortification offers a cost-effective solution for the complex problem of micronutrient deficiency
- In combination with other interventions, biofortification can alleviate malnutrition for millions of people

Zinc Rice
Up to 60% of daily zinc

Yellow Cassava
Up to 40% of daily vitamin A beta-carotenoids

Iron Pearl Millet
Up to 80% of daily iron

High-Iron Beans
Up to 50% of daily iron

Orange-Fleshed Sweetpotato
Up to 100% of daily vitamin A (beta-carotenoids)

Zinc Wheat
Up to 50% of daily zinc

Pro-Vitamin A Maize
Up to 25% of daily vitamin A (beta-carotenoids)

Key Takeaways

- Biofortification involves breeding varieties of staple crops with higher micronutrient content
- Accomplished through selective breeding (<u>not</u> GMO)

High Iron Beans

- Iron deficiency and anemia is a serious health issue, especially among women of reproductive age
- Consuming biofortified High-Iron Beans (HIB) has been shown to help alleviate iron deficiency

Key Takeaways

- Biofortification requires the support of farmers, consumers and local/international partners to succeed
- Developing crops with good agronomic and sensory qualities can drive adoption
- Nutrition messaging is key

Key Takeaways

- During initial introduction, direct, intensive support is critical
- Long-term sustainability requires scale / market share to anchor biofortified crops in national food systems

Objectives (Recap)

You should now be able to:

- Engage in discussions of micronutrient malnutrition with target groups, specifically about anemia/iron deficiency
- Describe how biofortified high-iron beans can address iron deficiency among vulnerable populations
- Summarize how breeders develop new HIB varieties
- Outline a strategy for promoting HIBs to farmers, consumers, partner organizations and the private sector
- Describe how HIBs can be integrated into a healthy diet
- Summarize key studies demonstrating the effectiveness of HIBs for addressing iron deficiency and anemia

Discussion

How might you apply the information presented in this training to your own work?

Any questions, in general?

20 m

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Building Nutritious Food Baskets

Combating hidden hunger though nutritious food baskets

The Building Nutritious Food Baskets: Scaling up Biofortified Crops for Nutrition Security seeks to reduce hidden hunger by catalyzing sustainable investment for the production and utilization of biofortified crops (Orange-fleshed sweetpotato (OFSP); vitamin A (yellow) cassava, vitamin A (orange) maize and high iron/zinc beans) at scale. The project is implemented in Nigeria and Tanzania, to demonstrate how biofortified crops can be scaled up through a multi-crop ("food basket") approach. BNFB draws on complementary expertise for scaling up through a partnership between CGIAR centers and programs, regional organizations and other public and private sector agencies to create a movement that will eventually reach the target populations. BNFB's hypothesis is that scaling up is dependent on supportive policy environment, strong institutional capacities and availability of proven technologies.