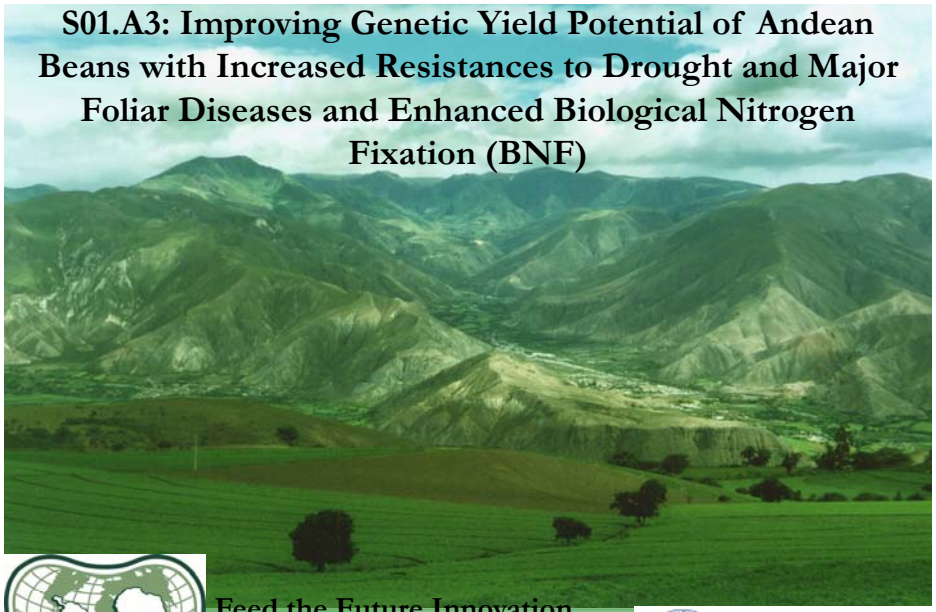
S01.A3: Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF)

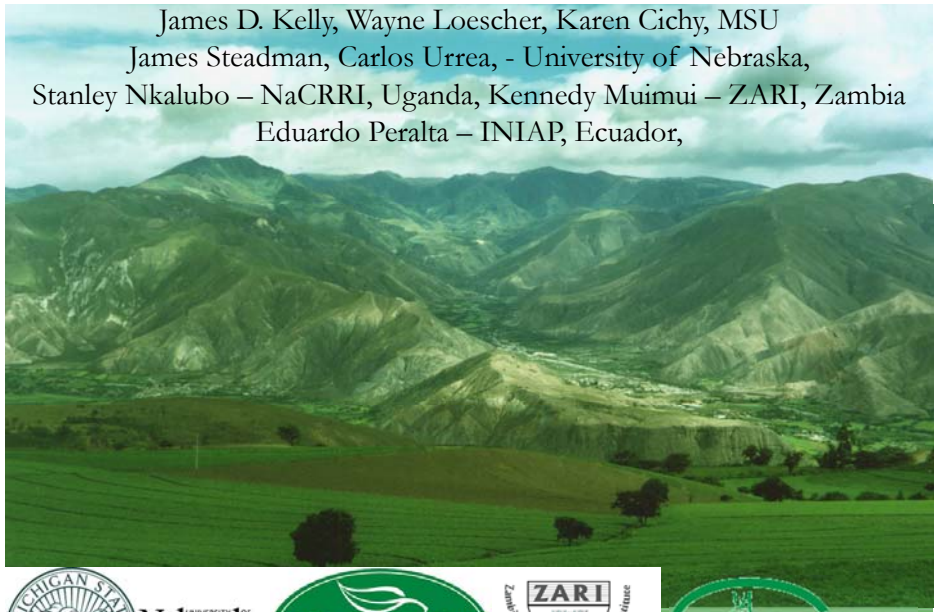


Legume Innovation Lab

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

USAID FROM THE AMERICAN PEOPLE

James D. Kelly, Wayne Loescher, Karen Cichy, MSU
James Steadman, Carlos Urrea, - University of Nebraska,
Stanley Nkalubo – NaCRRI, Uganda, Kennedy Muimui – ZARI, Zambia
Eduardo Peralta – INIAP, Ecuador,



Researching Soils, Crops and Water in Zambia

ECUADOR		PLANTED AREA (ha)	HARVESTED AREA (ha)	PRODUCTION TM
Dry Bean	MONO	19,438	17,261	8,509
	ASSOCIATED	85,689	72,528	9,541
Green Shell Beans	MONO	4,941	4,297	5,296
	ASSOCIATED	11,523	9,274	3,152

25,000 ha

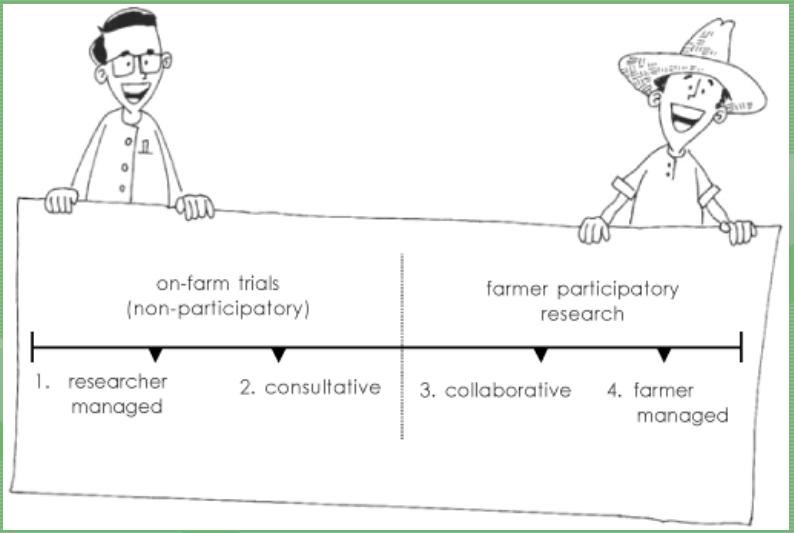
100,000 ha

Fuente: SICA-MAG. 2002

Dry Seed

Green Shell

Local Agricultural Research Committees – CIAL – Comites de Investigacion Agricola Local



Researcher-Farmer Continuum Gonsolves et al., 2005

INTERACTION: CIALs
Farmers – Researchers





NEW VARIETIES

FIELD DAYS

180 participants

A total of 10 new bush bean varieties have been released in Ecuador through CRSP / LIL programs over last 15 years

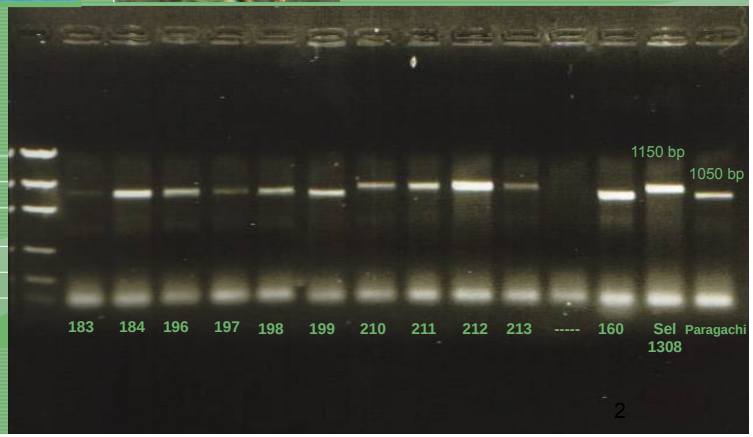
Marker-Assisted Selection



SH 13

SU 91

SBB14



Screening for Root Rot Resistance

INIAP

CENTENARIO

Resistant to Fusarium Wilt

Resistant to
4-diseases

SAID

Future

Bean Production in Uganda

- The common bean is most important legume crop grown and consumed in Uganda
  - Food security
  - Source of household income
  - Important source of nutrient
  - Contributes to improving and sustaining soil fertility

Bean production in Uganda

- Uganda is the second largest producer and consumer of common bean after Tanzania
- Estimated bean production is 665,000 MT and as a non-traditional agricultural export crop, beans have gained a major dominance in terms of tonnage and monetary value among Uganda's exports.
- Uganda is a major supplier of beans to markets in Kenya, Rwanda and South Sudan (15-58%) of farmers produce is sold.
- Approx. 85% of the 18 million rural Ugandans grow and depend majorly on beans as a food and for income generating purposes.

Agroecological Bean Production Zones

- Beans are produced in all the major agroecological regions within Uganda

- 43% South western region
- 26% Central region
- 21% Eastern region
- 10% Northern region

Bean production in general

- Bean production mostly occurs in traditional systems on small plots of land averaging 0.2 – 3.0 hectares

- About 65% of common bean is grown in mixed stand while 35% is pure stand.

- Yields are estimated at less than 500 kg ha^{-1}, much less than the SSA average of more than 770 kg

- Bean production declined at the rate of 4.55% per year over a 10 year period. (1990-2000) particularly during the mid 1990s .

- Trend has been reversed due to interventions through research and currently beans are increasingly becoming more competitive with the major staple crops in terms of land allocation.

Bean Types & Regions of Production

- Types of beans grown in the different regions may from one region to another.

- The types bean grown in a certain region mainly depended on the households' consumption preferences within a specific region.

- Most regions grow and produce the red mottled bean types due to their high marketability within and outside Ugandan boarders

Challenges faced by Ugandan bean Producers

- Diseases & Insect Pests
- Climate change - drought
- Declining soil fertility
-
- Marketing challenges
- Inadequate seed quality regulation.

Bean Production in Zambia

- Beans rank second to groundnuts as major legumes produced in Zambia
- Production Area: Cooler, higher altitude and high rainfall areas of Northern Zambia
- Most farmers grow landraces favored for color and taste
- The purple speckled commonly known as Kabulangeti is the most popular
- Low landraces yields: >500 kg/ha
- Improved varieties have been developed, but their adoption is low
- Strong preference for the landraces seed types - Lack of adequate seed

POPULAR LANDRACES IN ZAMBIA

LUNDAZI

SOLWEZI

SERENJE

KABULANGETI

IMPROVED VARIETIES

CHAMBESHI

CARIOCA

LYAMBAI

LUKUPA

Production Constraints

- Diseases and pests,
- Low soil fertility
- Inadequate agronomic inputs particularly fertilizer
- Use of local inherently low yielding, disease susceptible land races
- Low quality of seed

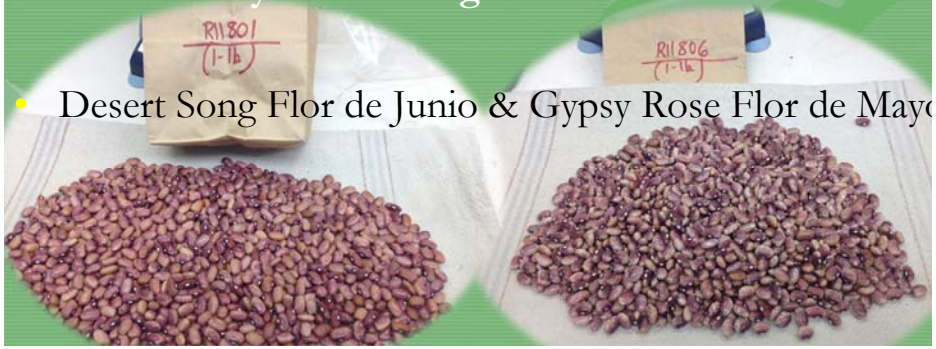
- Diseases are the major constraint to production distribution pattern of diseases follows that of temperature and rainfall
- Important diseases cool, high rainfall vs. warm moderate rainfall areas: re
  - Anthracnose
  - Angular leaf spot
  - Ascochyta blight
  - Rust
  - Bean Common Mosaic Virus
  - Common Bacterial Blight

Objective 1.

- **Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved biological nitrogen fixation (BNF) and assess acceptability of fast cooking, high mineral content in a range of large-seeded, high-yielding red mottled, white and yellow Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda), Ecuador and the U.S.**

Four New Varieties - MSU

- **Zumba black bean with excellent color retention following canning.**
- **Alpena navy bean, high-yielding upright with excellent dry down – negates use of desiccant**



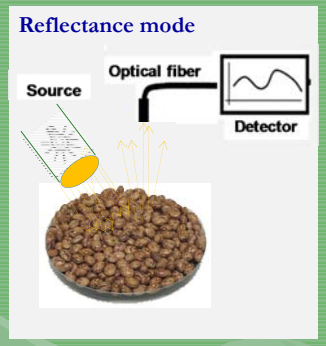
- Desert Song Flor de Junio & Gypsy Rose Flor de Mayo

Nondestructive Sensing Methods

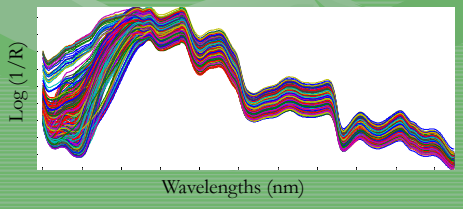
1. Color Imaging System

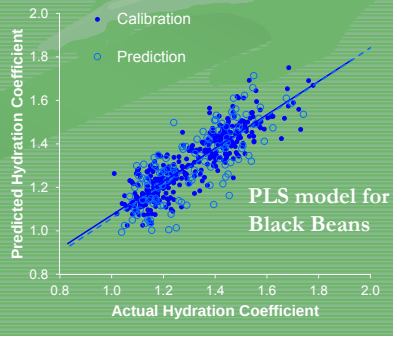
- **Visible range , λ= 380 – 780 nm**
- **For measuring surface features:**
  - Standard color (RGB, L*a*b*, hue and Chroma)
  - Morphological features (shape and size)
  - Surface texture
  - Other appearance features

2. Near Infrared Spectroscopy



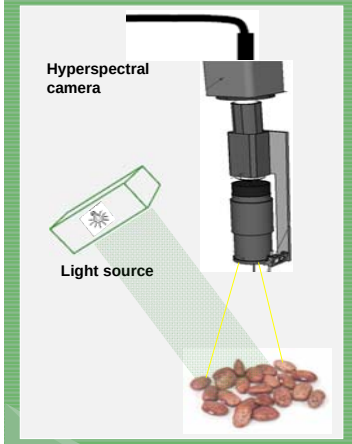
- Vis-IR range, λ= 350 – 2500 nm
- For evaluating internal properties:
  - Moisture content and hydration coefficient
  - Washed drained Coefficients
  - Cooking properties
  - Nutrients
  - Texture





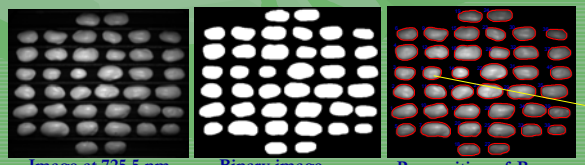
PLS model for Black Beans

3. Hyperspectral Imaging

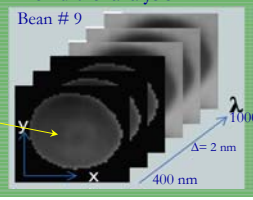


- Combination of Imaging and Spectroscopy
  Spatial + Spectral = Hypercube (data)
- For evaluating chemical and physical properties
  - Moisture content
  - Ratio cooked to dry seed
  - Ratio soaked to dry seed
  - Cooking properties
  - Texture and nutrient distribution
  - Other external and internal properties

IMAGE PROCESSING & ANALYSIS



Hypercube from each Bean for further analysis



Objective 2.

- Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, Zambia and Ecuador and identify sources of resistance to angular leaf spot (ALS), anthracnose (ANT), common bacterial blight (CBB), bean common mosaic virus (BCMV) and bean rust present in Andean germplasm.
- Steadman, HC Partners

Anthracnose Screening

- Screening the ADP with wide range races of anthracnose
- Using races reported in Ecuador, Uganda, Zambia
- To identify sources of resistance for breeding
- Conduct Genome Wide Association Mapping of Resistance using 6K Beadchip SNP markers
- Grady Zuiderveen

Objective 3.

- **Use single nucleotide polymorphism (SNP)-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, cooking time and BNF to identify QTLs for use in MAS to improve Andean germplasm.**
- **Cichy, Kelly, Urrea, Kamfwa**

Evaluation of ADP for BNF in Zambia

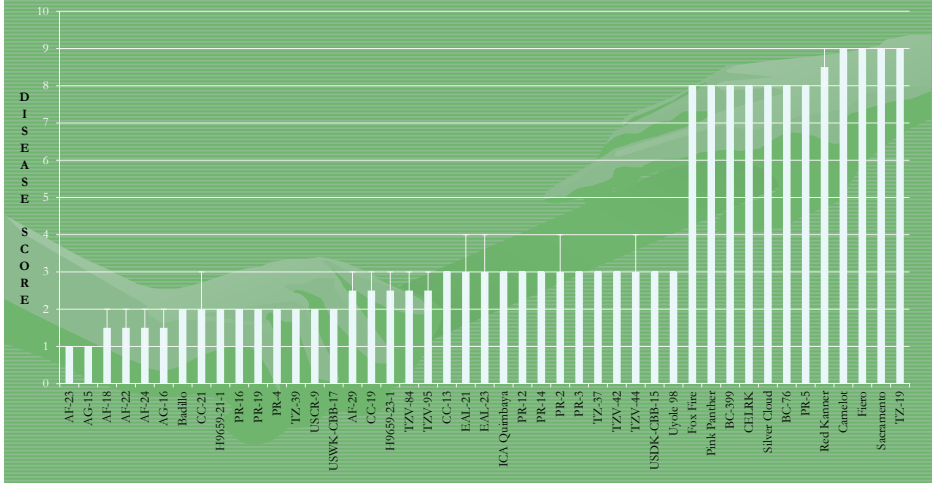
- **Lusaka-UNZA Farm**
  - Altitude: 1280 m
  - Avg Temp: 27^{0}C (81^{0}F)
  - Rainfall: 882mm (34.7 inches)
  - pH=6.51, Total N=0.21mg/kg, P=24.0mg/kg
- **Kasama –Misanfu**
  - Altitude: 1400 m
  - Avg Temp: 26^{0}C (78^{0}F)
  - Rainfall: 1270mm (50 inches)
  - pH=6.07, Total N=0.18 mg/kg, P=7.8 mg/kg

•TZV-95 Showed exceptional performance on the low fertility soils, Kasama

•Good performance under heavy disease pressure in Lusaka

Common Bacterial Blight Ratings-UNZA Farm

Scale: 1-9 (CIAT, 1987)
1=Immune, 9=Susceptible
Groupings: 1-3 Resistant; 4-6 Intermediate; 7-9 Susceptible



Drought Trials in Nebraska

STRESS VS. NON STRSS

COMMON BACTERIAL BLIGHT SCREENING

Treatment	Total water mm Irrigation + Precipitation	Max. average Temperature ^{0}C	Min. average Temperature ^{0}C
NON STRESS	553	29.3	18.4
STRESS	248		

Drought Screening - Nebraska

- **49 Andean lines BeanCAP; DII = 0.47**
- **81 lines ADP; DII = 0.38**
- **Evaluated drought stress(DS) & non stress (NS) in Mitchell, NE 2013**
- **Measured yields, geometric mean, DSI index**
- ADP-7 (Bukoba), ADP-626 (Dolly), and ADP-41 (Morondo) were well adapted to both NS and DS
- ADP-45 (RH No. 2) and ADP-63 (Soya) had the lowest cooking time under stress and non stress

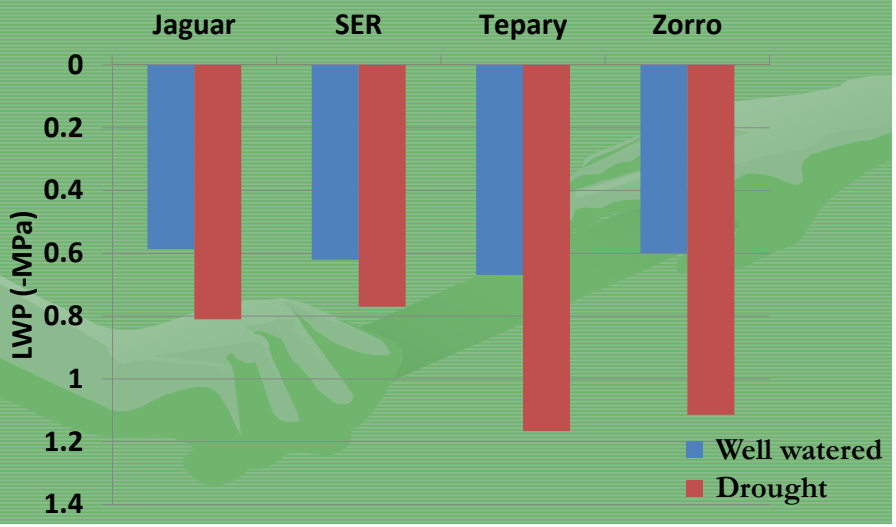
Objective 4.

- **Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought.**
- Loescher, Kramer, Traub

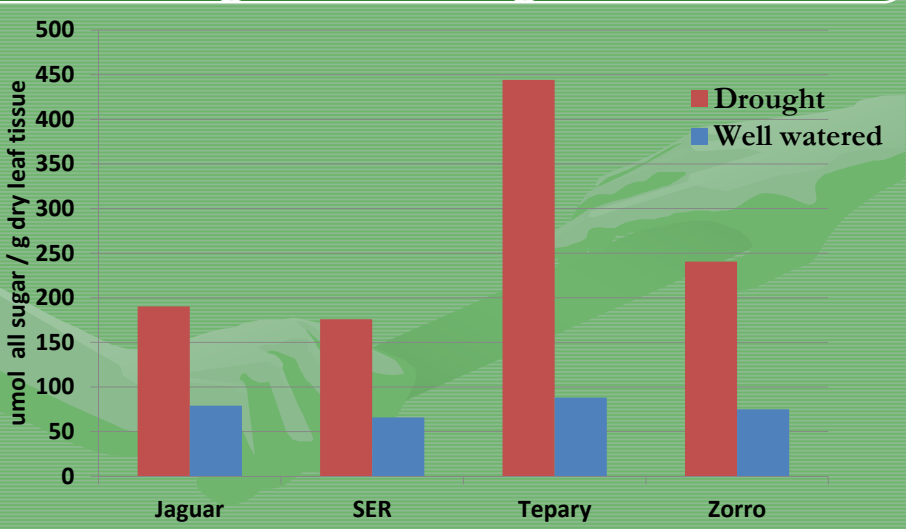
Physiological responses to abiotic stress – Jesse Traub

- Measured photosynthesis and stomatal conductance with gas exchange methods – four genotypes (3 common, one tepary bean)
- Accumulation of drought-related metabolites in leaf tissue
- Leaf water potential responses to drought stress
- Electrolyte leakage to infer oxidative damage
- Stomatal response to exogenous ABA

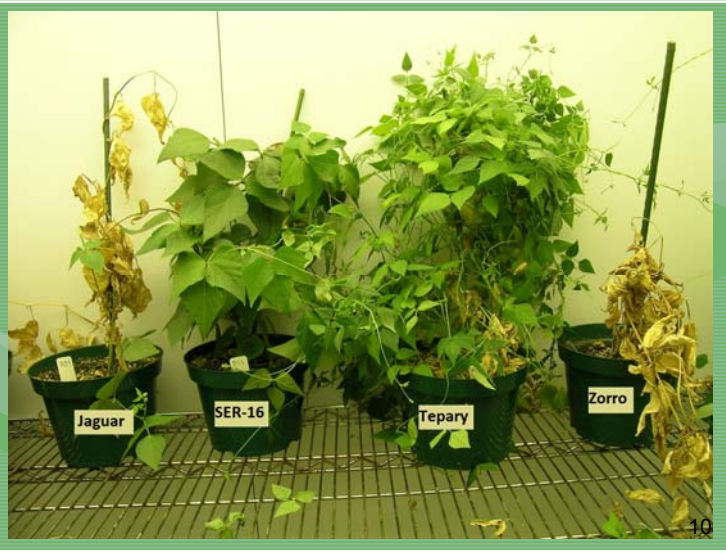
Leaf Water Potential



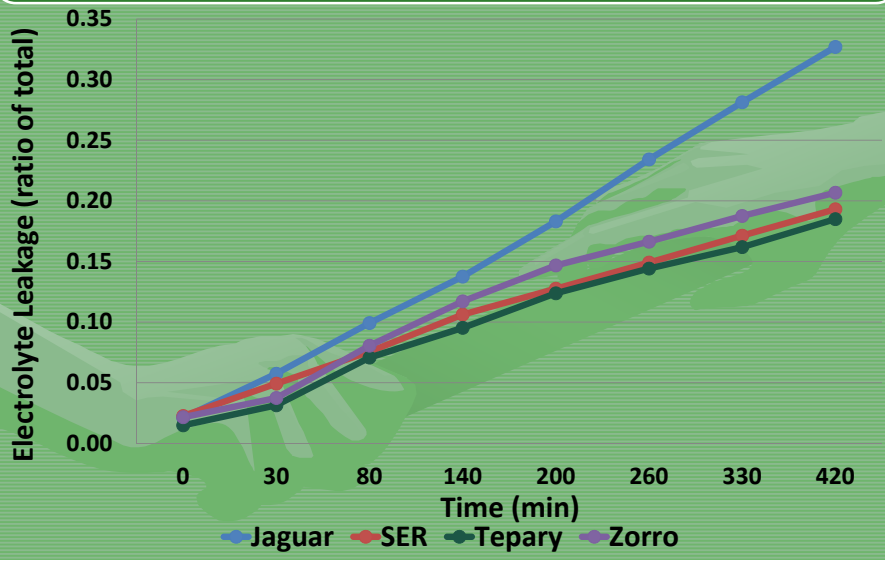
Drought-induced accumulation of sugars and organic acids



Recovery after exposure to 40° C



Electrolyte leakage after exposure to heat stress



Objective 5.

- Institutional Capacity Building and Training.
- Kelvin Kamfwa from Zambia is one of the PhD students being trained at MSU in Plant Breeding, Genetics and Biotechnology under this project. Kelvin Kamfwa retains his position at University of Zambia.
- Isaac Dramadri will be trained under this project and is expected to return to Makerere University, Kampala upon the successful conclusion of his degree program – genetics/physiology.

Objective 5.

- Other African students with funding through BHEARD and Mastercard programs will be actively recruited for degree programs as part of this project.
- Short term training programs in country will be conducted and additional training through LIL partner workshops, Borlaug LEAP program and WorldTAP short courses at MSU where the emphasis is to train the trainer in aspects of Molecular Breeding.
- Established linkages with BecA Hub in Nairobi and the African Biosafety Network of Expertise at MSU to expand capacity building and future training workshops.

Linkages

- **USDA-NIFA: "Developing Common Bean (*Phaseolus vulgaris*) Germplasm with Resistance to the Major Soil Borne Pathogens in East Africa" focused on Bean Root Health in Rwanda and Uganda – PI-Kelly, MSU with partners in USDA-ARS /OSU/SDSU/CIAT/PABRA**

- **USDA-NIFA: "Genetic Approaches to Reducing Fungal and Oomycetes Soilborne Problems of Common Bean in Eastern and Southern Africa" – PI-Steadman UNL with partners USDA-ARS/ ZARI/ IIAM, Mozambique**

•NIFA project- Reduction of fungal root rot problems using genetic approaches on common bean has interactions with Legume Innovation Lab in Eastern and Southern Africa

Mt. Makulu Central Research Station, ZARI, Zambia

•405 entries from Andean Diversity Panel and Nebraska were planted in screening Nurseries in Zambia and Mozambique

•60 bean lines that had good stands and showed resistance to 4 foliar bean diseases: ALS, ANT, CBB Rust were identified

• In 2014, the same 60 lines were planted for evaluation in Uganda, Mozambique and Zambia in replicated plots with landrace/local bean lines as controls

Test plots- Mt. Makulu Central Research Station, Zambia

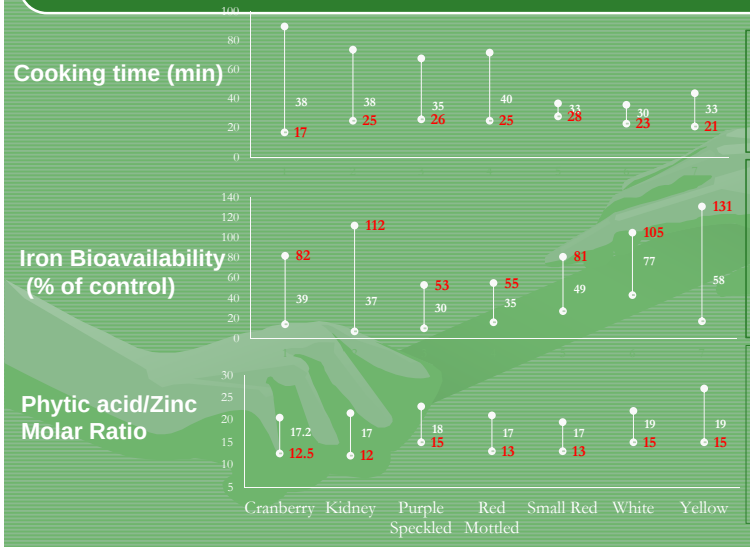
Linkages

- **Legume Innovation Lab Project S01.A04 "Developing, Testing and Dissemination of Genetically Improved Middle American Bean Cultivars for Central America, Caribbean and Eastern Africa" – PI Beaver UPR with partners in USDA-ARS, Zamorano, NDSU**
- **USDA-ARS FtT project: Breeding locally-adapted pulse crops for enhanced yield and seed qualities: an integrated, outcome-based plan for ARS, involving Dr. Cichy with partners in USDA-ARS.**

Fast Cooking Andean Beans with High Bioavailable Iron and Zinc

1. Andean Diversity Panel Screening

(Data on 217 ADP lines grown in MI in 2012, from USDA-Ftf Project)



Cook time: Mattson cooker when 80% of pins drop

Fe Bioavailability based on Caco 2 assay by Dr. Glahn, USDA-ARS

PA/Zinc Bioavailability Estimates
≥15: Low
5-15: Moderate
<5: High

Participatory Evaluation of Fast Cooking High Bioavailable Iron and Zinc Lines in Uganda

- Farmers in 3 districts (**Hoima, Kamuli, Mbale**) will be recruited to grow and evaluate 12 fast cooking genotypes that are high in bioavailable Fe and Zn.
- Preferred farmers variety for each district will be included as a local check

Genotype	Seed Type	Origin	Cook time (min)	Fe Bioavail.	PA/ZN molar ratio
Bonus	CRAN	S. Africa	32.0	43	12.6
OPS-RS4	CRAN	S. Africa	27.0	64	16.7
Dolly	CRAN	USA	35.5	83	20.0
Charlevoix	DRK	USA	38.5	84	16.1
Selian 97	DRK	Tanzania	26.6	68	17.8
KIBUMBULA	DRK	Tanzania	27.5	112	18.2
ROZI KOKO	Red Mott	Tanzania	32.6	29	14.3
Maalasa	Red Mott	Tanzania	27.5	55	14.8
KIDUNGU	Sm Red	Tanzania	35.8	81	13.4
Myasi	Yellow	USA	34.7	131	20.9
Chumbo, Cela	Yellow	Angola	23.7	85	22.1
Ervilha	Yellow	Angola	21.5	109	23.1

Dennis Katuuramu
PhD student MSU

Linkages

- CIAT network [including Idupulapati Rao, Bodo Raatz] and CIAT-Uganda (Clare Mukankusi) PABRA network (Mathew Abang, Roland Chirwa).
- USAID program on Climate Resilient Legumes: "An Integrated Program to Accelerate Breeding of Resilient, More Productive Beans for Smallholder Farmers" PI-Lynch, PSU with partners NDSU/ZARI

MSU Bean Breeding & Genetics Lab-2014