Improving Income and Nutrition of Smallholder Farmers in Eastern Africa Using African Traditional Vegetables

September 08-09, 2016, Sepang Utara, Malaysia

USAID Program in Integrated Horticulture/Nutrition

Jim Simon, Distinguished Professor of Plant Biology

D. Hoffman, S. Weller, R. Govindasamy, D. Byrnes, X. Morin, E. Van Wyk, F. Dnissa, N. Nyabinda

USA: Rutgers University, Purdue University

Kenya: AMPATH, MOI University, Kenyan Agricultural & Livestock Research Organization (KALRO); University of Eldoret

Tanzania: AVRDC – The World Vegetable Center

Zambia: AgriSmart-Zambia, University of Zambia, MAWA

FEED THE FUTURE — The U.S. Government's Global Hunger & Food Security Initiative

USAID FROM THE AMERICAN PEOPLE

HORTICULTURE INNOVATION LAB

UC DAVIS UNIVERSITY OF CALIFORNIA

Projected Population Growth

Region	2011	2050	Change	Percent
World	6,987	9,587	+2,600	+ 38
High Income	1,242	1,333	+ 91	+ 7
Low Income	5,745	8,254	+2,509	+ 44
East & S.E. Asia	2,183	2,308	+ 125	+ 6
South Central Asia	1,795	2,574	+ 779	+ 43
Sub-Saharan Africa	883	2,069	+1,186	+134
Lat. America/Carib	596	746	+ 150	+ 25
N. Africa & W. Asia	451	725	+ 274	+ 61

Source: Population Reference Bureau. 2011 World Population Data Sheet.

State of Nutrition in Sub-Saharan Africa: Case studies from Kenya and Zambia*

- While undernutrition is decreasing in many developing regions, parts of Sub-Saharan Africa have yet to begin the “nutrition transition”.
- Broad-based efforts to reduce the prevalence of undernutrition in these countries need to focus on reducing the prevalence of undernutrition without promoting excess weight gain.
- Future economic advances need to consider integrated approaches to improving economic standings of households without increasing risk for overnutrition or increase in consumption of processed foods.
- Interventions promoting consumption of nutrient rich foods, presenting stronger cases to parents & educators as to the importance of diet for improved health and success in schools are recommended (*Hoffman et al., unpublished, 2016).

Why focus on African Traditional Vegetables (AIVs*)?

- Mainstay in traditional diets
- Neglected crops ~ 400 species, rich history, locally adapted, many easy to grow
- Not normally cash crops
- Periods of abundance and periods of scarcity – rainy vs. dry season
- Many contain high levels of nutrients- comparable to European vegetables being rich in proteins, vitamins, minerals and with medicinal/health properties
- Health, Nutrition and Medicinal value – natural bridge linking agriculture and nutrition and health
- Tremendous market potential & undervalued nutrient source
- Consumer interest and levels of consumption largely unrecognized

*African Traditional Vegetables are also called African Indigenous Vegetables (AIVs)

Horticulture Innovation Lab Nutrition Research Program

- Overall goal of our program is to improve the production and increase consumption of African Traditional Vegetables in communities to improve nutrition, income and health outcomes of people at risk for malnutrition in Eastern Zambia and Western Kenya
- Builds upon a prior pilot study which showed significant interest and acceptance in these undervalued crops.
- Using the Rutgers Models of Market-First, Science Driven Development for Income Generation and Increased AIV Consumption

Horticulture Innovation Lab Nutrition Research Program Builds Upon the 4 A's:

Access

Affordability

African Indigenous Vegetables:

Nutrition, Health, Income Generation

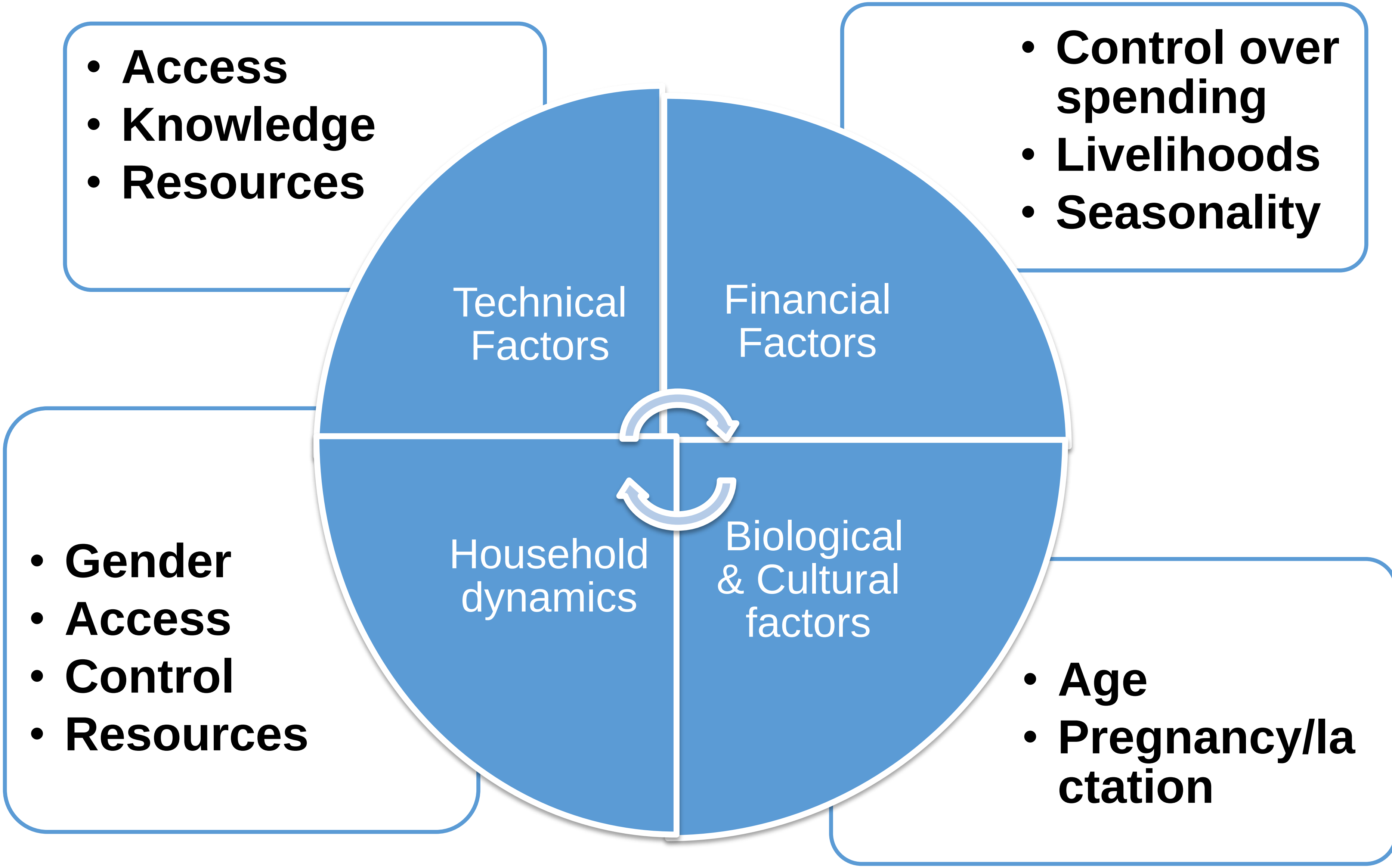
Availability

Adoption

(Increased Consumption)

Leading to Measureable Health Indicators in targeted populations in Kenya and Zambia

Factors Impacting Nutritional Success



Frequency of AIV Consumption: Pilot Survey Zambia

AIV	Rarely	Sometimes	Everyday
Maize Processed	3.9	29.4	66.7
Amaranth	24.1	**69.0**	**6.9**
Nightshade	46.2	**53.8**	0
Spider Plant	39.1	**60.9**	0
Cowpea	59.1	**40.9**	0
Jute Mallow	23.1	**76.9**	0
Kale	26.1	**69.6**	**4.3**
Sweet potato leaves	28.6	**71.4**	0
Orange sweet potato	64.3	**35.7**	0
Okra	26.9	**73.1**	0
Ethiopian mustard	35.3	**64.7**	0
African eggplant	41.4	**58.6**	0
Other AIVs	28.6	**71.4**	0

1=Rarely (once a month); **2**=Sometimes (1-2 times a week); **3**=Every day (6-7 times a week)

Obj. 1 Hypothesis: Appropriate interventions can increase access to and consumption of AIVs among producers & consumers within Kenya and Zambia

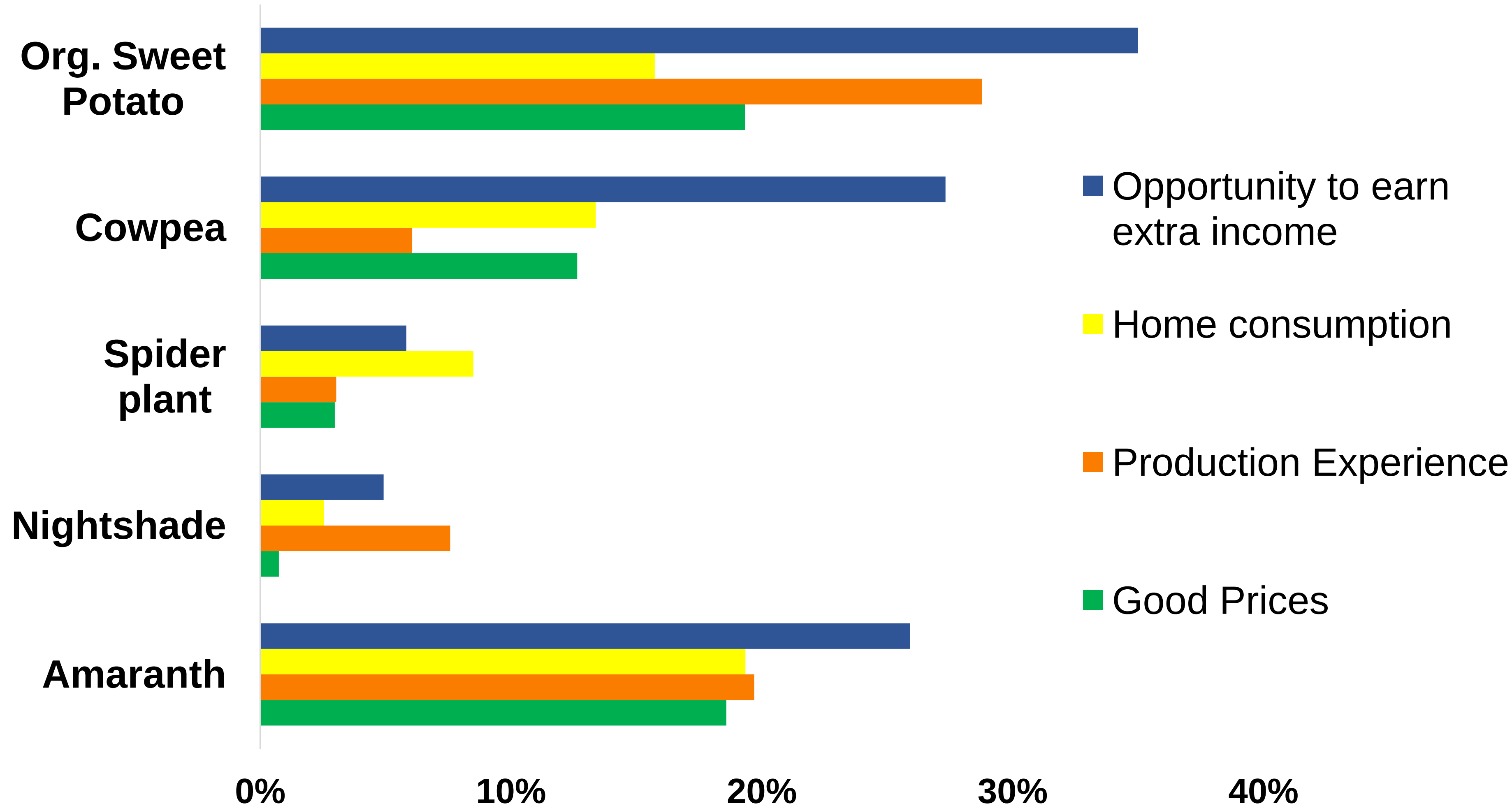
Assessing the context, determine and report the nutritional status, dietary intake and diversity, and AIV consumption for adults in Kenya and Zambia initially using published data and existing datasets.

Food and nutrient intake: Data is being analyzed to determine the following:
Nutritional status
Dietary diversity
AIV consumption by gender, geographical area, season, and income.

Tracking changes to 500 households on dietary intake and diversity & AIV consumption in Kenyan & Zambian communities that are being exposed to AIV production, marketing, and BCC compared to control communities receiving no special treatment

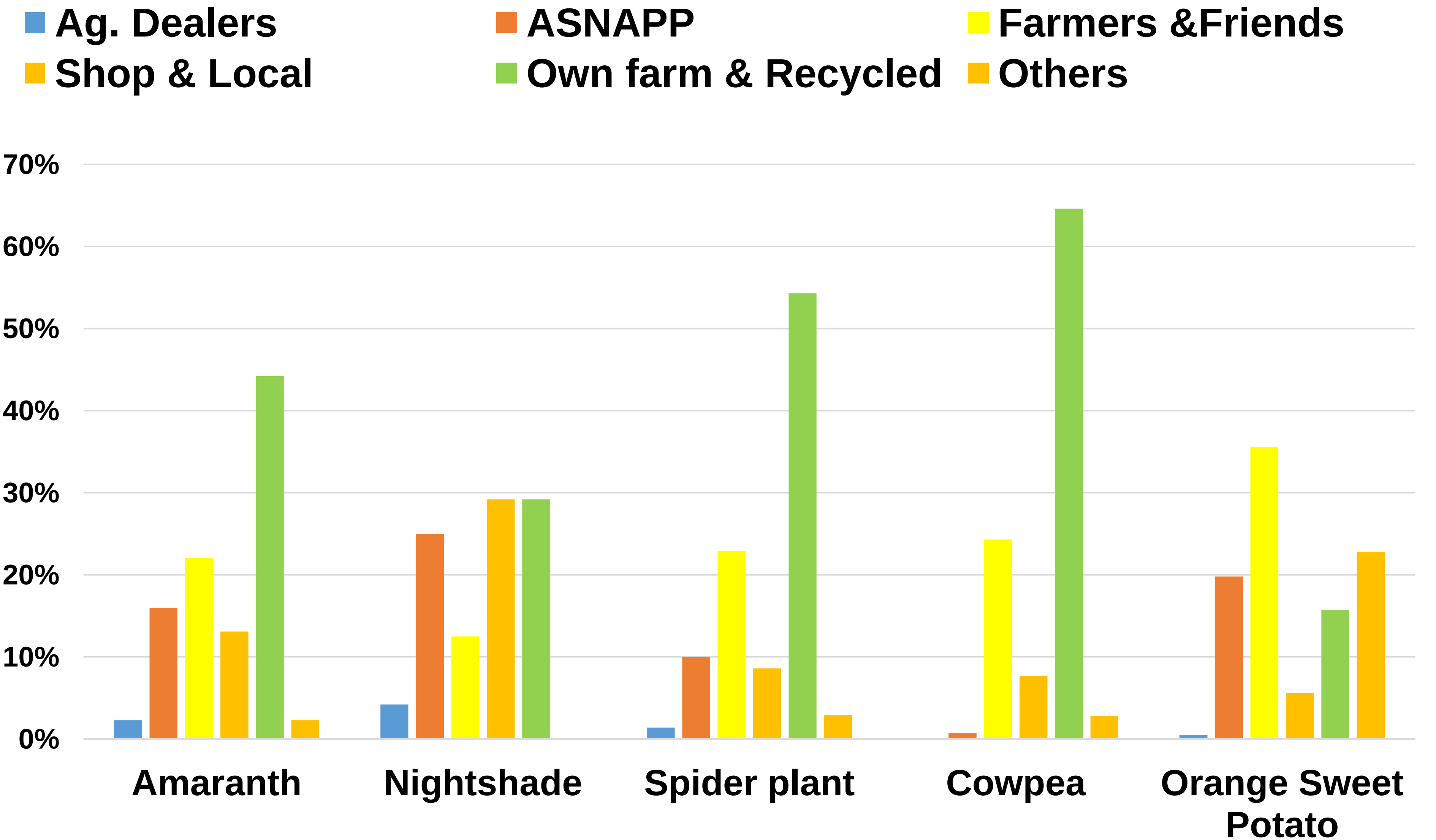
Obj. 2: Hypothesis: Appropriate promotion & expansion of availability of AIVs at the local level will strengthen market access and sales for producers of AIVs:

(Production & Preferences of AIVs)

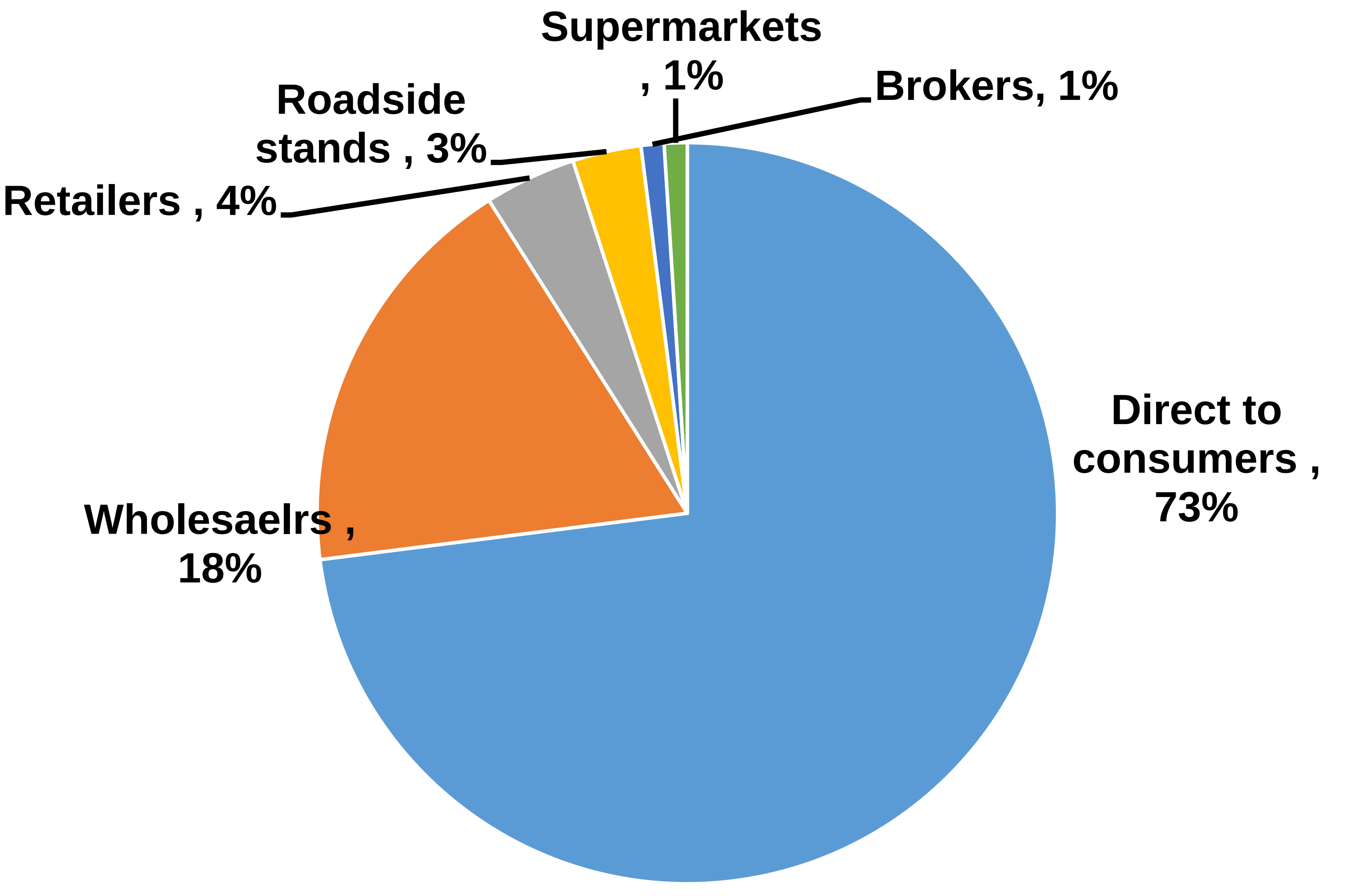


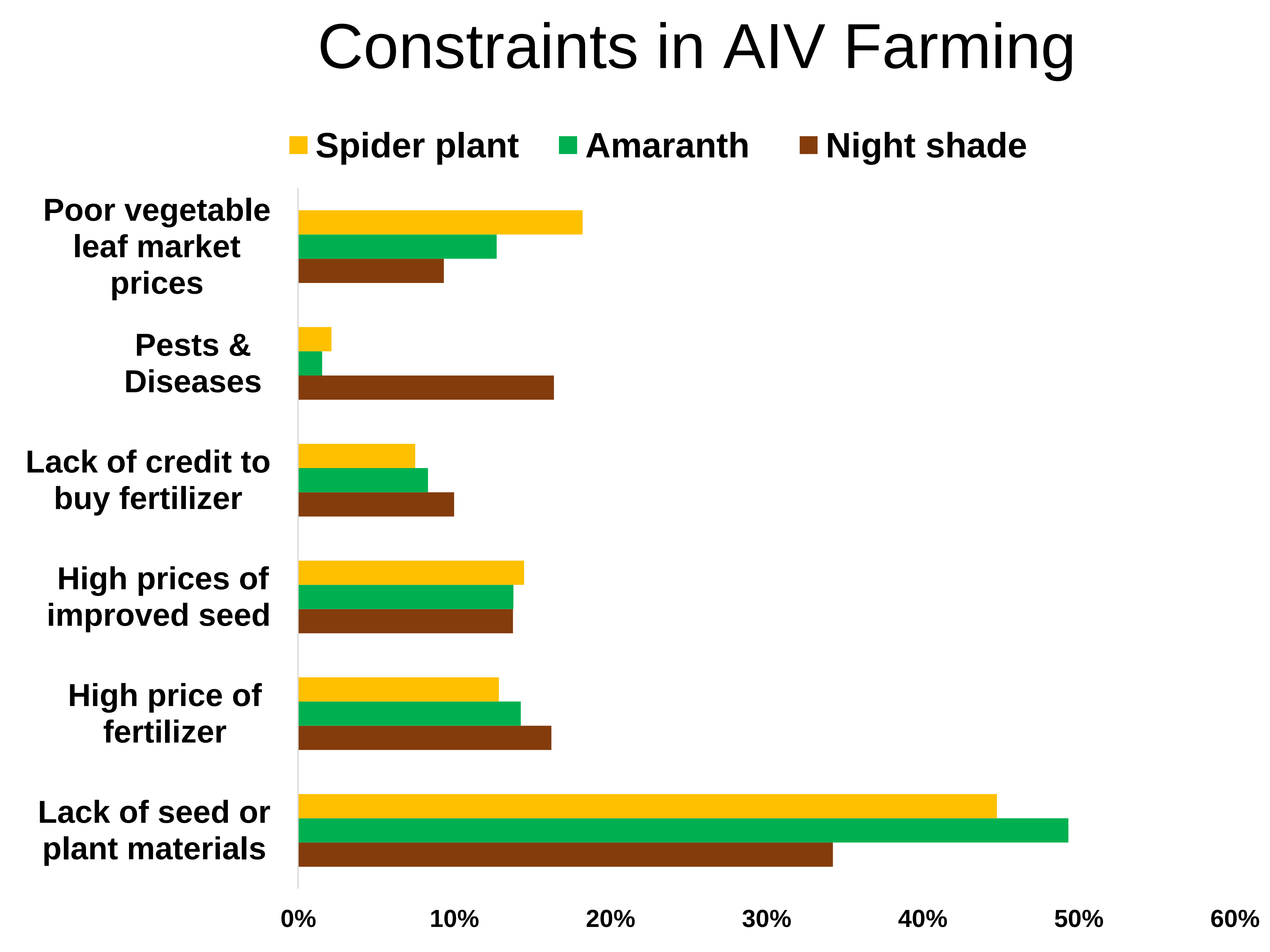
Note : Rest of the % belongs to Other AIV's

From where do they get their African Traditional Vegetables seeds?



AIVs Trading Partners




Constraints in AIV Farming
Spider plant
Amaranth
Night shade
Poor vegetable leaf market prices
Pests & Diseases
Lack of credit to buy fertilizer
High prices of improved seed
High price of fertilizer
Lack of seed or plant materials
0%
10%
20%
30%
40%
50%
60%

Obj. 3. Determine best management practices for AIV production and increase capacity and access to AIVs

- Survey results,
- Focus groups and
- Participatory research guide intervention activities

Obj. 4. Evaluation of nutrient composition of AIVs:

Quantifying AIV nutritional components toward being officially categorized as "nutrient-rich" by comparing to per-100 gram "high-source" thresholds according to *Codex Alimentarius* Guidelines on Nutrition Labeling.

Step 1: Characterizing AIVs as "nutrient-rich"
Step 2: Selection of those species and landraces/varieties which are nutrient rich.

Nutrient	Unit of measure	per 100 gm
Vitamin A	µg	240
Thiamin	mg	0.36
Riboflavin	mg	0.36
Niacin	mg NE	4.5
Vitamin B6	mg	0.39
Folate	µg DFE	120
Vitamin C	mg	18
Calcium	mg	300
Iron	mg	4.2
Zinc	mg	4.5
Vitamin D	µg	1.5
Vitamin K	µg	18
Pantothenate	mg	1.5
Biotin	µg	9
Magnesium	mg	90
Iodine	µg	45

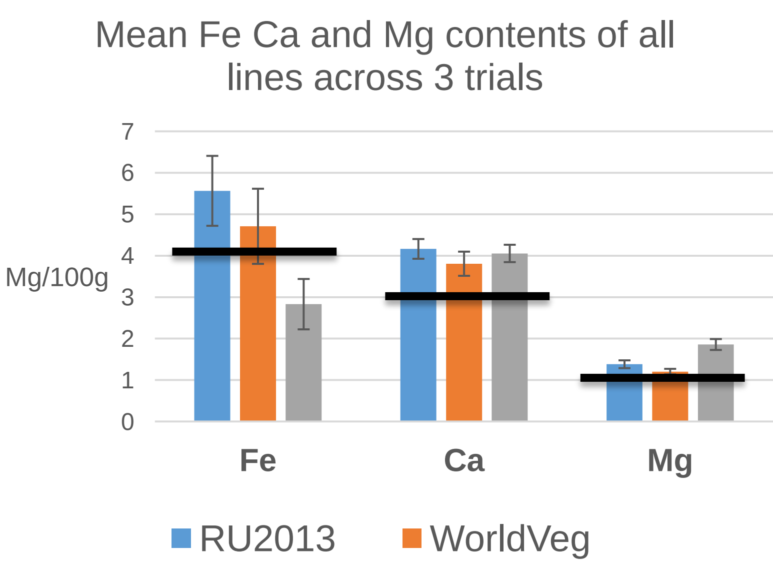
"Problem" nutrients for women and children highlighted

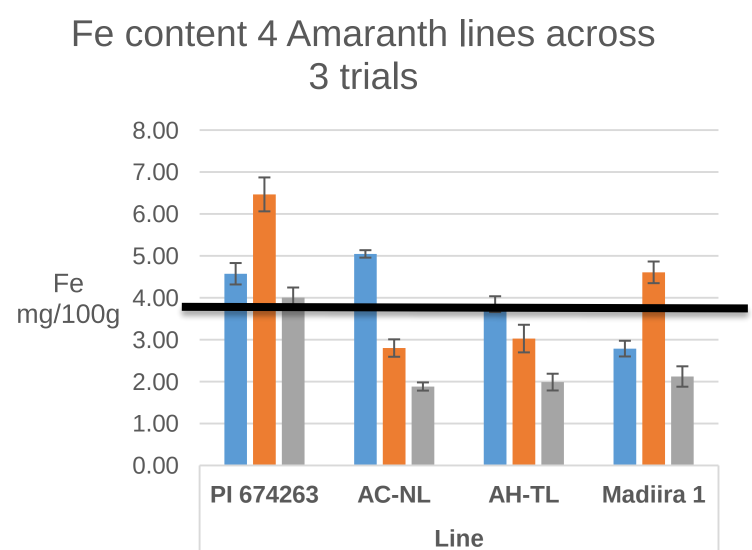
Vegetable amaranth field performance: Identifying those (i) nutrient rich lines; (ii) those acceptable to farmers and (iii) acceptable to consumers/markets

RUAM24 (left) and Madiira (center) in RCB, Arusha, Tanzania 2014. Photo: David Byrnes

Selecting Vegetable Amaranth for Elevated Fe, Ca and Mg

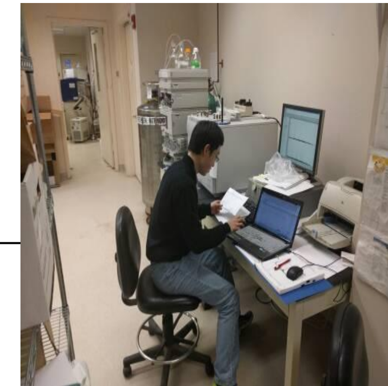
- Ca and Mg above "high-source" thresholds in all amaranth populations *grown in Tanzania and New Jersey in all field trials and across years*
- Fe varies by line and environment; *yet we identified a WVC PI 674263 from which we made further improvements now as an* ***RUM24 High Iron Amaranth***

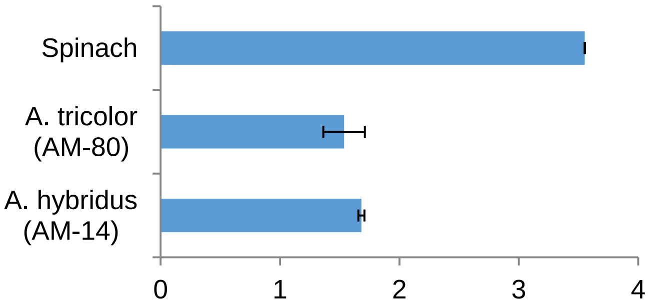




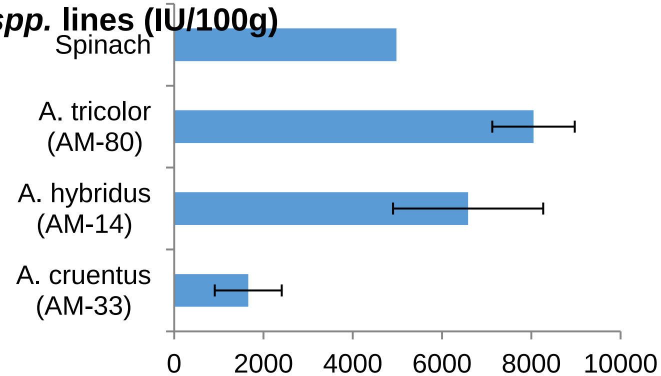
Black horizontal lines represents *Codex Alimentarius* "high-source" thresholds per micronutrient

Amaranth spp.

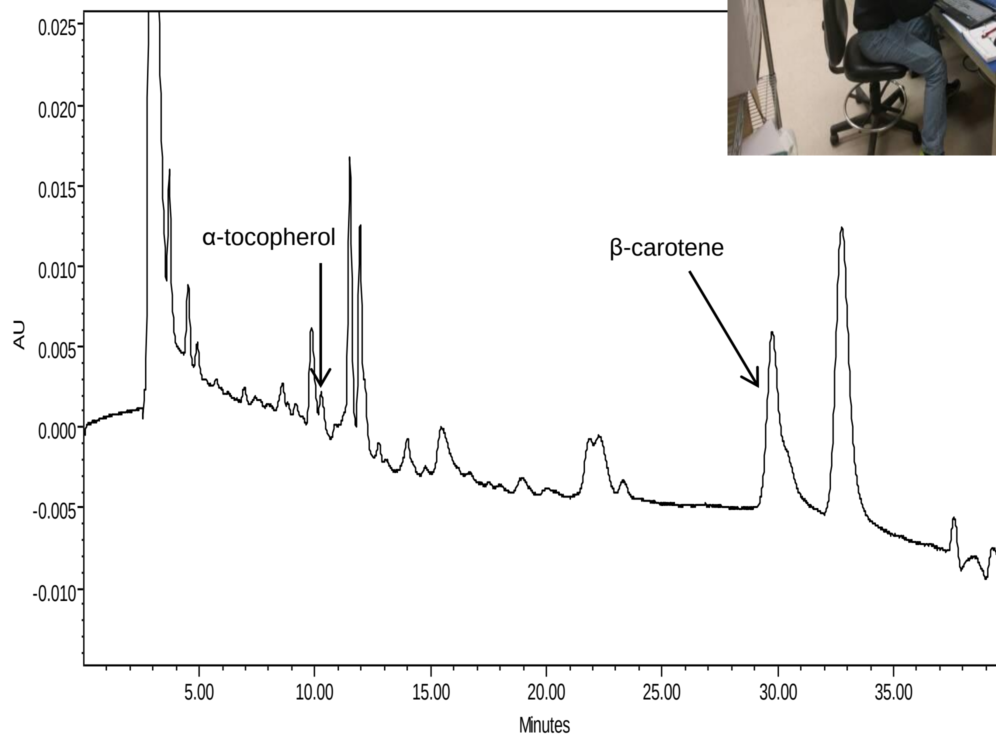




Vitamin E (α-tocopherol) content of *Amaranthus spp.* lines (IU/100g)



Beta carotene content of *Amaranthus spp.* lines (IU/100g)

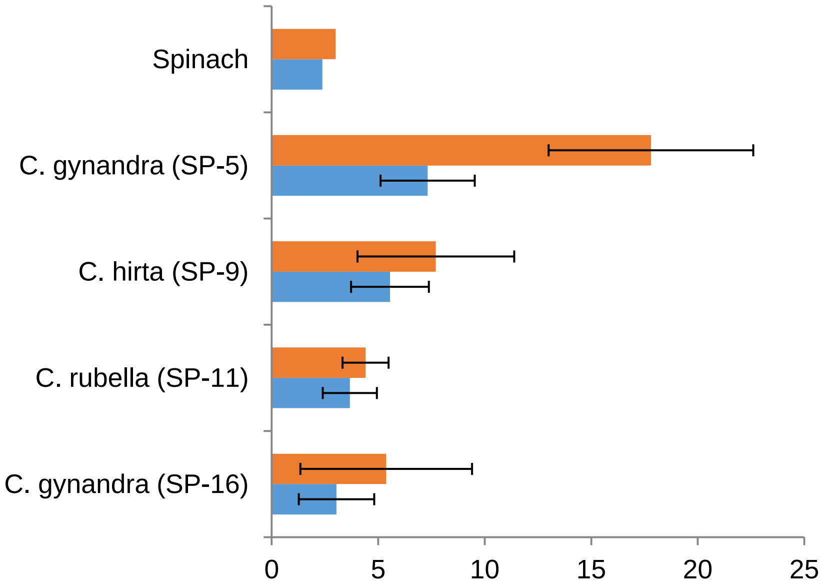


Representative HPLC chromatogram of *A. hybridus* (AM-14) at 290nm

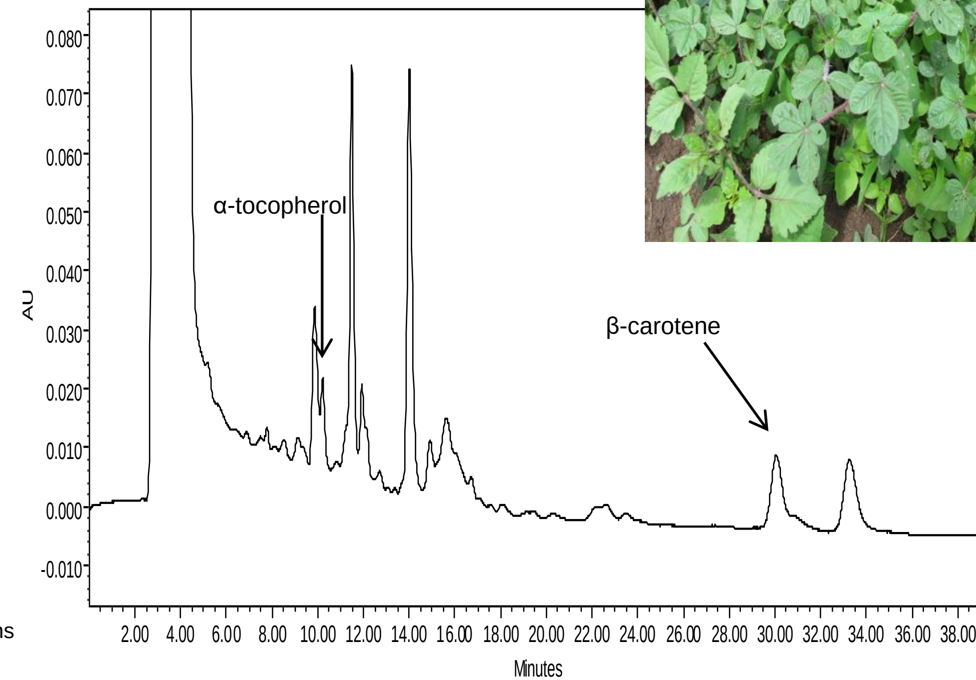
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
A. Cruentus (AM-33)	<0.517	1.00±0.45	<0.77	1659.91±750.14	2.21±0.39
A. Hybridus (AM-14)	1.13± 0.02	3.97±1.01	1.68±0.03	6585.15±1681.74	3.94±0.77
A. Tricolor (AM-80)	1.03± 0.12	4.85±0.56	1.54±0.17	8049.65±923.98	35.70±0.48
Spinach*	2.38	3	3.55	4980	

*USDA online; ** Indian J. Med. Res. 71, 1980 pp

Spiderplant (*Cleome* spp.)



Vitamin E (α-tocopherol-blue) and b-carotene (red) content of *Cleome spp*. accessions (mg/100g)

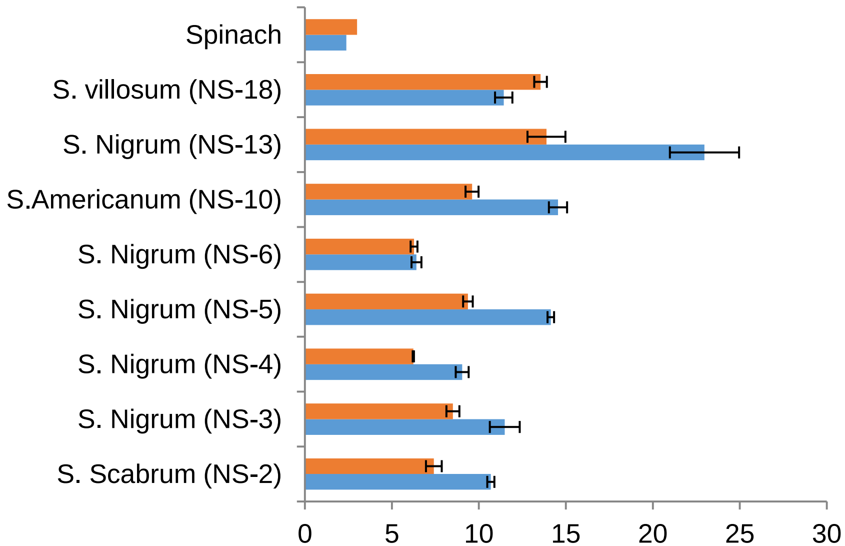


Representative HPLC chromatogram of *C. rubella* (SP-11) at 290nm

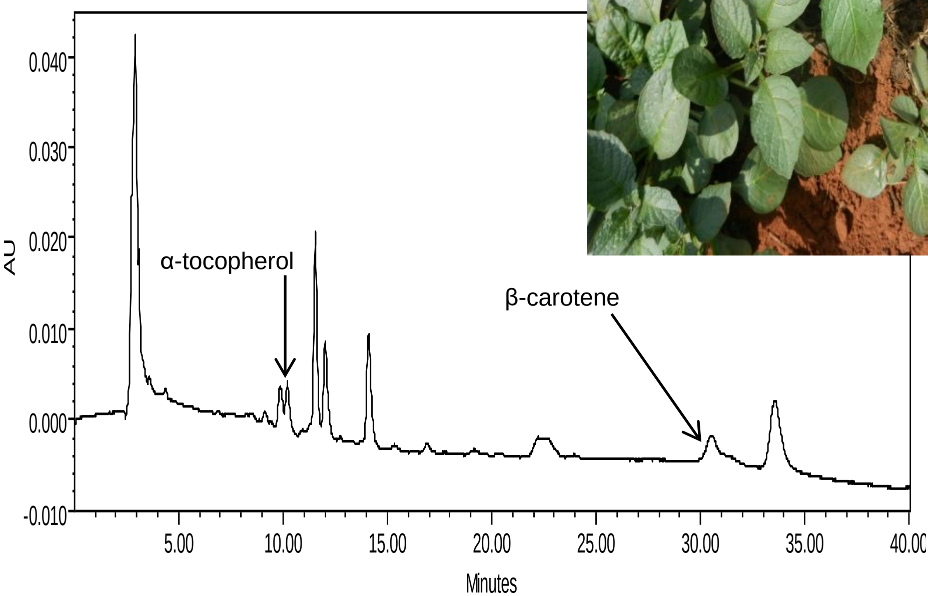
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
C. gynandra (SP-16)	3.04±1.77	5.37±4.03	4.54±2.64	8924.00±6688.92	3.53±0.89
C. rubella (SP-11)	3.67±1.27	4.40±1.08	5.47±1.90	7313.15±1793.79	10.00±0.87
C. hirta (SP-9)	5.55±1.83	7.70±3.68	8.29±2.72	12790.75±6107.05	6.84±1.35
C. gynandra (SP-5)	7.32±2.21	17.80±4.80	10.92±3.30	29551.45±7972.55	6.60±0.96
Spinach*	2.38	3	3.55	4980	

*USDA online; ** Indian J. Med. Res. 71, 1980 pp 53-56

Nightshade (*Solanum* spp.)



Vitamin E (α-tocopherol – blue) and b-carotene (red) content of *Solanum spp*. accessions (mg/100g)



Representative HPLC chromatogram of *S. nigrum* (NS-6) at 290nm

	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
S. Scabrum (NS-2)	10.69±0.20	7.41±0.45	15.95±0.67	12302.07±752.98	3.83±0.35
S. Nigrum (NS-3)	11.49±0.86	8.51±0.37	17.14±0.56	14120.08±619.71	7.31±0.37
S. Nigrum (NS-4)	9.04±0.37	6.23±0.04	13.49±0.05	10343.37±58.46	Pending
S. Nigrum (NS-5)	14.13±0.19	9.37±0.28	21.10±0.41	15555.23±460.88	Pending
S. Nigrum (NS-6)	6.41±0.28	6.27±0.20	9.57±0.29	10411.42±326.37	Pending
S.Americanum (NS-10)	14.55±0.52	9.61±0.37	21.71±0.56	15947.41±621.35	7.22±0.77
S. Nigrum (NS-13)	22.97±1.99	13.88±1.09	34.28±1.63	23047.75±1810.53	Pending
S. villosum (NS-18)	11.43±0.36	13.54±0.36	17.05±0.54	22483.78±602.64	5.76±0.79
Spinach*	2.38	3	3.55	4980	

*USDA online; ** Indian J. Med. Res. 71, 1980 pp 53-56

Possible Anti-Nutrititive Properties- Are Alkaloids Present?

Leaf extracts of Solanum *nigrum* (USDA PI 312110) by HPLC-ESI-MS revealed a lack of alkaloids, yet are rich source of saponins, which are oxygenated analogues of nitrogenous alkaloids.
These can be either good (=bioactive & improve health) or exhibit anti-nutritive properties. BUT: the fruit contained high levels of both alkaloids & saponins.

No.	Retention time/min	compounds tentative identification	molecular ions and fragments identification (HPLC-ESI-MS)
1	9.5	dehydrodiosgenin-G-G-R-R	$[M+ACN]^+$ 1069.9, $[M+H]^+$ 1030.0, 883.8, 737.7, 575.6, 413.6
2	10.5	diosgenin-G-G-R-R (isomer 1)	$[M+ACN]^+$ 1071.9, $[M+H]^+$ 1031.9, 885.9, 739.8, 577.7, 415.5
3	12.6	diosgenin-G-G-R-R (isomer 2)	$[M+H]^+$ 1031.6, 885.7, 739.7, 577.6
4	14.3	diosgenin-G-G-R-R (isomer 3)	$[M+H]^+$ 1031.6, 885.5, 739.6, 577.6

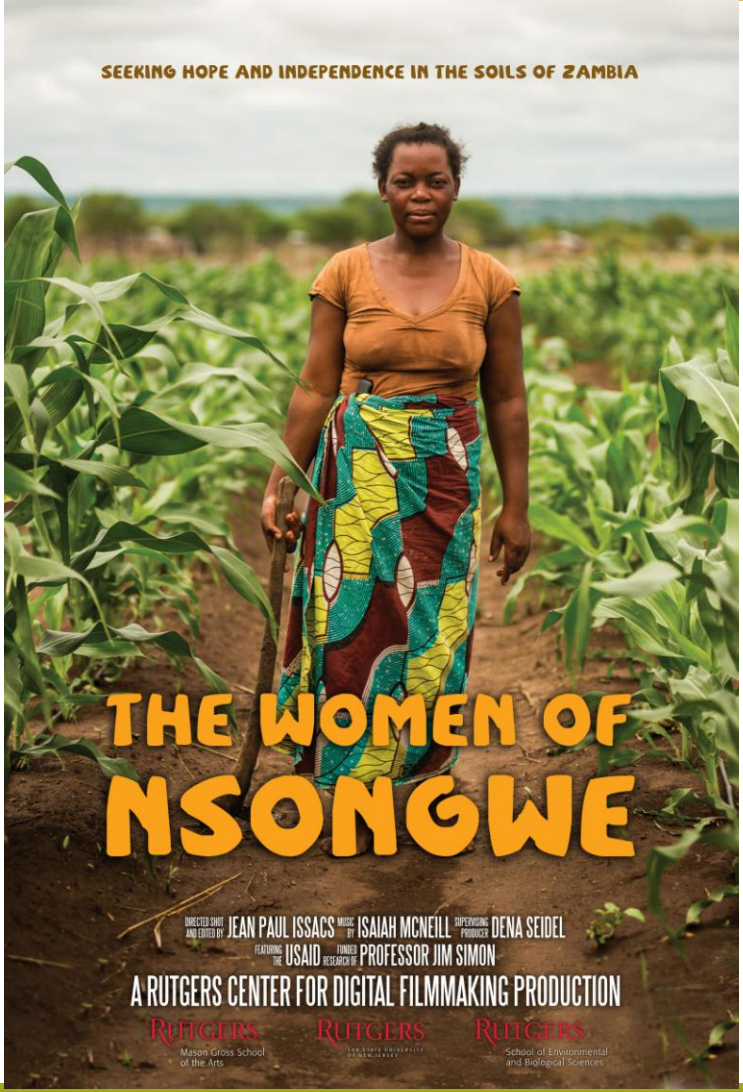
Nutritional Benefit of Moringa: Mineral Content

Mineral	Range of Milligram Nutrient/100g sample	Daily Value (%)*	Source Threshold**
Iron	**13-41**	**72-225%**	**High**
Magnesium	**260-380**	**65-95%**	**High**
Calcium	**1330-1870**	**133-187%**	**High**
Zinc	**1.6-3.2**	**11-21%**	**High**

*Daily Value Based on FDA standards; **Threshold based on Codex Alimentarius standards

Figure : Compares the mineral composition of Moringa dried leaves grown in Zambia in this project with both the FDA and CODEX for daily values and threshold respectively. Moringa is both a **high source of Iron and Zinc**, making it a very important crop for cultivation in areas such as Zambia

Recommendations: Hear it in Their Voices



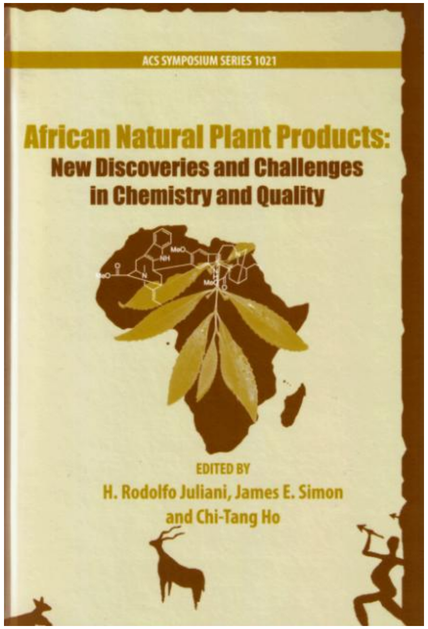
Women of Nsongwe
https://vimeo.com/127078444

For AIVs:
https://vimeo.com/1069643

Challenges

- Need greater understanding as to current best intervention practices that will lead to increased consumption of fresh produce including AIVs.
- Rural communities and peri-urban households need greater access to affordable AIVs.
- AIVs often unavailable particularly during dry seasons.
- Strengthening of AIV value chains needed from access to improved varieties, fertilizer and more. SWOT analyses have been conducted in both Kenya and Zambia (with 200 producers and >50 intermediaries in each country) to identify the gaps; dietary diversity studies now ongoing in Kenya and Zambia.

Using our Market-First Science-Driven Models



academicJournals

Vol. 15(7), pp. 199-206, 17 February, 2016
DOI: 10.5897/AJB2015.14936
Article Number: 4770CF157195
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Ascorbic acid content in leaves of Nightshade (*Solanum spp.*) and spider plant (*Cleome gynandra*) varieties grown under different fertilizer regimes in Western Kenya

Emmanuel Ayua[1], Violet Mugalavai[1]*, James Simon[2], Stephen Weller[3], Pamela Obura[3] and Naman Nyabinda[4]

[1]Department of Family and Consumer Sciences, University of Eldoret Box 1125-30100, Eldoret, Kenya.
[2]New Use Agriculture and Natural Plant Products Unit, Department of Plant Biology and Plant Pathology, Rutgers University, New Brunswick, NJ, USA.
[3]Horticulture Department, Purdue University, West Lafayette, IN, USA.
[4]Academic Model Providing Access to Healthcare (AMPATH), P.O Box 4606, Eldoret, Kenya.

Received 21 August, 2015; Accepted 25 January, 2016

Vitamin C is an important micronutrient because of its antioxidant and health promoting properties. With the introduction and commercialization of improved African indigenous plants, few studies have examined the impact of leaf age or the nutrient status of the plants by fertilizer. This study sought to determine amounts of vitamin C using redox titration in mature and immature leaves of spider plant

Sustainable production for more resilient food production systems: case study of African indigenous vegetables in eastern Africa

S.C. Weller[1], E. Van Wyk[2] and J.E. Simon[3,a]

[1]Dept. Horticulture & Landscape Architecture, West Lafayette, IN 47907-2010, USA; [2]AgriSmart, Lusaka, Zambia; [3]New Use Agriculture and Natural Plant Products, Dept. Plant Biology & Plant Pathology, Rutgers University, New Brunswick, NJ, 08901 USA.

Abstract

African indigenous vegetables are an important crop for providing nutrition, improved health and income security to African populations. Often considered as underutilized crops, these indigenous and naturalized fruits and vegetables generally harvested from wild populations are easy to grow, often require lower inputs than the European and 'western' vegetables, are more adapted to local conditions and environmental stress, and could provide local opportunities for income generation and improving health and nutrition. This paper focuses on the incorporation of African indigenous vegetables as additional crop enterprises to their traditional agronomic ones to provide more resilient food production systems for smallholder farmers in sub-Saharan Africa. This work highlights only a few such indigenous vegetables including amaranth (*Amaranthus* spp.), African nightshade (*Solanum scabrum*, *S. villosum*) and spiderplant (*Cleome gynandra*) while others including African kale (*Brassica carinata*), cowpea (*Vigna unguiculata*) leaves and African eggplant (*S. aethiopicum*), are common staple crops for smallholder farmers and rural populations in eastern Africa. We posit that by strengthening the African Indigenous Vegetables (AIVs) using a market-first approach to overcome constraints along the value chain leading to improved production practices, supply, postharvest handling, distribution and consumer acceptability of AIVs, opportunities for smallholder farmers to become more engaged in the supply chain will emerge. These key ingredients are needed to develop a sustainable and resilient AIV system providing opportunities to smallholders. We suggest that focus is needed first on improving AIV genetic materials, then ensuring systems are put in place for growers to access such materials, coupled with the development of sustainable production and postharvest systems that allow for year-round production as well as seed production/saving techniques. By doing this in parallel and in partnership with industry and the private sector, greater gains can be made in improved market access and building capacity of stakeholders through outreach programs across the AIV value chain while creating awareness of health and nutritional benefits of AIVs which further serve to drive market demand.

Keywords: African indigenous vegetables, traditional vegetables, amaranth, moringa, nightshade, spiderplant, *Amaranthus* spp., *Cleome gynandra*, *Moringa oleifera*, *Solanum scabrum*, *S. villosum*, *S. nigrum*, diversity, health and nutrition, income generation, market-first, science-driven

INTRODUCTION

Sub-Saharan Africa (SSA) is the only major region in the world where poverty is increasing rather than decreasing and where human development indicators are worsening. An estimated 925 million of the world's population are undernourished. Of these, 239 million (representing 26%) are inhabitants of sub-Saharan Africa (FAO, 2010) and

[a]E-mail: jimsimon@rci.rutgers.edu

State of Nutrition in Sub-Saharan Africa: Case studies from Kenya and Zambia

Daniel J. Hoffman[1,*], Thomas Cacciola[1], Pamela L. Barrios[1], and James E. Simon[2]

SUBMITTED TO:

JOURNAL OF POPULATION HEALTH AND NUTRITION

[1] Department of Nutritional Sciences, Rutgers, the State University of New Jersey
[2] Department of Plant Biology & Plant Pathology, Rutgers, the State University of New Jersey
* Corresponding author: dhoffman@aesop.rutgers.edu

Considerations

- Project findings indicate that in the targeted rural and peri-urban households in western Kenya and Eastern and central Zambia AIVs are known to over 90% of the populations and viewed as culturally acceptable, desired as preferred food options but they are still rarely to periodically only consumed. This translates to a potential untapped market demand of millions.
- A systems approach to enhance access, and adoption (production and consumption) has been leading to significant new income generation opportunities to those that were not previously involved in commercial horticulture production and a greater awareness to communities of their nutritional and health value.

Lessons Learned

- Small-holder farmer yields on AIVs limited due to poor soils, low fertility, low inputs, lack of knowledge, and not considered 'commercial crops'.
- Improved varieties recognized by growers are needed.
- Improved water management needed
- Pest management important
- Improved postharvest handling from farm-storage-cleaning/grading & transportation
- Need collection centers/aggregation points for bulking
- Educational and outreach programs are effective in increasing interest and awareness of the benefits of AIVs.
- New introduced AIV lines (mostly originating from collaboration with WVC) are being well accepted by growers.

Key Takeaways

- Households and communities in rural areas are far more interested AIVs (and other horticultural crops) when they can be used to generate income streams over the year as well as have greater access to use them in their own household preparations.
- Using a market-first approach including surveys and focus groups as to what they now consume vs. what they would consume is an effective way to plan interventions and build-in sustainability strategies from the outset.
- Effective BCC venues can be identified by community members.
- AIVs targeted in this project are among those selected by those surveyed and which can be scientifically shown to be nutrient rich. Nutritional benefits can be a key driver in the increased consumption & trade in indigenous plants such as AIVs.

Acknowledgements: The Horticultural Innovation Research Nutrition Team

Led by Rutgers University and Purdue University:

Jim Simon, PI, Rutgers, Horticulture, Breeding, Natural Products and Nutrition
Steve Weller, co-PI, Purdue, Horticulture/ Production Systems
Dan Hoffman, co-PI, Human Nutrition
Ramu Govindasamy, co-PI, Economics, Marketing, Consumer studies
Qingli Wu, chemistry, pharmagnosy and nutrition of AIVs

Rutgers:
Xenia Morin, Qingli Wu, Albert Ayeni

Ph.D. Graduate Students: David Byrnes, Thomas Villani, Ariane Vasitalis, Bo Yuan, Dan Giurleo, Bernie Somers; William Reichert; and Surendran Arumugam (postdoc)

Purdue:
Steve Yaninek (Pest Management)

Kenya
AMPATH and Moi University:
Naman Nyabinda
Norah Maiyo

University of Eldoret:
Linnet Gohole
Angeline Mnene (MS student)

Kenya Agric. Res. Institute (KALRO):
Christine Nyabinda
Martins Odendo

AVRDC, Tanzania:
Fekadu Dinssa
Victor Afari-Sefa
Hassan Mndiga

Zambia:
AgriSmart
Emil Van Wyk
Lupiya Sakala
Muunga Mapenzi
Inonge Siziya (MS student, UNZA)
Kenneth Chali

University of Zambia
John Shidano

Catholic Relief Services, MAWA

UC-Davis:
Beth Mitcham
Britta Hanson

USAID:
John Bowman

USAID FROM THE AMERICAN PEOPLE
HORTICULTURE INNOVATION LAB
UCDAVIS UNIVERSITY OF CALIFORNIA