African Indigenous Vegetables, a Neglected Treasure, for Improved Nutrition and Income in Eastern and Southern Sub-Saharan Africa

Jim Simon, PI, Rutgers; **Steve Weller,** co-PI, Purdue; **Dan Hoffman,** co-PI, **Ramu Govindasamy,** co-PI, **David Byrnes, Emil Van Wyk**, AgriSmart, Zambia; **Fekadu Dinssa**, World Vegetable Center; **Naman Nyabinda,** AMPATH-Kenya**; Martins Odendo & Christine Ndinya**, KALRO-Kenya; **Xenia Morin**, Rutgers; **Qingli Wu**, Rutgers; **Steve Yaninek,** Purdue; **Linnet Gohole**, Eldoret

Projected Population Growth (billions)

Region	2011	2050	Change	Percent
World	6.9	9.5	+2.6	+ 38
High Income	1.2	1.3	+ 91	+ 7
Low Income	5.7	8.2	+2.5	+ 44
East & S.E. Asia	2.2	2.3	+ 125	+ 6
South Central Asia	1.8	2.6	+ .8	+ 43
Sub-Saharan Africa	.9	2.0	+1.1	+134
Lat. America/Carib	.6	.7	+ 150	+ 25
N. Africa & W. Asia	.45	.73	+ .27	+ 61

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

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

- **Undernutrition is decreasing in many developing regions but parts of SSA have only begun "nutrition transition";**
- **Efforts to reduce undernutrition must focus on reducing undernutrition w/o promoting excess weight gain;**
- **Economic advances must consider integrated approaches to improved household economics w/o increasing over-nutrition;**
- **Advance maternal education & household wealth w/o introducing processed foods and/or foods not of traditional diets;**
- **Interventions should promote consumption of nutrient rich foods with interventions showing importance of diet for improved health for all and success of children in school.** *Hoffman et al. 2017. J. Health, Population and Nutrition 36:27

Why Focus on African Indigenous Vegetables (AIVs)?

- **AIVs address serious undernutrition problems in sub-SSA;**
- **AIVs are a mainstay in traditional diets;**
- **Neglected crops ~ 400 species, rich history and locally adapted;**
- **Not normally cash crops but with growing urban markets have potential for income generation to smallholders;**
- **Our research can overcome periods of abundance and periods of scarcity through improved production practices and scheduling;**
- **Many AIVs contain high essential nutrients, proteins, vitamins, minerals and possible medicinal/health properties;**
- **Natural bridge linking agriculture and improved nutrition and health.**

Horticulture Innovation Lab Nutrition Research Program:

- **Goal of program is to improve production and increase consumption of AIVs to improve nutrition, generate income and improve health of nutritionally at risk populations in Eastern and Central Zambia and Western Kenya;**
- **Program builds upon a previous studies showing significant interest and acceptance of AIVs by rural farmers;**
- **We use the Rutgers Models of Market-First and Science Driven Development for Income Generation and Increased AIV Consumption.**

Challenges

- Need greater understanding 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, other inputs. SWOT analyses have conducted in Kenya and Zambia (with 200 producers and >50 intermediaries in each country) to identify the gaps and from that to build interventions programs to meet those needs.

Considerations

- Project findings indicate in the targeted rural and peri-urban households in W. Kenya and E. and central Zambia AIVs are known to > 90% of the populations. AIVs in these countries are viewed as culturally acceptable, desired as preferred food options, yet rarely to periodically consumed.

- This translates to a potential untapped market demand (millions of dollars) and major economic opportunity for growers and > consumers access to nutrient rich foods of interest to them.
- Our systems approach has enhanced access and adoption (production and consumption) and leading to significant new income generation opportunities to those not previously involved in commercial horticulture production; and a greater awareness to nonproducing communities of the AIV nutritional and health value.

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

Access

Affordability

African Indigenous Vegetables:

Nutrition, Health, Income Generation

Availability

Adoption*

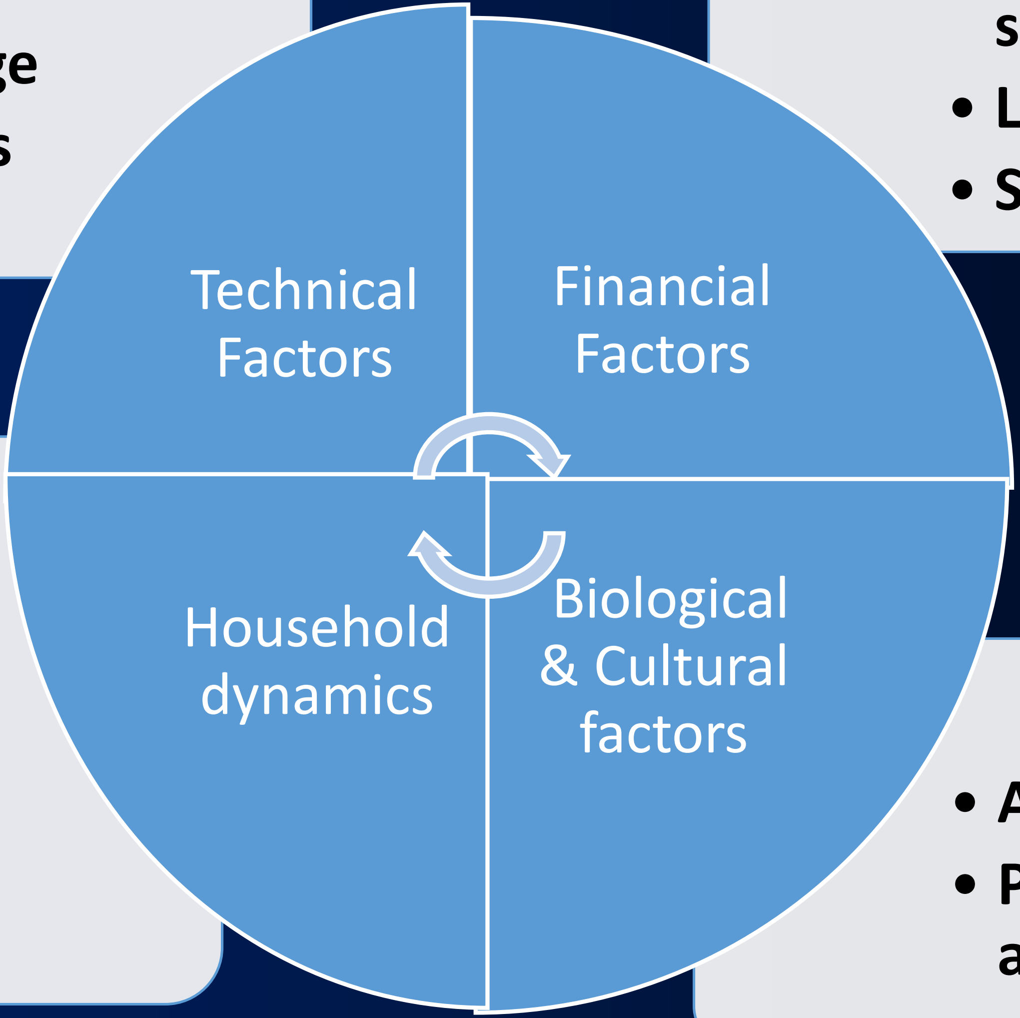
(Increased Consumption, and to others increased production)

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

Factors Impacting Nutritional Success

- Access
- Knowledge
- Resources

- Control over spending
- Livelihoods
- Seasonality



- Gender
- Access
- Control
- Resources

- Age
- Pregnancy/lactation

Frequency of AIV Consumption Pilot Survey Zambia

AIV	Rarely	Sometimes	Everyday
Green Maize (fresh)	66.7	29.4	3.9
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 in Kenya & Zambia.

Lesson 1. Developing & identifying the most effective intervention methods toward improved access, affordability, availability, and adoption of AIVs must be based on solid survey consumer data

Pilot survey's conducted indicated:

1. AIVs very popular- but not consumed regularly!
2. **Kenya's and Zambians would opt to consume AIVs** (at greater frequency and quantities) but don't due to issues of **access, affordability, availability**, with **many unaware of their nutritional benefit**.
3. **Preference for specific AIV and their popularity drives our R&D**.

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.

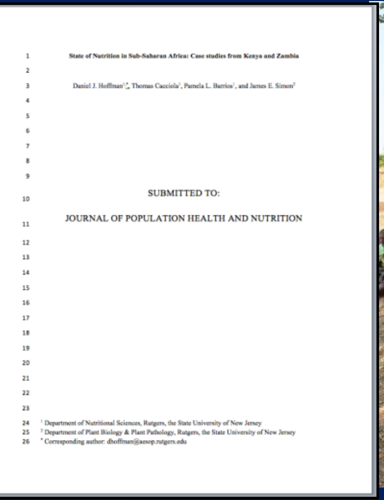
Women's Dietary Diversity

Lessons Learned from Pilot Study in Kenya and Zambia

- Collected data on household consumption and dietary diversity
- Data used to inform subsequent baseline data collection in 2016

Average WDD score was below 5, indicating low dietary diversity

WDD is a robust outcome that will allow for differentiation between groups studied in 2017 and 2018



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:

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[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

Consumer Surveys Conducted to Compare Effect of Production and Nutrition-education Interventions – Done after Preliminary Survey

500 households with at least one woman of childbearing age and at least one child were surveyed in both Kenya and Zambia in 2016 to evaluate baseline AIV production & consumption in communities prior to intervention activities.

Our Approach:

125 households are now either being provided with: (T1) Nutrition education intervention activities; (T2) Production intervention activities; (T3) Both types of intervention activities; and (T4) A Control group treatment

Follow-up consumption surveys following intervention activities will allow a quantitative evaluation of the effect of each intervention approach.

Sites of Surveys and Interventions in Zambia and Kenya

USAID | ZAMBIA

Status of African Indigenous Vegetables in Zambia: Baseline Production Survey and Analysis

May 2016

Lesson 2: ***98.8%*** producers want access to better management practices, technology and pest management

Action Plan - Promote AIV Cultivation, Marketing & Consumption

- AIV intervention for producers consists of a series of discrete activities to promote AIV cultivation and marketing for those providing fresh produce to informal and formal market.
- One goal of AIV intervention is to increase availability of AIVs in target communities all year long!
- Nutrition program and the nutrition interventions are different and will:
  - Evaluate if learning about the nutritional and health benefits of AIV increases consumption among non-producers as our primary dietary diversity surveys and goals are to increase consumption and adoption of AIVs when they are accessible, affordable and available. That is, our primary focus is on consumers that are not involved with actual production of AIVs within select communities of Kenya and Zambia.

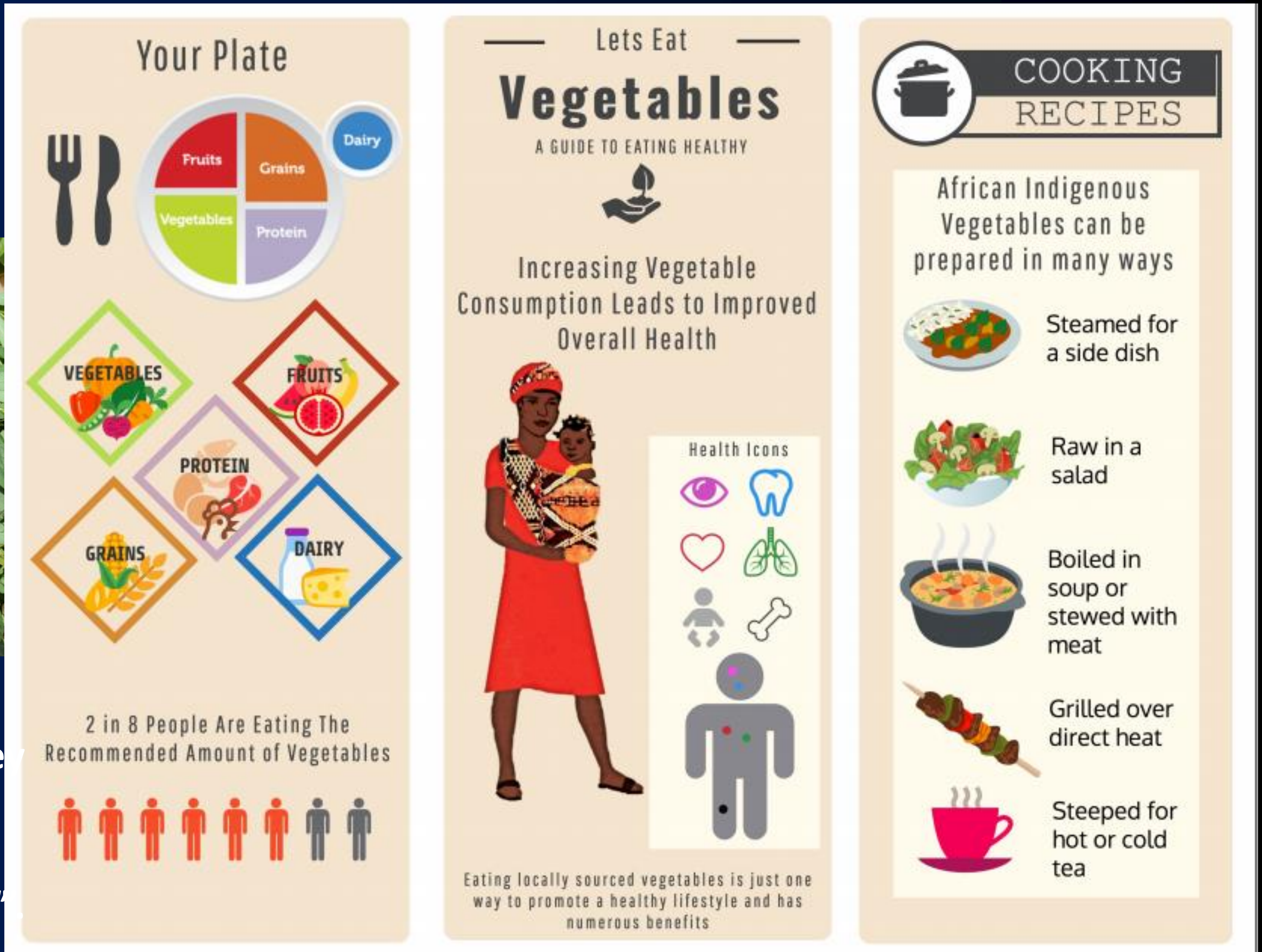
Nutritional Evaluation of AIV Intervention

- **Determine change in AIV consumption and dietary quality between a community that participates in the intervention and a control community.**
- **Assess change in AIV consumption and dietary quality following study for consumption patterns and to determine appropriate nutritional interventions.**

Nutrition Education Intervention (BCC)

500 Individuals in Kenya and 500 in Zambia will be provided with on-going nutrition education trainings (BCC):

- **Nutrition content of AIVs**
- **Recommended intake amount**
- **Health Applications**
- **Recipes and meal preparations**



Lesson 4 Learned: Parents, grandparents and even **school teachers far more excited about AIVs when the understand their nutritional content! Source of pride, source of tradition, easy to collect yet still perceived to be wild harvested not cultivated and "*undervalued*"**

Obj. 2: Hypothesis: Appropriate Promotion and Expansion of Availability of AIVs at the Local Level will Strengthen Market Access and Sales for Producers of AIVs:

In each Zambia and Kenya, 300 AIV producers and 75 intermediaries were surveyed to identify the most substantial bottlenecks in productivity to guide the focus of production interventions.

Lesson 3. Growers report AIV requires same level of management and skills as vegetables and report difficulties in:

*Access to seeds and plant materials; unaware of improved germplasm; identified problems with some current AIVs; high price of fertilizers and farm credit limiting, and insect problematic with a few AIVs. 75% of producers cant access credit (agric. inputs after medical bills identified as primary use of credit)

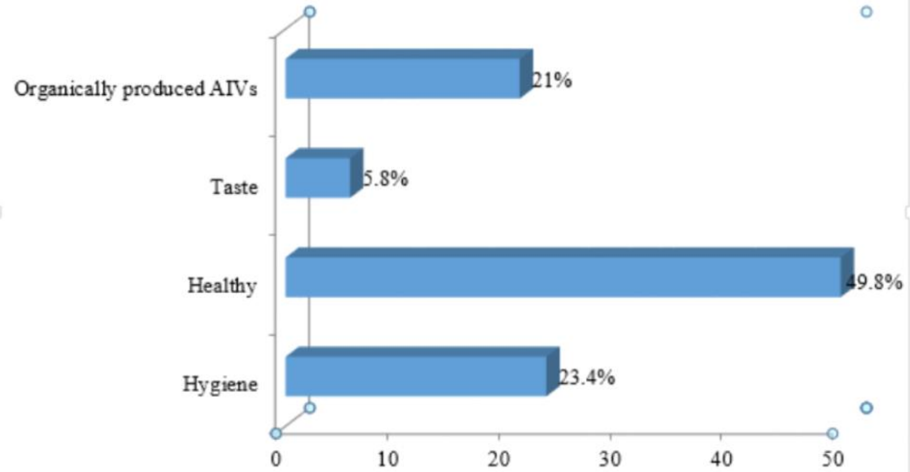
A vast majority (88%) of the respondents felt that there was no difference in overall farming experience between the production and sale of AIVs compared to other vegetable (Table 3.6.5).

Table 3.6.5: Existence of difference between production and sale of AIVs

S.NO	Particulars	Frequency	Percent
1.	No	256	88
2.	Yes	35	12
	Total	291	100

The respondents attributed their willingness to pay a premium (Figure 3.6.7) for certain improved characteristics like healthiness (50%), hygiene (23%), taste (6%), and organically produced AIVs (21%) if they were to buy their AIVs in the market.

Figure 3.6.7: Willing to pay (WTP) a Premium Price



Amongst the respondents, about 61% had sold AIVs in the past 2 years (Table 3.6.6). Orange sweet potato ranked first at 318 kg in terms of quantity sold (Table 3.6.7) in the last completed

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S.No	Particulars	Very much	Much	Moderate	A little	Not at all	Total
1.	Amaranth	119	56	35	1	1	212
	%	56.1	26.4	16.5	0.5	0.5	100
2.	Nightshade	11	10	4	1	0	26
	%	42.3	38.5	15.4	3.8	0	100
3.	Spider plant	46	10	14	4	0	74
	%	62.2	13.5	18.9	5.4	0	100
4.	Cowpea	75	31	12	4	0	122
	%	61.5	25.4	9.8	3.3	0	100
5.	Jute mallow	23	8	4	1	0	36
	%	63.9	22.2	11.1	2.8	0	100
6.	Kale	17	7	4	2	0	30
	%	56.7	23.3	13.3	6.7	0	100
7.	Sweet Potato Leaves	165	30	17	2	6	220
	%	75	13.6	7.8	0.9	2.7	100
8.	Orange Sweet Potato	108	21	14	38	0	181
	%	59.7	11.6	7.7	21	0	100
9.	Okra	83	38	5	3	1	130
	%	63.8	29.2	3.8	2.3	0.8	100
10.	Other	8	10	1	0	0	19
	%	42.1	52.6	5.3	0	0	100

The buyers were also asked to rank their preferences in characteristics that they look for when they buy AIVs (Table 3.6.18). Appearance (34%) and freshness (18.4%) were ranked the most for amaranth. These two characteristics were ranked at 36% each for nightshade, at 29% and 20% for spider plant. It was nutritive quality (31%) and freshness (8%) for cowpea. Appearance (19%) and marketability (11%) topped the list for jute mallow, and for kale it was 27% and 13% respectively. Appearance (34%) and tolerance towards diseases and pests (8%) topped the list for sweet potato leaves. Nutritive quality (24%) and appearance (17%) topped the list for orange sweet potato and it was freshness (30%) and appearance (20%) for okra. In general the top two characteristics that the buyers look for when they buy AIVs is appearance and freshness.

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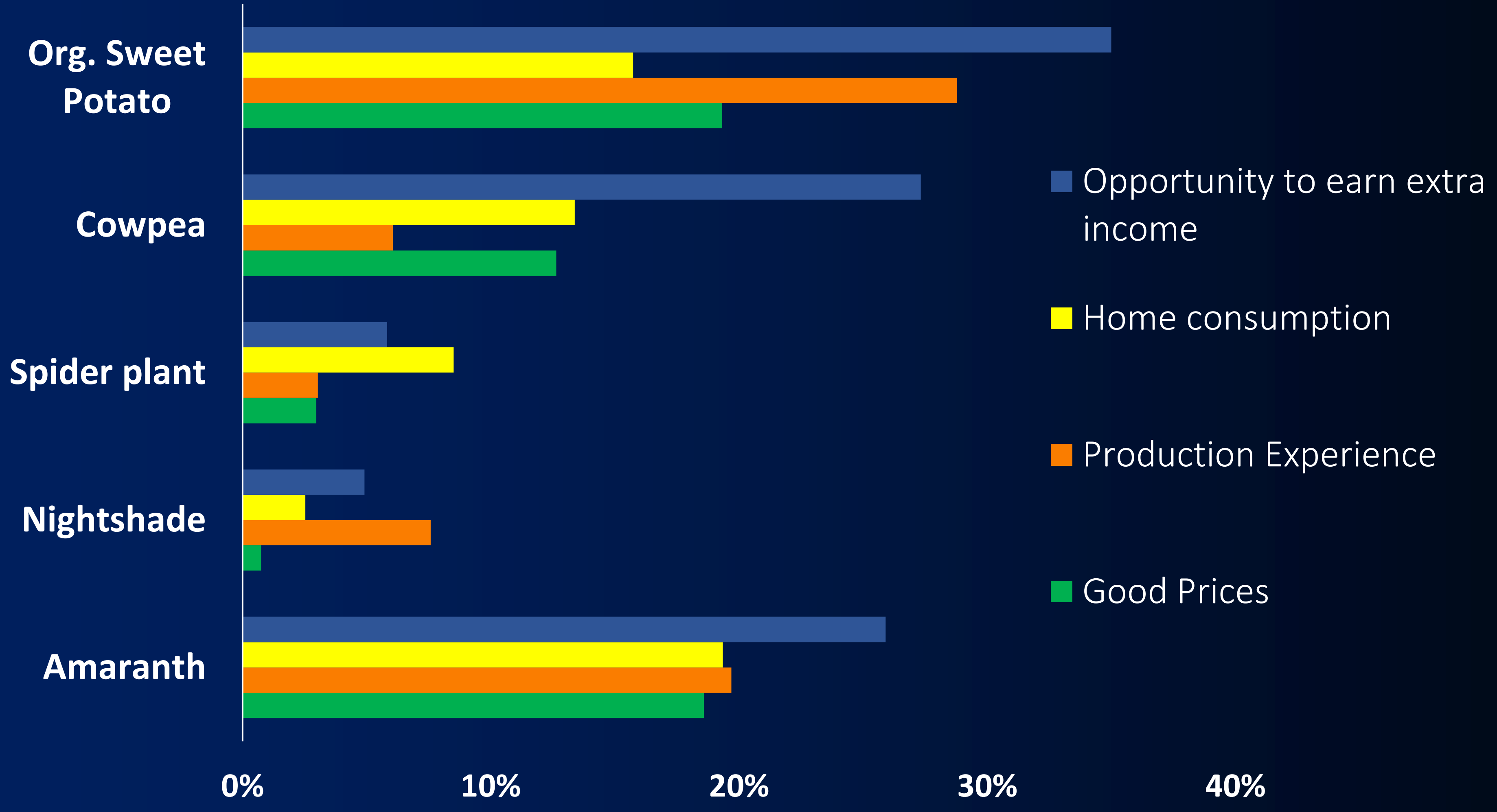
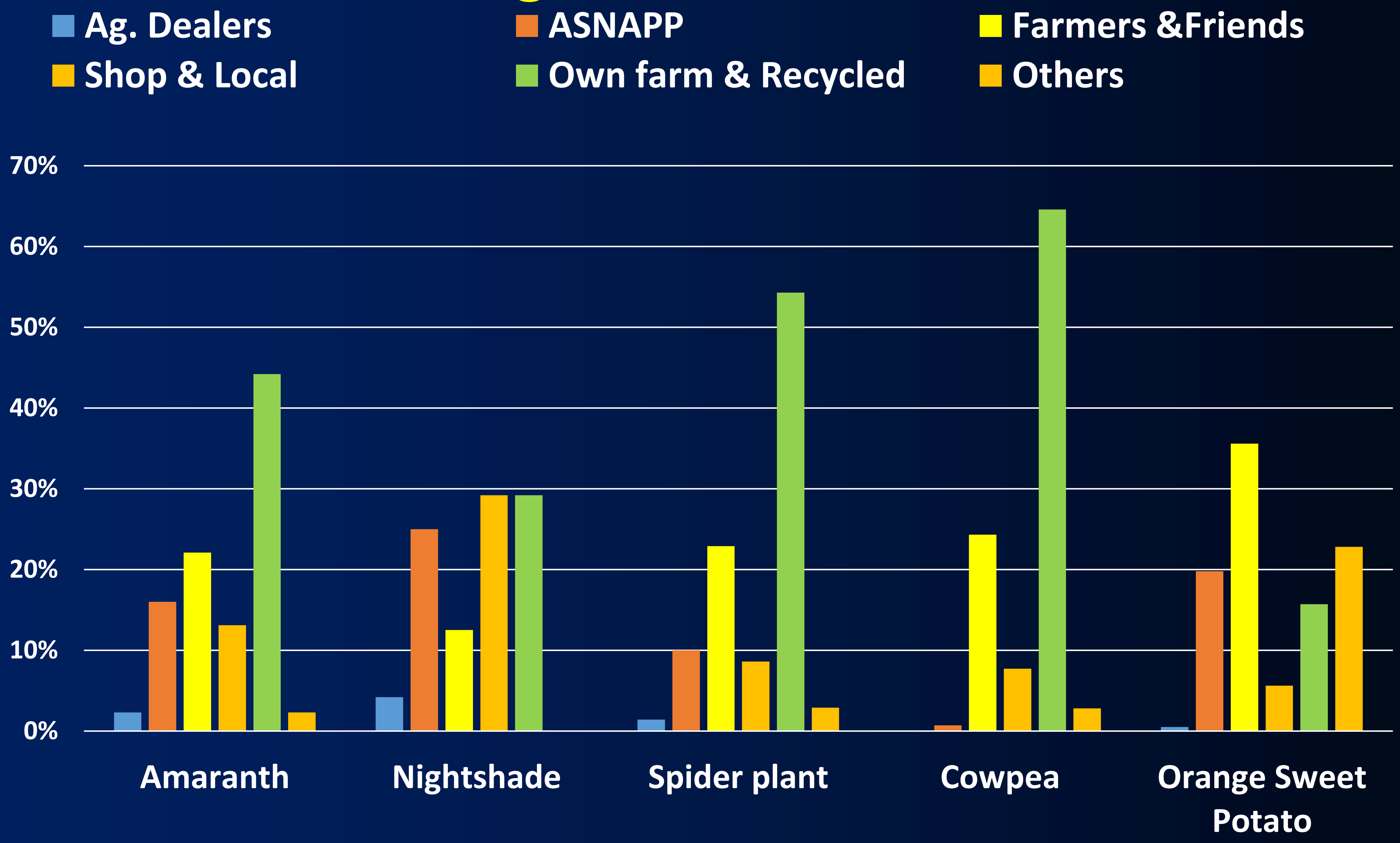
Obj. 2: Hypothesis: Appropriate Promotion & Expansion of Availability of AIVs at the Local Level will Strengthen Market Access and Sales for Producers of AIVs:

(Production & Preferences of AIVs)

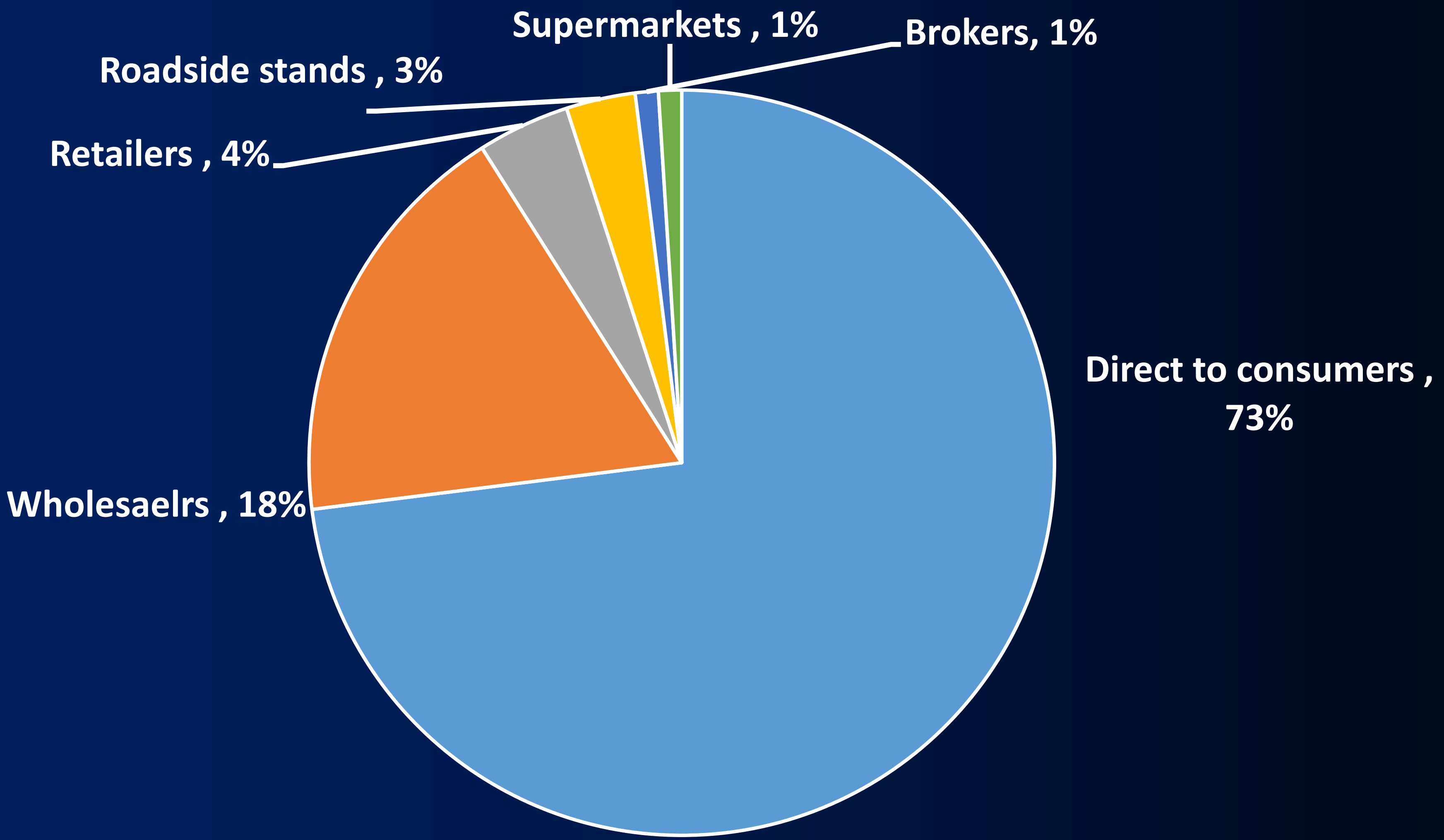


Note : Rest of the % belongs to Other AIV's

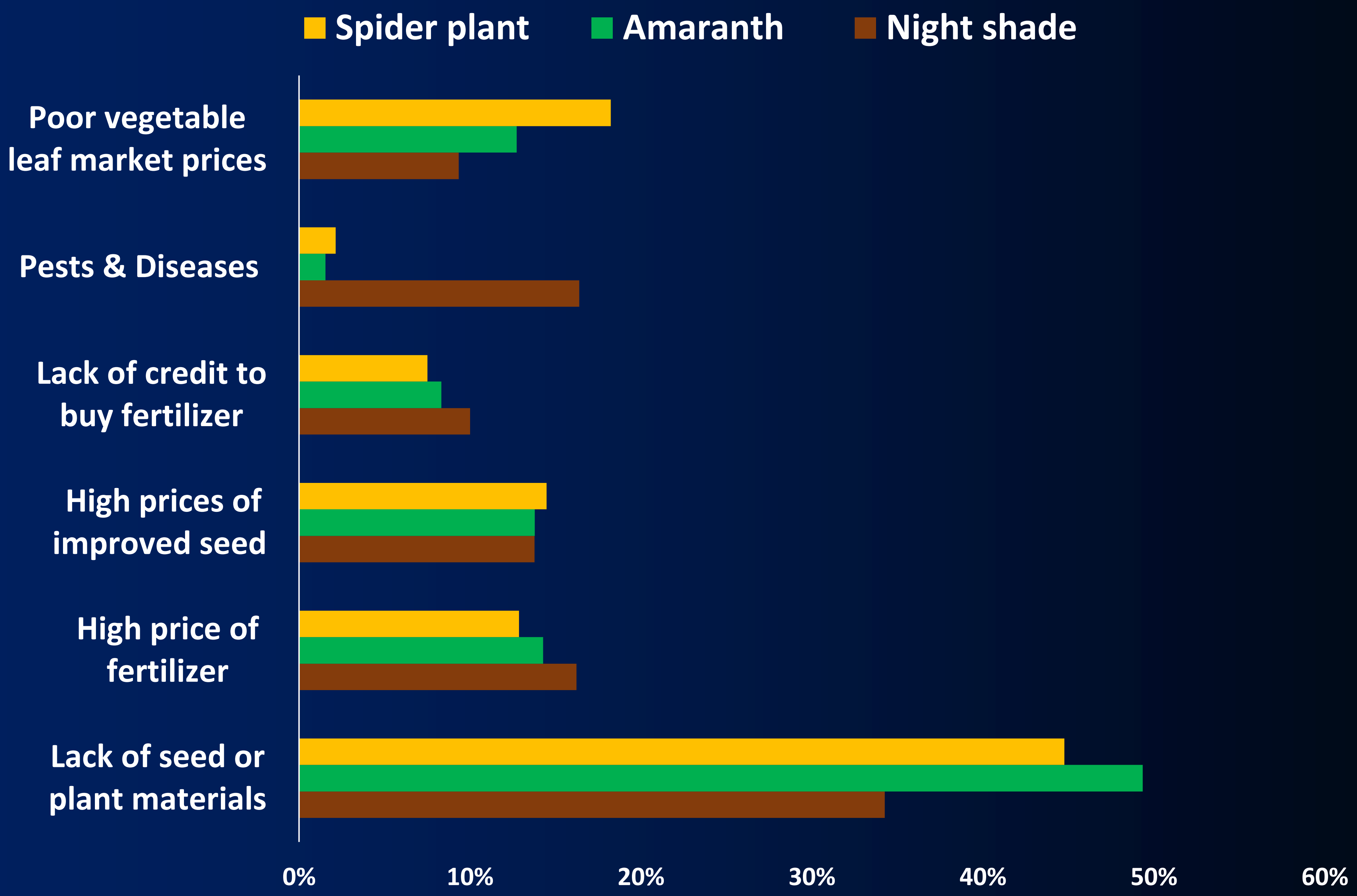
Where do Farmer get Their African Traditional Vegetables Seeds?



AIVs Trading Partners



Constraints in AIV Farming



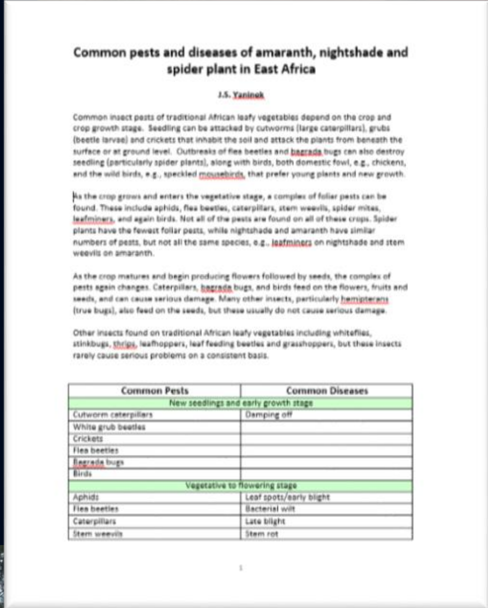
Obj. 3. Determine Best Management Practices for AIV Production, Increase Capacity and Access to AIVs

Participatory research prioritized by survey results to provide accurate information and recommendations for farmers

- Cultural practices
- Management technologies
- Improved seed, collection
- Integrated pest management
- Irrigation and drought tolerance

Lesson 5: *90.9%* producers want better AIV seed quality.

Lesson 6: 75% of producers want training for production during dry seasons & drought.



Common pests and diseases of amaranth, nightshade and spider plant in East Africa

J.S. Yaninek

Common insect pests of traditional African leafy vegetables depend on the crop and crop growth stage. Seedling can be attacked by cutworms (large caterpillars), grubs (beetle larvae) and crickets that inhabit the soil and attack the plants from beneath the surface or at ground level. Outbreaks of flea beetles and bagrada bugs can also destroy seedling (particularly spider plants), along with birds, both domestic fowl, e.g., chickens, and the wild birds, e.g., speckled mousebirds, that prefer young plants and new growth.

As the crop grows and enters the vegetative stage, a complex of foliar pests can be found. These include aphids, flea beetles, caterpillars, stem weevils, spider mites, leafminers, and again birds. Not all of the pests are found on all of these crops. Spider plants have the fewest foliar pests, while nightshade and amaranth have similar numbers of pests, but not all the same species, e.g., leafminers on nightshade and stem weevils on amaranth.

As the crop matures and begin producing flowers followed by seeds, the complex of pests again changes. Caterpillars, bagrada bugs, and birds feed on the flowers, fruits and seeds, and can cause serious damage. Many other insects, particularly hemipterans (true bugs), also feed on the seeds, but these usually do not cause serious damage.

Other insects found on traditional African leafy vegetables including whiteflies, stinkbugs, thrips, leafhoppers, leaf feeding beetles and grasshoppers, but these insects rarely cause serious problems on a consistent basis.

Common Pests	Common Diseases
New seedlings and early growth stage	
Cutworm caterpillars	Damping off
White grub beetles	
Crickets	
Flea beetles	
Bagrada bugs	
Birds	
Vegetative to flowering stage	
Aphids	Leaf spots/early blight
Flea beetles	Bacterial wilt
Caterpillars	Late blight
Stem weevils	Stem rot

1

Solar Dryer < $100 to build


academicJournals

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]

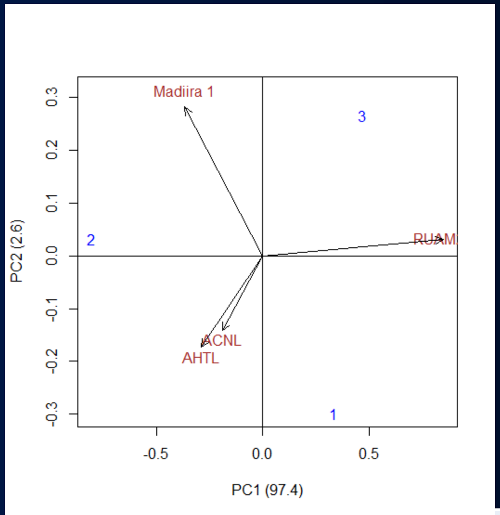
[1]Department of Family and Consumer Sciences, University of Eldoret Box 1125-30100, Eldoret, Kenya.
[2]New Use Agriculture and Natural Plant Products Unit, Department of Plant Biology and Plant Pathology, Rutgers University, New Brunswick, NJ, USA.
[3]Horticulture Department, Purdue University, West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

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

Obj. 4. Evaluation of Nutrient Composition of AIVs:

Determining the content and stability of micronutrients in AIVs

Lesson 8: Many of the AIVs are nutrient rich and can be submitted to USDA for inclusion.



Result: Spiderplant flower rapidly ca. 1 month in field limiting production. We then screened populations for photoperiodicity. **In 2016 we identified spiderplants that remain vegetative for >6 months, and now field testing. This could be transformative!**

AMMI results

	Fe	Ca	Mg	Zn	Total Yield	Height	Spread
Env	<.0001	0.0009	<.0001	<.0001	<.0001	<.0001	<.0001
rep(env)	0.6617	0.264	0.0194	0.0113	0.045	0.0453	0.0001
Gen	<.0001	0.002	0.0366	0.004	<.0001	<.0001	0.0004
env*gen	0.0004	0.0009	0.0624	0.3097	0.0085	0.0035	0.088

Results of additive main effects and multiplicative interaction effect (AMMI) analysis of the four accessions which were grown in common across the three environments: PI 674263, AC-NL, AH-TL, and Madiira 1.

Lesson 7: Selection and breeding for micronutrients possible.

2017. Byrnes, D., F. Dinssa, S. Weller and J.E. Simon. Elemental micronutrient content and horticultural performance of vegetable amaranth types. JASHS: 142(4):265-271.

Result: A new high Fe Amaranth being developed by us with new variety release expected in 2017/2018.

Vegetable Amaranth Nutrition Performance

- Ca and Mg "high source" in all genotypes and environments
- Zn below "source" in all genotypes and environments
- Fe above "high source" and below "source" by genotype

Photo: David Byrnes

Genotype	fe	fe	ca	ca	mg	mg	zn	zn
AM8	160.34	d	3.4758	d	1.9398	ab	41.839	efghij
AM14	148.33	d	4.0381	abcd	1.7607	ab	61.63	abc
AM24	360.41	a	3.692	cd	1.6943	ab	55.314	abcde
AM27	254.8	abcd	3.7582	bcd	1.8788	ab	52.517	bcdefghi
AM31	199.54	bcd	3.5718	d	1.4389	b	51.726	bcdefghi
AM32	210.89	abcd	3.8	bcd	1.6968	ab	59.985	abc
AM33	213.3	abcd	3.6055	d	1.7481	ab	54.358	abcdefg
AM34	169.53	cd	3.9695	abcd	2.1033	ab	36.201	j
AM35	178.97	cd	4.6012	ab	2.0326	ab	39.718	ij
AM36	190.98	cd	3.8607	abcd	2.1884	a	40.375	hij
AM38	175.53	cd	4.2259	abcd	1.5637	ab	60.26	abc
AM39	196.7	bcd	3.9946	abcd	1.9168	ab	41.34	fghij
AM41	237.24	abcd	3.9771	abcd	2.2201	a	40.877	ghij
AM44	351.41	ab	4.5105	abc	1.7015	ab	67.692	a
AM71	302.91	abcd	4.5803	ab	1.9205	ab	48.548	cdefij
AM72	293.62	abcd	4.5546	ab	1.8938	ab	53.589	bcdefgh
AM74	212.83	abcd	4.2476	abcd	1.8557	ab	45.006	defghij
AM80	254.95	abcd	4.1516	abcd	1.922	ab	57.43	abcd
AM81	275.11	abcd	4.6748	a	2.0032	ab	63.54	ab
AM101	323.79	abc	3.9253	abcd	1.9197	ab	54.955	abcdefg
AM107	355.43	ab	3.9167	abcd	1.6103	ab	48.888	cdefghij

Fig. Tukeys mean separation analysis run on SAS on a single field evaluation. Genotypes are not significantly different from other genotypes with the same letter for each trait

Vegetable Amaranth Field Performance

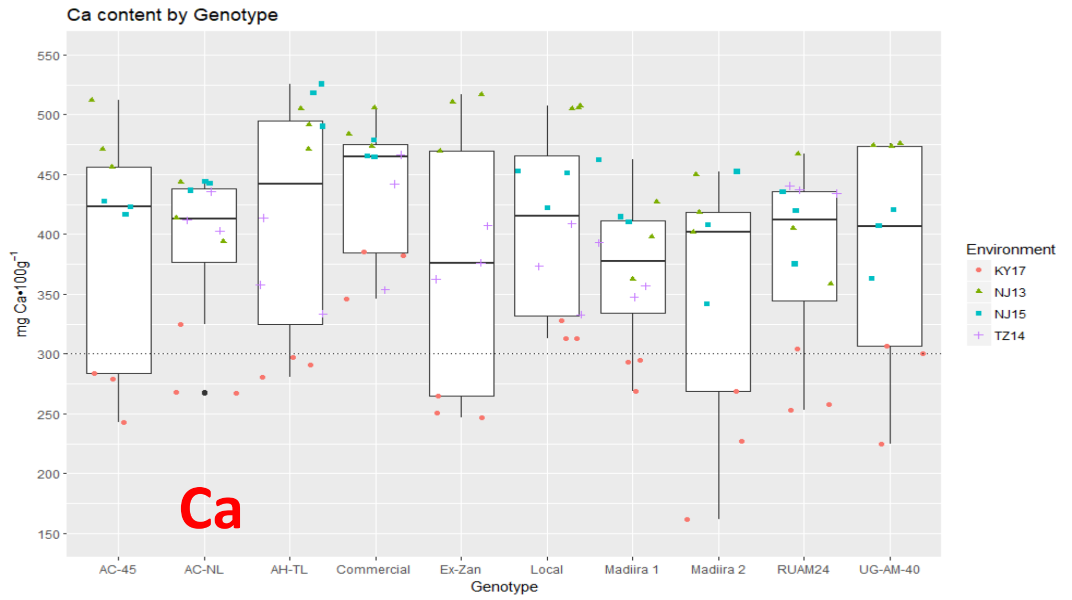
Photo: David Byrnes

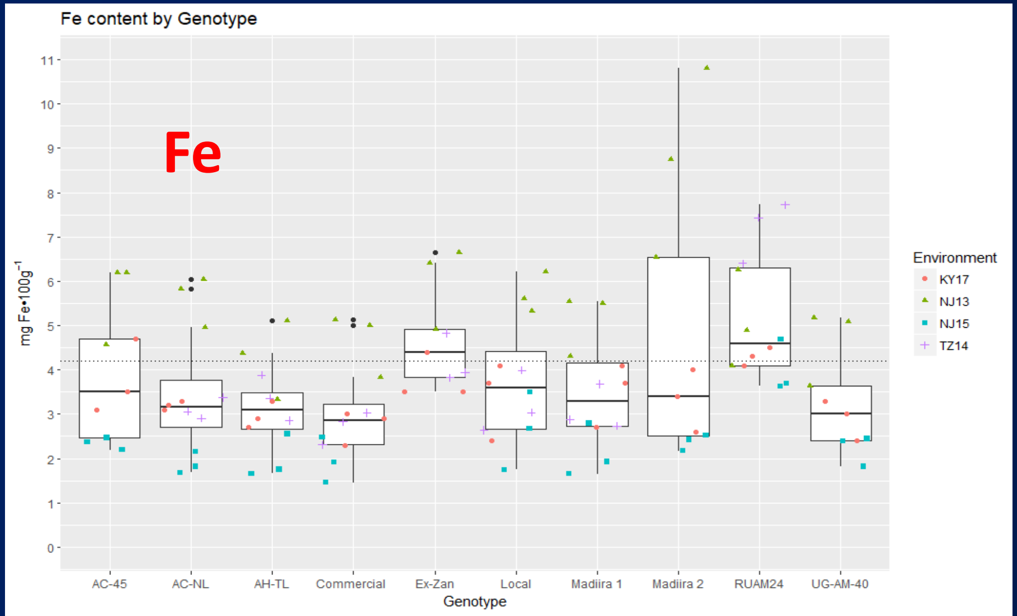
Genotype	Totyield	Totyield	height	height	spread	spread	market yield	market yield	market prop	market prop
AM8	1.3333	bcd	72.933	a	51.858	abc	0.7	bc	0.52705	bcd
AM14	1.7	abcd	80.133	a	52.036	abc	0.8333	bc	0.49076	cd
AM24	1.0167	cde	31.6	ghi	58.081	abc	0.7833	bc	0.77729	abc
AM27	0.8667	de	28.6	hi	42.757	c	0.7	bc	0.80365	ab
AM31			64.511	abcd	52.472	abc	.	.	.	
AM32	1.9	abc	71.133	ab	56.219	abc	0.8	bc	0.42463	d
AM33	2.1	ab	53.6	bcde	64.601	abc	1.2667	a	0.60556	abcd
AM34	1.3667	abcd	66.133	abc	54.695	abc	0.7333	bc	0.53908	bcd
AM35	2.25	a	70.067	ab	54.136	abc	0.9167	abc	0.41114	d
AM36	1.7667	abcd	78.067	a	51.985	abc	0.9167	abc	0.52082	bcd
AM38	1.6333	abcd	66.6	abc	52.239	abc	0.9333	abc	0.5754	cbd
AM39	1.7	abcd	73.667	a	56.557	abc	1.0667	ab	0.64306	abcd
AM41	1.0667	cde	45.2	efgh	51.139	abc	0.6333	c	0.59452	abcd
AM44	1.4167	abcd	52.533	bcdef	62.399	ab	0.7167	bc	0.51616	bcd
AM71	1.05	cd	34.333	fgh	49.53	abc	0.6	c	0.60573	abcd
AM72	1.3	bcd	38.867	efgh	50.885	abc	0.8167	bc	0.62865	abcd
AM74	1.1167	cd	53.267	bcde	55.118	abc	0.55	c	0.52632	bcd
AM80	0.9667	de	44.067	efgh	48.768	abc	0.65	bc	0.67593	abcd
AM81	1.0667	cd	46.6	defgh	48.26	bc	0.5167	cd	0.53236	bcd
AM101	0.9333	de	48.267	cdefg	50.648	abc	0.5833	c	0.62574	abcd
AM107	0.1333	e	13.4	i	12.277	d	0.1167	d	0.88889	a

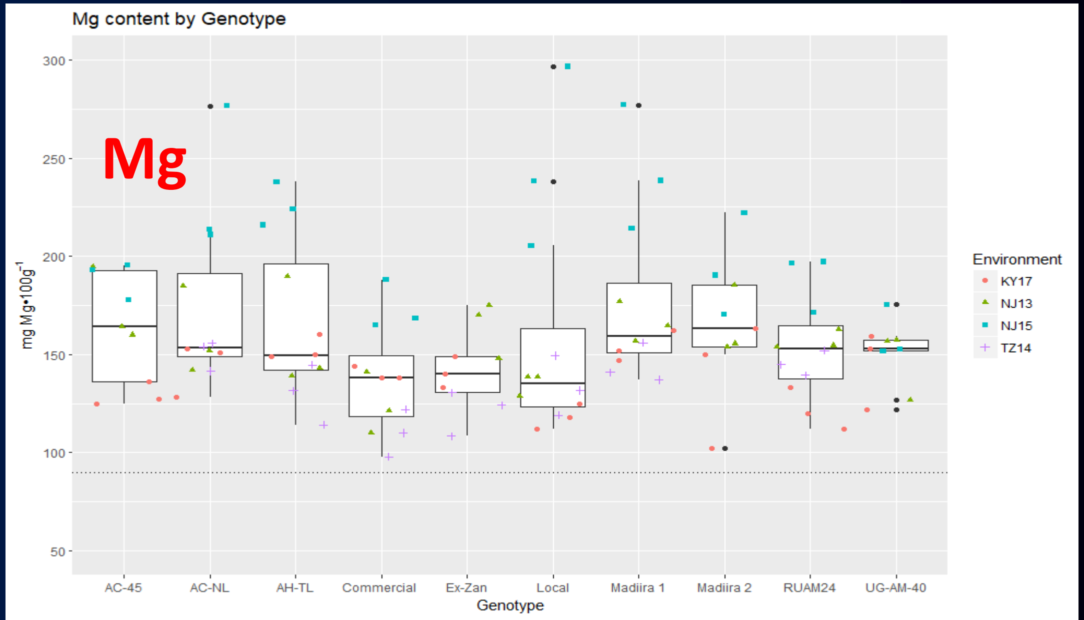
Fig. Tukeys mean separation analysis run on SAS on a single field evaluation. Genotypes are not significantly different from other genotypes with the same letter for each trait

Multi-environment Nutrition Content of Vegetable Amaranth

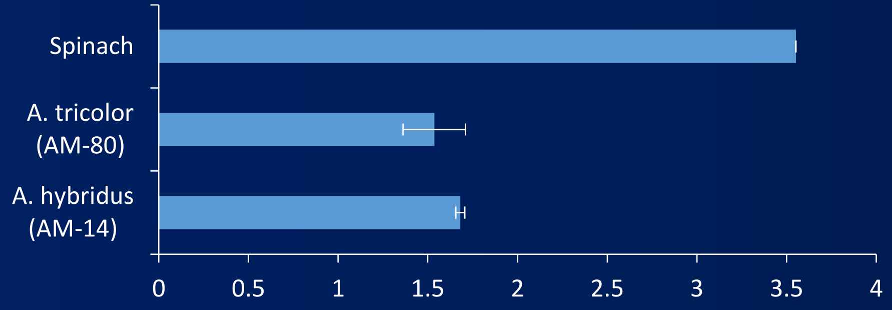
- **Results show we can select for high source iron varieties**
- **Further selection for high source levels of Ca and Mg unnecessary**



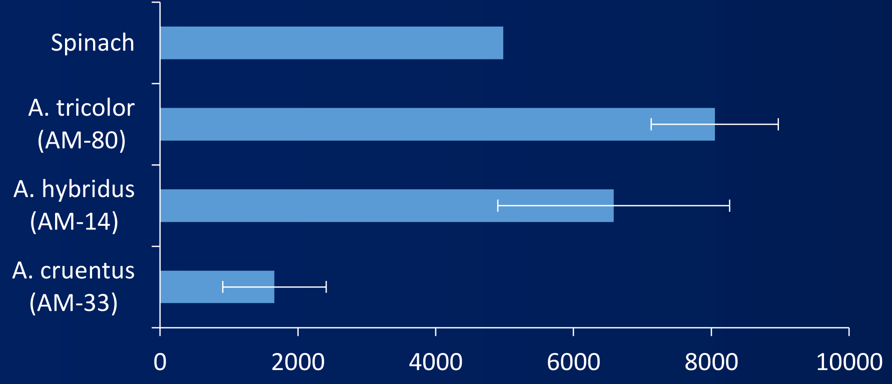




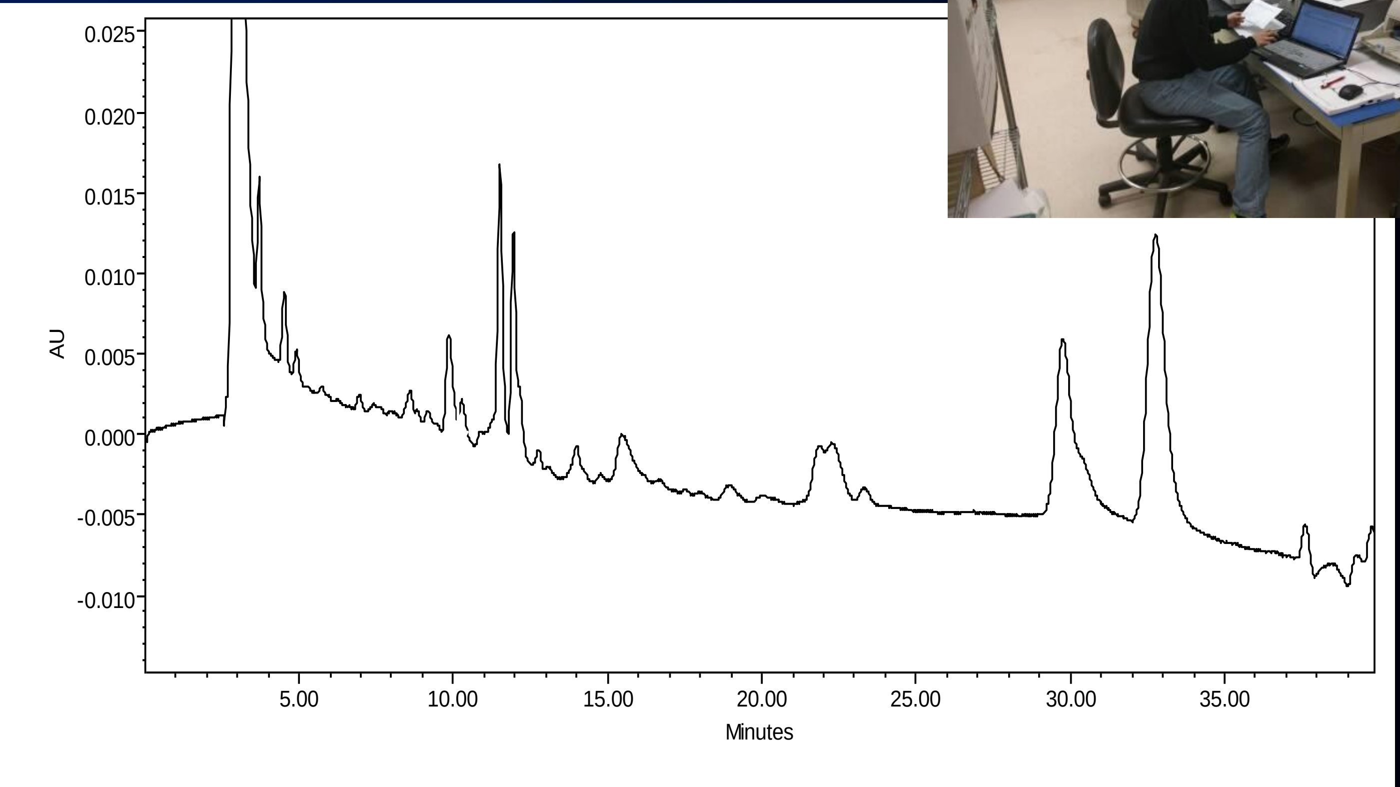
Amaranth spp.



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



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

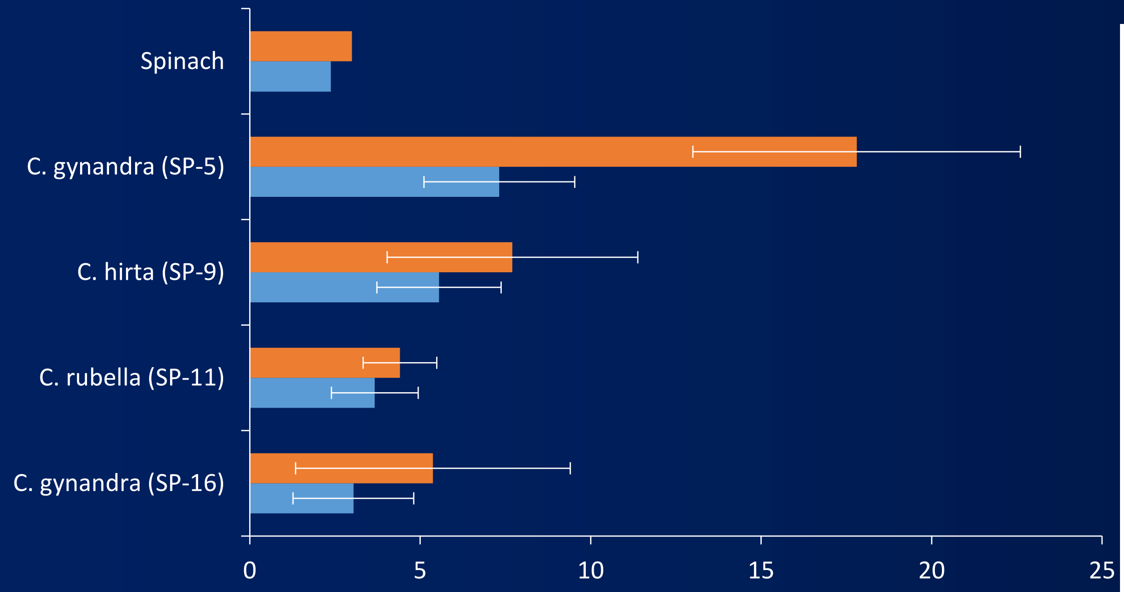


Representative HPLC chromatogram of *A. hybridus* (AM-14) at 290nm

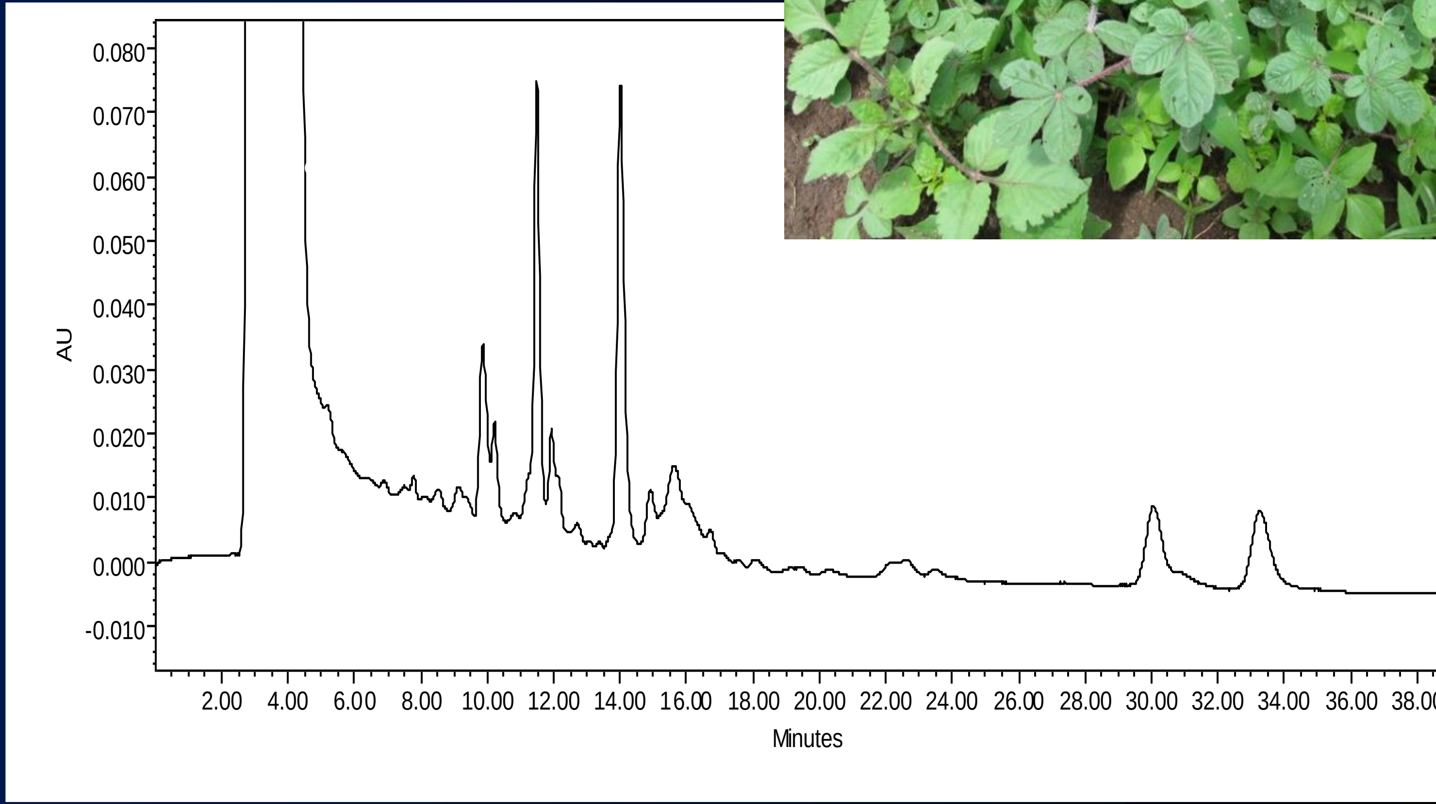
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
A. Cruentus (AM-33)	<0.517	1.00±0.45	<0.77	1659.91±750.14	2.21±0.39
A. Hybridus (AM-14)	1.13± 0.02	3.97±1.01	1.68±0.03	6585.15±1681.74	3.94±0.77
A. Tricolor (AM-80)	1.03± 0.12	4.85±0.56	1.54±0.17	8049.65±923.98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

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

Spiderplant (*Cleome* spp.)



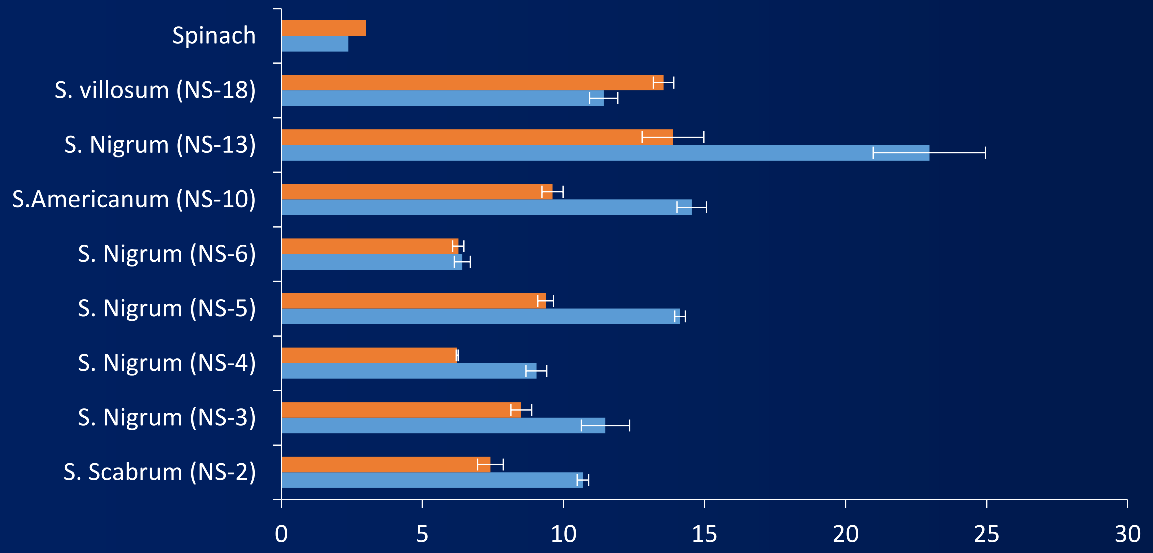
Vitamin E (α-tocopherol-blue) and b-carotene (red) content of *Cleome spp*. accessions (mg/100g)



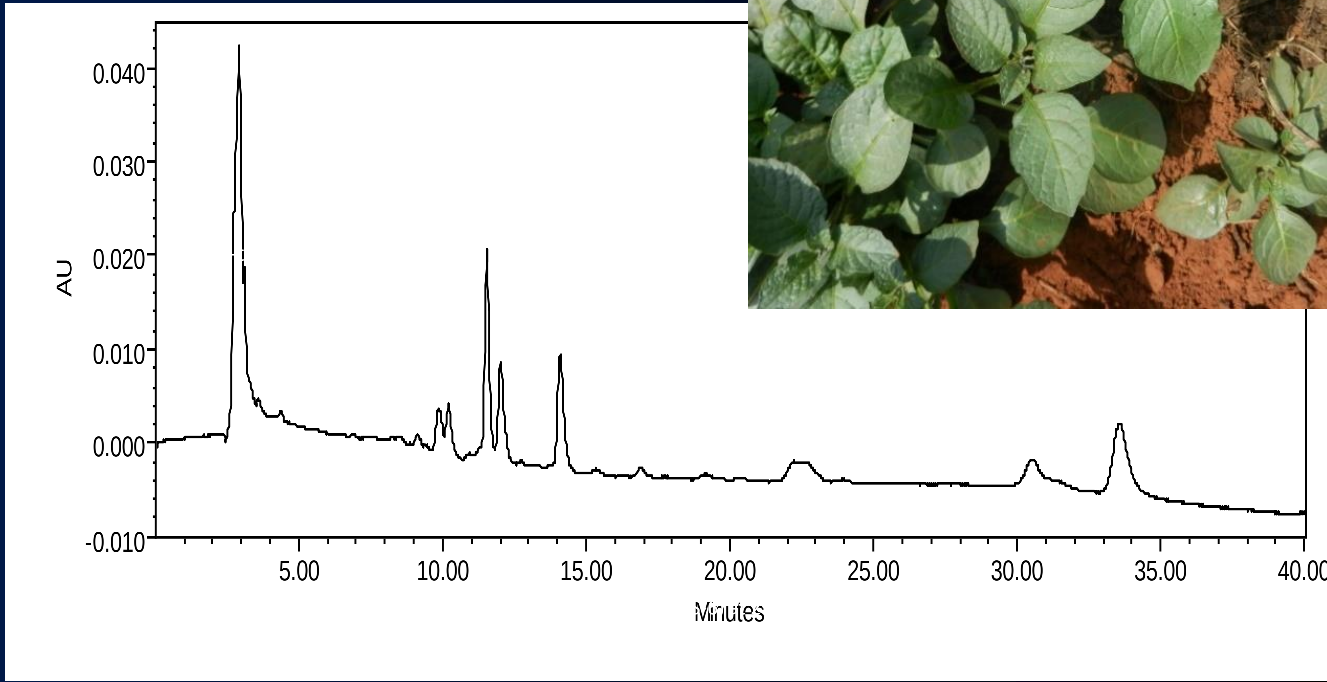
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
C. gynandra (SP-16)	3.04±1.77	5.37±4.03	4.54±2.64	8924.00±6688.92	3.53±0.89
C. rubella (SP-11)	3.67±1.27	4.40±1.08	5.47±1.90	7313.15±1793.79	10.00±0.87
C. hirta (SP-9)	5.55±1.83	7.70±3.68	8.29±2.72	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

Nightshade (*Solanum* spp.)



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



	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-Nutritive 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
5	21.8	hydroxydiosgenin-G-R-R-R	$[M+H]^+$ 885.7, 739.7, 593.6, 431.6, 413.6
6	25.2	trihydroxytigogenin-G-R	773.5, 627.5, 465.5, 433.5
7	36.6	dehydrodiosgenin-G-R-R	$[M+Na]^+$ 889.8, $[M+H]^+$ 867.6, 721.6, 575.5, 413.5
8	37.9	diosgenin-G-R-R	$[M+Na]^+$ 891.9, $[M+H]^+$ 869.7, 723.6, 577.5, 415.5

Tentative Identification of Alkaloid and Saponin in Solanum *nigrum* Mature Fruit

No.	retention time/min	Compounds tentative identification	molecular ions and fragment identification
1	10.5	solasodine-G-G-R(solasonine)	$[M+H]^+$ 884.8, 738.6, 576.7, 414.7
2	12.8	solasodine-G-R-R(solamargine)	$[M+H]^+$ 868.9, 722.8, 576.8, 414.7
3	18.6	hydroxyldiosgenin-G-G-R-G	$[M+ACN]^+$ 1103.6, $[M+H]^+$ 1063.4, 901.6, 755.6, 593.6, 431.7
4	19.9	hydroxyldiosgenin-G-G-R-R	$[M+ACN]^+$ 1087.9, $[M+H]^+$ 1047.5, 901.7, 755.7, 593.5, 431.6
5	21.3	solasodine-G-R-X-R	$[M+H]^+$ 954.9, 808.8, 722.9, 576.8, 414.7
6	22.4	diosgenin-G-G-R-R-G	$[M+H]^+$ 1193.6, 1031.6, 885.7, 739.7, 577.6, 415.6
7	23.0	tigogenin-G-G-R-R-G	$[M+H]^+$ 1195.6, 887.7, 741.7, 579.6, 417.6
8	24.1	diosgenin-G-G-R-R	$[M+H]^+$ 1031.9, 885.8, 739.8, 577.6, 415.5
9	25.2	diosgenin-G-G-X-P	$[M+ACN]^+$ 1071.9, $[M+H]^+$ 1031.6, 899.7 (?), 739.7, 577.6, 415.5
10	25.8	diosgenin-G-G-R-X-R	$[M+H]^+$ 1117.9, 971.7, 885.8, 739.7, 577.6, 415.6
11	27.7	diosgenin-G-X (possible isomer of 10)	$[M+H]^+$ 1118.1, 1043.9, 751.7 (?), 577.7, 415.6
12	29.3	diosgenin-G-G-X-R	$[M+H]^+$ 1129.6, 983.6, 739.6, 577.6, 415.6
13	34.5	dehydrodiosgenin-G-R-X-R-X	1149.9(?), 953.6, 807.5 (?), 721.5, 575.6, 413.5
14	41.1	diosgenin-G-R-R	$[M+H]^+$ 869.7, 723.6, 577.5, 415.5
15	42.3	tigogenin-G-R-R	$[M+H]^+$ 871.5, 725.7, 579.6, 417.6

G--glucosyl, galactosyl or other hexosyl; **R**—Rhamnosyl; **P**-xylosyl, apiosyl, or other pentosyl; **X**--Unidentified fragment, with corresponding side piece marked by "?". Molecular ions protonated in orange and adducted with acetonitrile in red, aglycone fragment in blue, fragment unidentified in green.

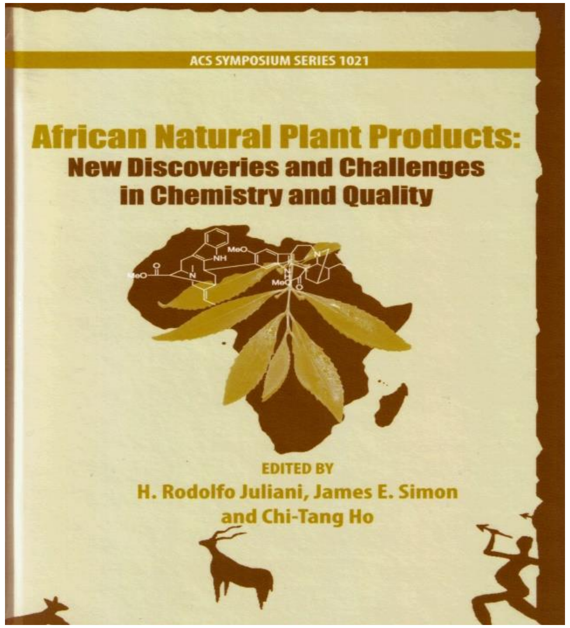
Nutritional Benefit of Moringa: Mineral Content Comparison

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

Science-Driven



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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.

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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

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RESEARCH ARTICLE Open Access

Temporal changes and determinants of childhood nutritional status in Kenya and Zambia

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Elemental Micronutrient Content and Horticultural Performance of Various Vegetable Amaranth Genotypes

David R. Byrnes
New Use Agriculture and Natural Plant Products Program, Department of Plant Biology, Rutgers University, 59 Dudley Road, New Brunswick, NJ 08901

Fekadu F. Dinssa
World Vegetable Center, Eastern and Southern Africa, P.O. Box 10 Duluti, Arusha, Tanzania

Stephen C. Weller
Department of Horticulture and Landscape Architecture, Purdue University, 625 Agriculture Mall Drive, West Lafayette, IN 47907-2010

James E. Simon[1]
New Use Agriculture and Natural Plant Products Program, Department of Plant Biology, Rutgers University, 59 Dudley Road, New Brunswick, NJ 08901

Additional index words. African indigenous vegetables, Ca, Fe, micronutrients, Mg, Zn

Abstract. **Vegetable amaranth (*Amaranthus* sp.), a leafy vegetable crop consumed around the world, is actively promoted as a source of essential micronutrients to at-risk populations. Such promotion makes micronutrient content essential to the underlying value of this crop. However, the extent to which micronutrient content varies by effect of genotype is not clear, leaving breeders uninformed on how to prioritize micronutrient contents as the criteria for selection among other performance parameters. A total of 32 entries across seven *Amaranthus* species were field-grown and analyzed for Fe, Mg, Ca, Zn, yield, height, and canopy spread comprising 20 entries at New Jersey in 2013; 12 entries at Arusha, Tanzania, in 2014; and 20 entries at New Jersey in 2015. The genotype effect was significant in all trials for Fe, Mg, Ca, Zn, total yield, marketable yield, height, and canopy spread. The Fe content range was above and below the breeding target of 4.2 mg/100 g Fe in all environments except for New Jersey 2015, where all entries were found to accumulate in levels below the target. All entries in each of the environments contained levels of Ca and Mg above breeding targets, 300 mg/100 g Ca and 90 mg/100 g Mg. None of the entries in any environment met the Zn breeding target of 4.5 mg/100 g Zn.**

Vegetable amaranth is a mostly self-pollinated, diploid eukaryote with C_4 photosynthesis known to be consumed in over 50 countries, primarily across sub-Saharan Africa, south Asia, and southeast Asia (Achigan-Dako et al., 2014; Jain et al., 1982; National Resource Council, 2006). Vegetable amaranth is commonly cited as having unrealized potential to deliver mineral and vitamin micronutrients as well as protein to at-risk

be effective as a food source for the improvement of human nutrition (Gregorio et al., 2000; Haas et al., 2005). Sufficient variability has also been shown to exist within the wheat (*Triticum aestivum*) germplasm to allow for the selection of high-Fe and high-Zn entries (Cakmak et al., 2000). The genotype × environment interaction (GEI) effect is a potential issue in selecting stable performance in any trait for plant

Increasing Access: Peri-Urban; Urban, Schools

Evaluating Sack-Gardens: Tumaini Center for Street Boys, Kenya

Our Project is:

Providing Training in AIV production, research methods and marketing to the boys and assisting in farm productivity

Lesson 9: Linking to Youth within our project provides new avenue to reach 'new generation of farmers', urban gardening/farming and families to improve health and generate income






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.

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 of 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 and > knowledge needed
- Improved postharvest handling from farm-storage-cleaning/grading & transportation
- Need collection centers/aggregation points for bulking
- Educational and outreach programs are effective to increase interest and awareness of the benefits of AIVs.
- New introduced AIV lines (mostly originating from collaboration with WVC) are being well accepted by growers. 2 of these cvs of Amaranth & NS approved in Kenya for sale

Key Takeaways To Date:

- Households and communities in rural areas are far more interested in AIVs (and all horticultural crops) when growing them can generate yearly income streams and when there is greater access to use AIVs in their own household preparations.
- Using a market-first approach, including surveys and focus groups concerning what they now consume vs. what they would consume is effective in planning interventions and to create build-in sustainability strategies.
- Effective BCC venues can be identified by community members.
- The AIVs targeted in these studies 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.

Key Takeaways To Date, con’t:

- Our key goal is to link and bridge horticultural production by producers to increased consumption by consumers using the four ‘A’s: Access, Availability, Affordability, and Adoption.
- For growers: Adoption=producing the AIVs and possibly consuming them.
- For others, Adoption means purchasing and/or possibly starting to grow AIVs increasing consumption to improve health.
- We are tracking the nutrient content of the AIVs grown locally, and identifying those which are rich sources of vitamins and minerals.
- We are now tracking 1,000 households (500 in Kenya; and 500 in Zambia) and separating them into different treatment groups mentioned, will allow us to better understand what drives individuals to purchase and consume more AIVs and/or to grow their own.

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Jim Simon, PI, Rutgers, Horticulture, Breeding, Natural Products and Nutrition
Steve Weller, co-PI, Purdue, Horticulture/ Production Systems
Dan Hoffman, co-PI, Human Nutrition, RU
Ramu Govindasamy, co-PI, Economics, Marketing, Consumer studies, RU
David Byrnes, Program Coordinator & PhD student
Qingli Wu, Chemistry, Pharmagnosy and phytochemistry of AIVs, RU
Xenia Morin, Gender and development, RU
Steve Yaninek, Pest Management, Purdue
Albert Ayeni, Organic production, RU

Ph.D. Graduate Students*: David Byrnes, Ariane Vasitalis, Bo Yuan, Bernie Somers; William Reichert, Emily Merchant; Martin Zorde
MS Graduate Student*: Mara Sanders
PostDoc*: Surendran Arumugam
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Kenya

AMPATH and Moi University:
Naman Nyabinda
Norah Maiyo

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

Kenya Agric. Livestock Res. Organization (KALRO):
Christine Ndinya
Martins Odendo

Tanzania

WorldVeg Center:
Fekadu Dinssa
Victor Afari-Sefa
Hassan Mndiga

Zambia

AgriSmart
Emil Van Wyk
Lupiya Sakala
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Kenneth Chali
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