Africa Bio-fortified Sorghum (ABS) Project For Food and Nutritional Security.

Progress in technology development, regulatory and communication.

Africa Harvest Biotechnology Foundation International.

16 August, 2016.

Dr. Florence Wambugu, PhD. DSc.

Outline of Presentation

- Introducing Africa Harvest.
- Malnutrition in developing countries.
- Why Sorghum improvement.
- ABS Product development.
- Consortium partnership in ABS Project.
- Capacity building of scientists under ABS project.
- Key ABS project Strategic Issue.
- ABS Project achievements.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

INTRODUCING AFRICA HARVEST

- **Africa Harvest Biotech Foundation International - is an International Agricultural development Organization registered in USA under section 501(c) (3) of the IRS code as a public charity.**
- **Founded in 2001 by Dr. Florence Wambugu (Current CEO).**
- **Headquarters in Nairobi with offices in Washington DC, Johannesburg, and Toronto- Canada.**
- **Guided by a board approved 10 year strategic plan (2012-2022) approved targeting to impact 1 million smallholder farming Household and over 10 million beneficiaries along the whole value chain in 10 African countries, using a regional focus; EAC/SADC/ECOWAS.**

www.africaharvest.org.

STRATEGIC OVERVIEW

Vision: **"To be a lead contributor in making Africa free of hunger poverty & malnutrition"**

Mission: **To apply innovative technologies and institutional approaches for improving livelihoods of rural communities, particularly small landholders, through science & technology-based sustainable models of agricultural development.**

Approach: **Whole value chain.**

Focus: **Roots and Tubers - Cassava and sweet potato.**

Fruits **- Banana, Mangoes.**

Small Grains and Legumes **- sorghum, millet, groundnut, cowpea, common bean.**

Cereals **- Maize, rice.**

Livestock **- poultry, dairy goats and forage.**

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Governance: The Board

Well diversified and experienced International Board of Directors with a mix of professions, nationalities and experiences

- **Kenya, Senegal; South Africa, Canada, India, Malawi, USA, DRC and Zambia.**
- **Individuals from science, business, public policy and community development backgrounds.**
- **With four standing committees; Executive, Audit, Governance & Programme Committee.**

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Governance: The BoD in May 2016

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

THE PROGRAMMES

- Structured around 6 Thematic focus areas:
  1. **Food and Nutritional Security and sustainable livelihoods for smallholders.**
  2. **Technology development and deployment**
  3. **Natural Resource Management**
  4. **Agricultural Markets and Policy**
  5. **Communication for Development and Knowledge management**
  6. **Finance, Administration and New business development.**
- The strategy in the Whole value chain is mainly focusing in removing barriers and bottlenecks in production and marketing.
- Strategic focus is on site/ region/ country specific crop and livestock technologies with potential to benefit women and youth.

Part of AH Staff With the BoD.

STRATEGIC PLAN: 2011-2020

1. Reach *1 Million smallholder* households,10 million beneficiaries in 3 regions (East and Central Africa, South Africa and West Africa) in 10 African Counties in 10 years
2. To be achieved through *strategic partnerships* as well as organic growth.
3. Interventions to be based on *staple crops* in each region including Sorghum, Rice, Banana, Sweet Potato, Cassava, Pulses and Livestock.
4. Whole *value chain approach*; Start by identifying Barriers and Bottlenecks.
5. Encourage *Public-Private-Partnerships* in value chain development
6. Prioritize the *ASAL regions* as the next frontier for food self sufficiency in Sub-Sahara African Countries.
7. Ecosystem management and sustainable livelihoods through an *integrated approach* to rural development and resilience.

A Growing Nutritional Gap in Africa

- ***More stunted children* in Africa today than 20 years ago.**
- ***Zinc deficiency*** is prevalent in 50% of children under 5 across most of Africa.
- For children under 5 years, the prevalence of ***iron deficiency anemia*** ranges between 40% to 60%.
- ***Vitamin A deficiency* is the leading cause of preventable blindness in children and prevalence across Africa is 32%.**
- ***GDP loss in Africa* of 3% to 16% due to undernutrition.**

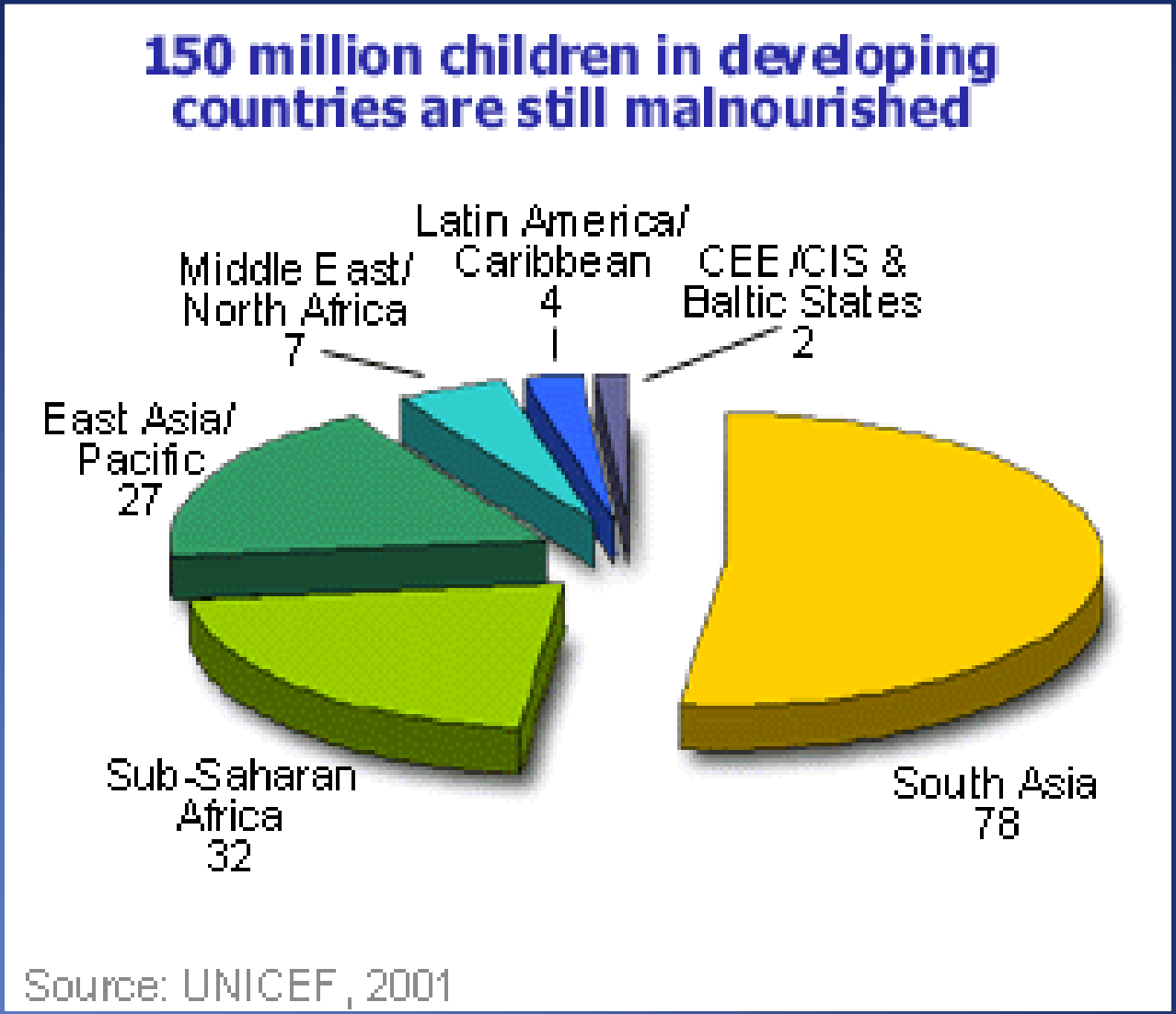
Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Micronutrient Deficiencies and Stunting

- Maternal short stature (stunted growth due to undernutrition) and iron deficiency anemia increase the risk of death of the mother at delivery accounting for at least 20% of maternal mortality.
- Micronutrient deficiency often called “hidden hunger”; is not obvious until too late, and permanent damage – mental and physical, leading to a lifetime of consequences.
- The World Health Organization (WHO) estimated in 2009 that approximately **190 M children under 5 years of age and over 19 M pregnant women are vitamin A deficient** (World Health Organization, 2009).
- Deficiencies of iron, zinc, vitamin A and other micronutrients impact pregnant women, women of reproductive age, infants and children more negatively than other age and gender groups (**Akthor et al., 2013).**

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Malnutrition in developing countries



http://www.childinfo.org/eddb/malnutrition

DUPONT PIONEER

Africa Harvest BIOTECH FOUNDATION INTERNATIONAL

Nutritional Status in Africa www.unitedcallaction.org/investing_in_the_future.pdf

Country	Pre-school age children with anemia	Pregnant women with anemia	Non-pregnant women with anemia	Pre-school age children with vitamin A deficiency	Population at risk of inadequate intake of Zn
Burkina Faso	91.5%*	68.3%*	52.0%	54.3%	13.3%
Niger	81.3%	65.5%	62.0%	67.0%	9.4%
Mali	82.8	73.4	61.0	58.6	11.1
Togo	52.4	50.2	38.4	35.0	22.9
Gambia	79.4	75.1	59.1	64.0	36.1
Nigeria	76.1%	66.7%	62.0%	29.5%	12.8%
Ghana	76.1	64.9	43.1	75.8	21.0
Kenya	69.0%	55.1%	46.4%	84.4%^	32.9%
Uganda	64.1	41.2	28.7	27.9	23.8
Rwanda	41.9	10.6	59.4	6.4	39.8
South Africa	24.1%	21.8%	26.4%	16.9%	19.7%
Zambia	52.9	46.9	29.1	54.1	38.0
Zimbabwe	19.3	18.8	34.3	35.8	38.0
Egypt	29.9%	45.4%	27.6%	11.9%	8.6%
Sudan	84.6	57.7	43.5	27.8	10.8
Ethiopia	75.2	62.7	52.3	46.1	21.7
USA	3.1%	5.7%	6.9%	0%	9.1%

Why Sorghum?

- Fifth most important grain for food use globally
- Adapted to Africa-Center of origin in Ethiopia and Sudan
- Primary cereal in arid and semi-arid geographies-Sahel
- Drought Tolerant Crop
- Grown as a staple food in many African countries
- But, the old OPVs and landraces being grown are not keeping up with changing environmental conditions and productivity demands
- Sorghum is resilient, a staple food for 300 million people in Africa with high consumption (60 to 400 grams/day)
- Approximately 70% of all sorghum globally is grown in Africa, by area. Millions of people rely on sorghum as a food crop, and is often the only possible source of income for these farmers (if they are connected to output markets).

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Sorghum Grain and Food Quality

- High energy value.
- Low Pro -Vitamin A content.
- Low Iron and Zinc availability.
- Low protein quality and quantity.
- Poor protein digestibility.
- low in Lysine, Tryptophan, Threonine and sulfur amino acids.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Biofortified Sorghum: A Collaborative Effort

- Initial funding from Bill and Melinda Gates Foundation
- DuPont Pioneer: Additional contributor and majority technical contributor
- Current efforts concentrated with Africa Harvest, National Biotechnology Development Agency (NABDA) & Institute of Ag Research (IAR), (NBMA) in Nigeria and Kenya Ag and Livestock Research Organization (KALRO) & National Biosafety Authority (NBA) in Kenya.

Original ABS Consortium partners – 2005 - 2011

Technology Development	Pioneer/DuPont - USA
	UC Berkeley - USA
	CSIR – South Africa
Product Development	ICRISAT – India
	ARC – South Africa
	University of Pretoria – South Africa
	KALRO, NBA - Kenya
	INERA – Burkina Faso
	IAR, NABDA, NBMA - Nigeria
Management, biosafety and regulatory, communication and capacity building	Africa Harvest - Kenya
	AATF - Kenya
	CORAF - Senegal

DUPONT PIONEER

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Current ABS Consortium partners – 2011 - 2016

- DuPont Pioneer
- Kenya Agricultural and Livestock Research Organisation (KALRO)
- Inst. of Agric. Research - Nigeria
- NABDA – Nigeria
- Regulatory Agencies in Nigeria – NBMA and others.
- Regulatory Agencies in Kenya – NBA, KEPHIS and others.
- University of Nairobi
- Africa Harvest Biotech Foundation Intl.
- Howard Buffet Foundation

Critical Success Factors in a Consortia Partners.

Critical success factors include:

I. **A champion institution to provide leadership, identify gaps among partners and stakeholders, develop interventions to strengthen the process, identify and facilitate linkages – played by Africa Harvest.**

II. **Supportive partners and stakeholders.**

III. **Training of partners to bridge any information, skills and technology gaps.**

IV. **Identifying and promoting relevant technologies that promote success.**

V. **Financing consortia partners for identified activities.**

VI. **Strong Monitoring and Evaluation system focusing on milestone achievements commensurate to the Log frame and budget.**

VII. **Effective, efficient management coordination and reporting.**

VIII. **Communication & Issues management**

IP Donations & freedom to operate for ABS

- **DuPont** donated IP estimated at $ 4.8 million dollars and facilities for training African scientists, and secured bio-fortification and marker IP accessibility where necessary.
- **Japan Tobacco** donated technology for transformation.
- **AATF** did gene audit and search for freedom to operate in Africa.
- **Africa Harvest** carrying on IP stewardship, Consortia management, accountability and risk management.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Sources of Africa Biofortified Sorghum Genes

- ***HV-HGGT,* from *Hordeum vulgare.***
- ***At-DXS,* from *Arabidopsis thaliana*.**
- ***ZM-PSY1,* Maize - *phytoene synthase* 1.**
- ***CRT I (EU),* from Bacterial (*Erwinia)* CRT I gene (*carotenoid reductase*), for Vitamin A biosynthesis. Also used in Golden Rice.**
- **CRT B, from Bacterial (Erwinia) CRT B gene.**
- **PMI (ABS), *phosphomannose isomerase* (PMI) isolated by PCR from *Bacteria (E. coli)***

  A Marker gene instead of Antibiotic Markers.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Increase β–carotene Accumulation with Improved Stability

WT → ABS168 → ABS198 → ABS203

0.5µg/g

Gene Sorting

5µg/g

5-9µg/g

12µg/g
(First demonstration of Increased stability)

Gene expression optimization

ABS214 → ABS235 → ABS239

25µg/g

30~40µg/g

40~50µg/g

ABS Sorghum seeds

B – carotene conversion into Retinol

- **Vitamin A equivalency rations for β-carotene from plants Range from 3.8:1 to 28:1.**
- **Golden Rice (3.8:1).**
- **Orange Sweet Potato (13:1) Hashell et al (2004)**
- **Biofortified Maize (6.5:1)**
- **ABS - Bio-fortified sorghum (4.3:1)**
- **Carrots (14.8 :1)**
- **Spinach (20.9 : 1)**
- **Note:** Smaller ratio mean better conversion and hence ABS is better than; Orange sweet potato, Orange maize, Carrots & Spinach!
- **Bio-fortified sorghum can provide levels of pro-vitamin A (beta-carotene) to alleviate vitamin A deficiency equivalent to those of a pure β-carotene supplement.**

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

ABS F1 and Parents--Null, ABS 188 F1 and Gadam - Kenya

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Factors determining Bio-efficacy availability of β-Carotene

- Stability of vitamin A during storage.
- Stability of pro-vitamin A during food preparations and processing.
- Percent Intestinal Absorption of β-carotene into the blood stream.
- Bio-conversion of β-carotene into retinol.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Study on impact of ABS genes on the Environment

Completed gene flow studies and results.

Review done by a panel of Environmental experts from USA and Africa as well as experimental studies done by University of Nairobi in Kenya and Nebraska in USA concluded the following;

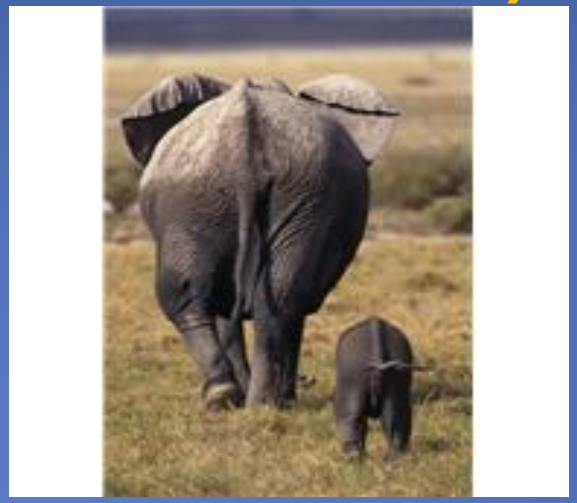
- ABS genes escape have no impact on wild sorghum or any negative impact in the environment.
- No negative effects on any livestock and wildlife.
- No morphological characteristics that indicate increased vigour or potential to be a weed.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

ABS Observes Stringent Regulatory Compliance in Africa

Which ensures that;

- **Gene flow into the environment through pollen or seeds does not occur (genetic confinement).**
- **Vegetative materials should not be eaten by animals / humans or be released into the environment (material Confinement).**



Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Scientists trained by the ABS project

	Name	Field of training	Institution
1	Dr Luke Mehlo	Transformation technologies	CSIR
2	Dr AndileGrootboom	Transformation technologies	CSIR
3	Dr GetuBeyene	Transformation technologies	CSIR
4	Mrs NompumeleloMkhonza	Biosafety assessments, tests and monitoring	CSIR
5	Dr Joel Mutisya	Transformation technologies	KARI/ KALRO
6	Mrs BosiboriBett	Biosafety assessments, tests and monitoring	KARI/ KALRO
7	Dr Clement Kamau	Breeding	KARI/ KALRO
8	Dr Mary Mgonja	Breeding	KARI/ KALRO
9	Mr Kenneth Mburu	Transformation technologies	KU/AH
10	Prof ShireenAsam	Transformation technologies	AGERI
11	MrOuedraogoMahamadi	Breeding	INERA
12	Clarisse Barro	Breeding	INERA
13	Dr Silas Obukosia	Biosafety assessments, tests and monitoring	AH
14	Dr Nemera Shargie	Breeding	ARC

DUPONT PIONEER

Africa Harvest BIOTECH FOUNDATION INTERNATIONAL

Key ABS Strategic Issue

- Strong partnerships are in place - very important.
- There are efforts to develop the sorghum seed systems in Africa for product deployment.
- Final construct will be a stack of genes to enhance and stabilize beta-carotene along with genes to increase the bioavailability of iron and zinc in the final product.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Key ABS Strategic Issue

- ABS has most promising lead events with potential economic impact - pro-vitamin A, zinc and iron.
- A system for developing and deploying the final product to end users in Africa will be developed.
- ABS has excellent capacity for technology development, product development and deployment processes - in African target countries and USA.
- Africa has solid capacity for introgression of traits through CFTs.
- Efficient material and genetic confinement is possible in Africa.
- There is political will for use of GMOs in target countries - Nigeria passed Bio-safety Act.
- There are efforts to develop the sorghum seed systems in Africa for product deployment.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Role of ABS CFT in Africa

- Building capacities of local scientists in trait introgression, agronomic performance evaluation, compliance, Biosafety and regulatory.
- Environmental safety studies.
- Trait introgression into into local varieties.
- Confirming stability of Agronomic traits in converted local varieties.
- Confirmation of presence of transgene in the converted local variety.
- Establish trackable field database for all activities for regulatory use.

Confined Field Trials; Nigeria (Left) and Kenya (Right)

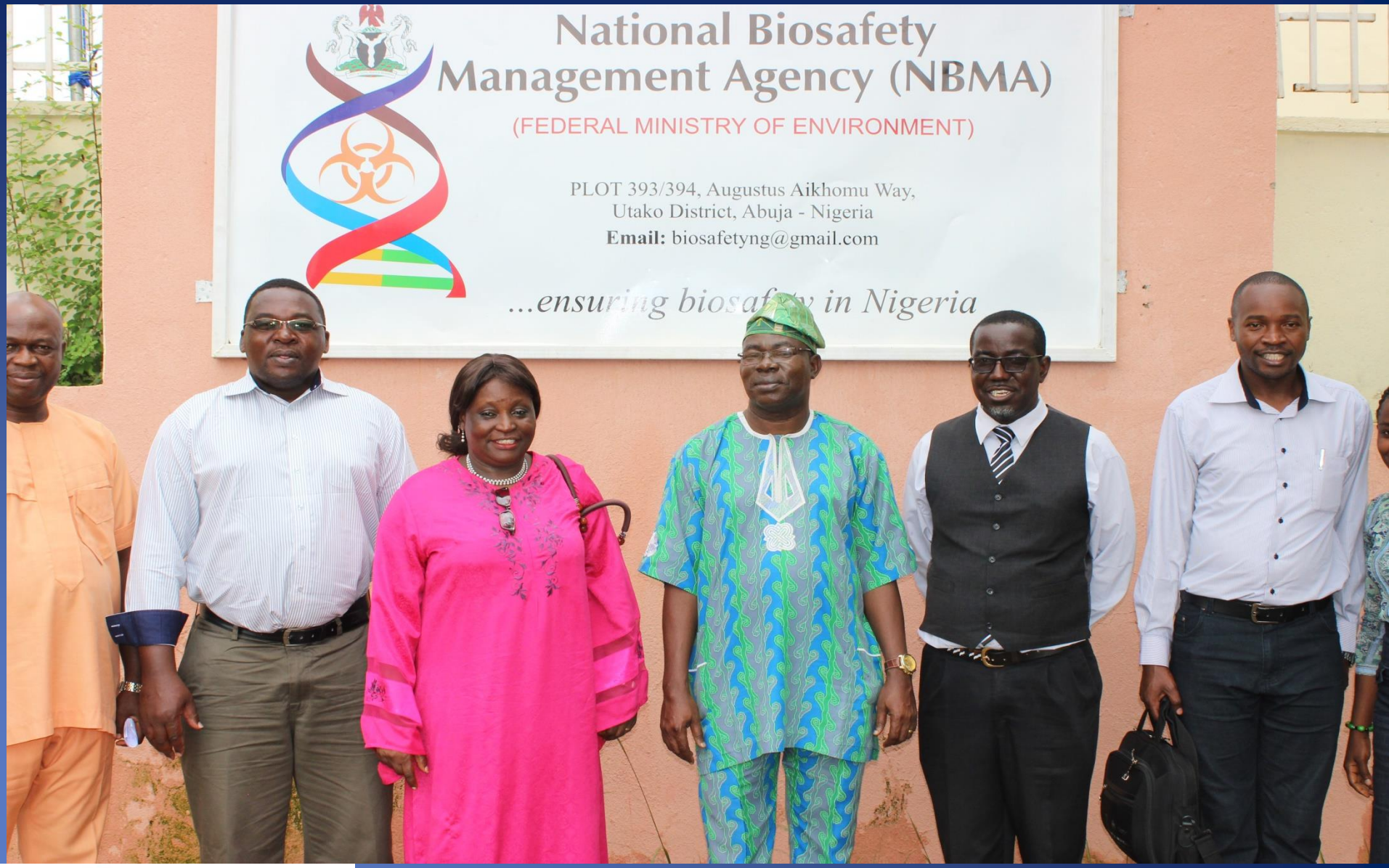
Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

ABS CFT in KALRO - Kiboko, Kenya.

ABS CFT in IAR – Zaria State, Kaduna Nigeria

ABS Sorghum in a CFT in KALRO, Kiboko – Kenya.

ABS project team visiting regulator in Nigeria.



Key ABS Project achievements

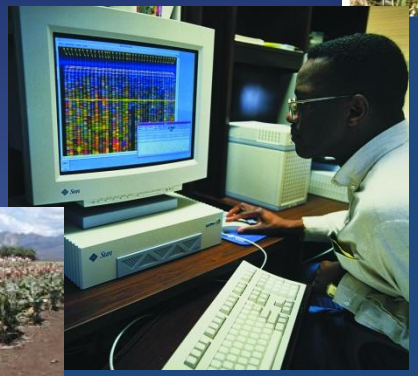
- Initiated the first African CFT of transgenic sorghum , a total of 6 CFTs were completed in Kenya and 8 CFTs in Nigeria from 2011 to 2016.
- Eight CFTs conducted in the USA from 2011 to 2014.
- Development of suitable sorghum CFT protocols for Kenya and Nigeria
- Completed gene flow studies
- Use of Vitamin E (HGGT) to stabilize pro-vitamin A
- ABS trial permit granted by regulators to continue with studies in Kenya and Nigeria.
- Good direct transformation results for three African sorghum varieties, reducing transformation duration by 60% (to 4 months).

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

Steps in developing a biotech crop.

Farmer release

Extensive risk assessment



Field testing

Glasshouse

Laboratory

Biosafety regulations are adopted at each stage

Conclusion

- ABS project is a good example of how African Scientists and Institutions can partner with private sector companies with desired IP to solve an African Wide problem such as Malnutrition using modern GM technology and traditional breeding.
- Sorghum is an indigenous crop grown all over African, it has no varieties with sufficient levels of Vit. A, Iron and Zinc.
- Traditional breeding efforts world wide have not been able to introduce these nutritional traits to Sorghum.
- The regions where Sorghum is eaten as staple happen to be the same regions where Vit. A and Micronutrient deficiencies have highest prevalence, similar to challenge of Rice eating areas in Asia.
- ABS has a huge potential of resolving African malnutrition challenges based on these traits, just like Golden Rice has in Asia .
- Africa Harvest and ABS Consortium appeal to regulators in Africa to continue supporting the project until we deliver finished products.

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL


Thank You
Merci Beaucoup
Asante Sana