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

Improving Income and Nutrition of Smallholder Farmers in Eastern Africa using a Market Driven Approach to Enhance Value Chain Production of African Indigenous Vegetables

Overall goal of this program is to improve the production and increase consumption of AIVs in communities as an effort to improve nutrition, income and health outcomes of people at risk for malnutrition

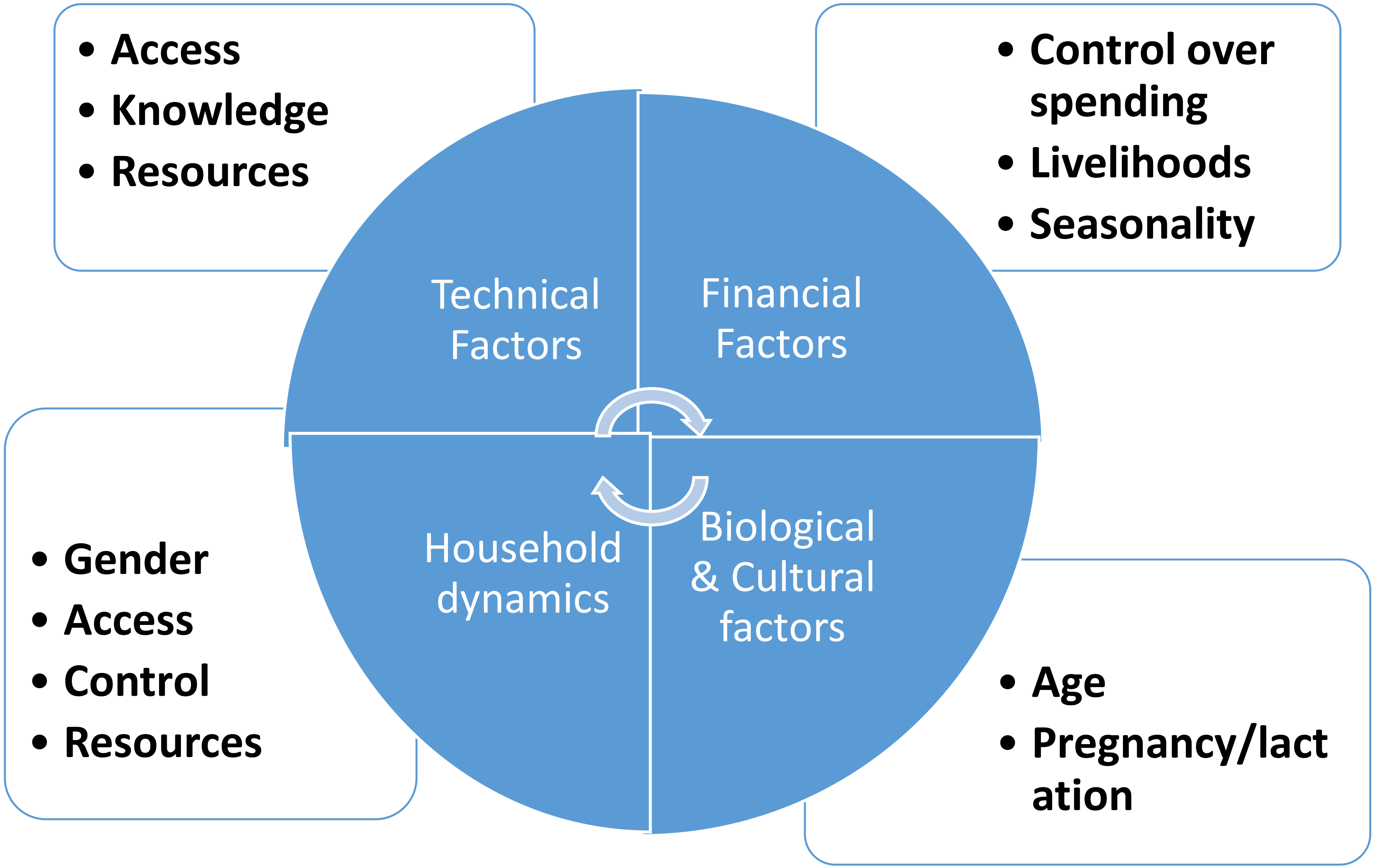
USA: Rutgers University, Purdue University

Zambia: AgriSmart-Zambia, University of Zambia, MAWA

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

Tanzania: AVRDC – The World Vegetable Center

Factors Impacting Nutritional Success



Horticulture Innovation Lab Nutrition Research Program

Access

Affordability

African Indigenous Vegetables:

Nutrition, Health, Income Generation

Adoption

(Increased Consumption)

Availability

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

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

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

<u>Food and nutrient intake.</u>, All data will be analyzed to determine the following:
Nutritional status
Dietary diversity
AIV consumption by gender, geographical area, season, and income.

Determine changes in dietary intake and diversity & AIV consumption of households in Kenyan and Zambian communities that were exposed to AIV production, marketing, and behavior change communication compared to a control community that receives no special treatment

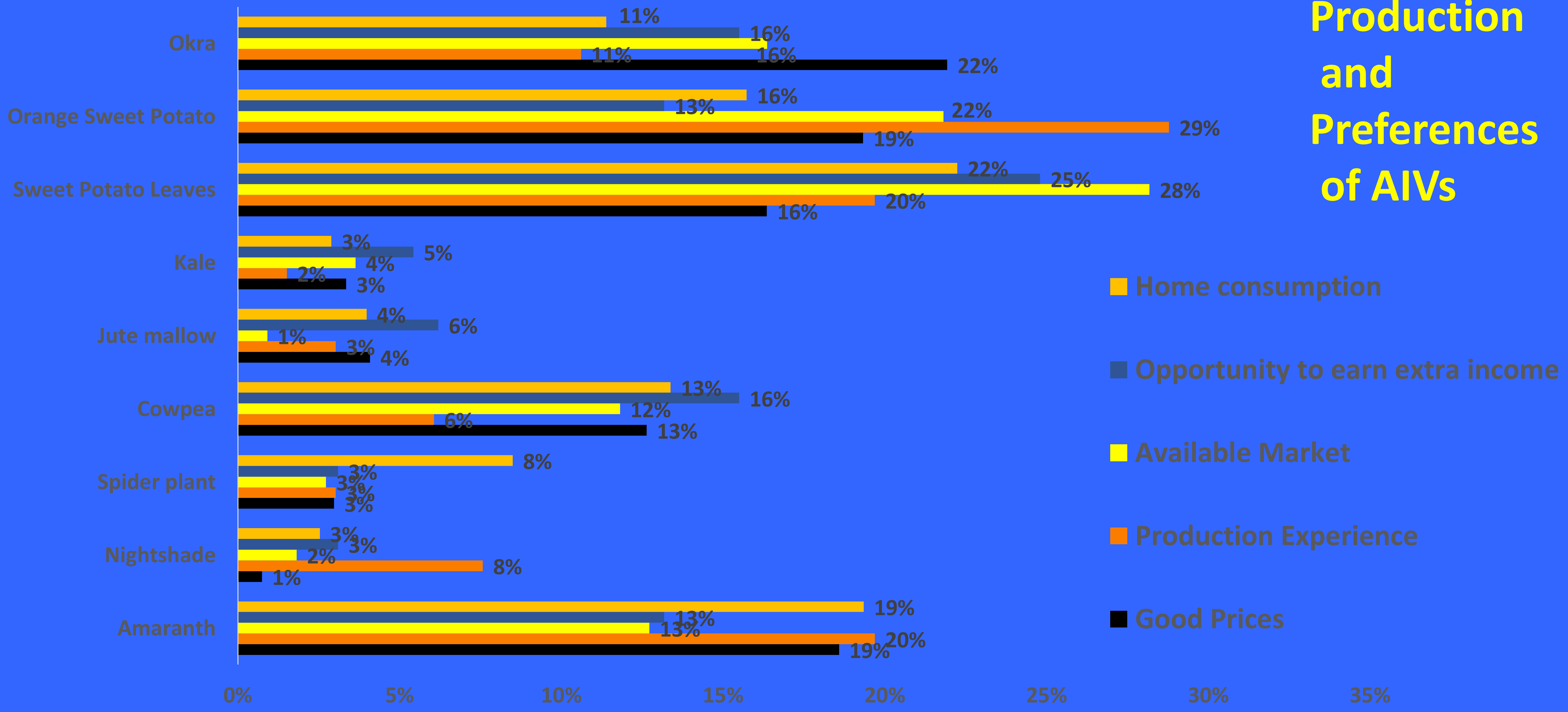
Evaluation of AIV Intervention (500 households)			
Baseline nutrition and purchasing surveys			
Control (Group 1) (125 households)	Production Intervention (Group 2) (125 households)	BCC Intervention (Group 3) (125 households)	Production and BCC Intervention (Group 4) (125 households)
Follow-up nutrition and purchasing surveys			

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

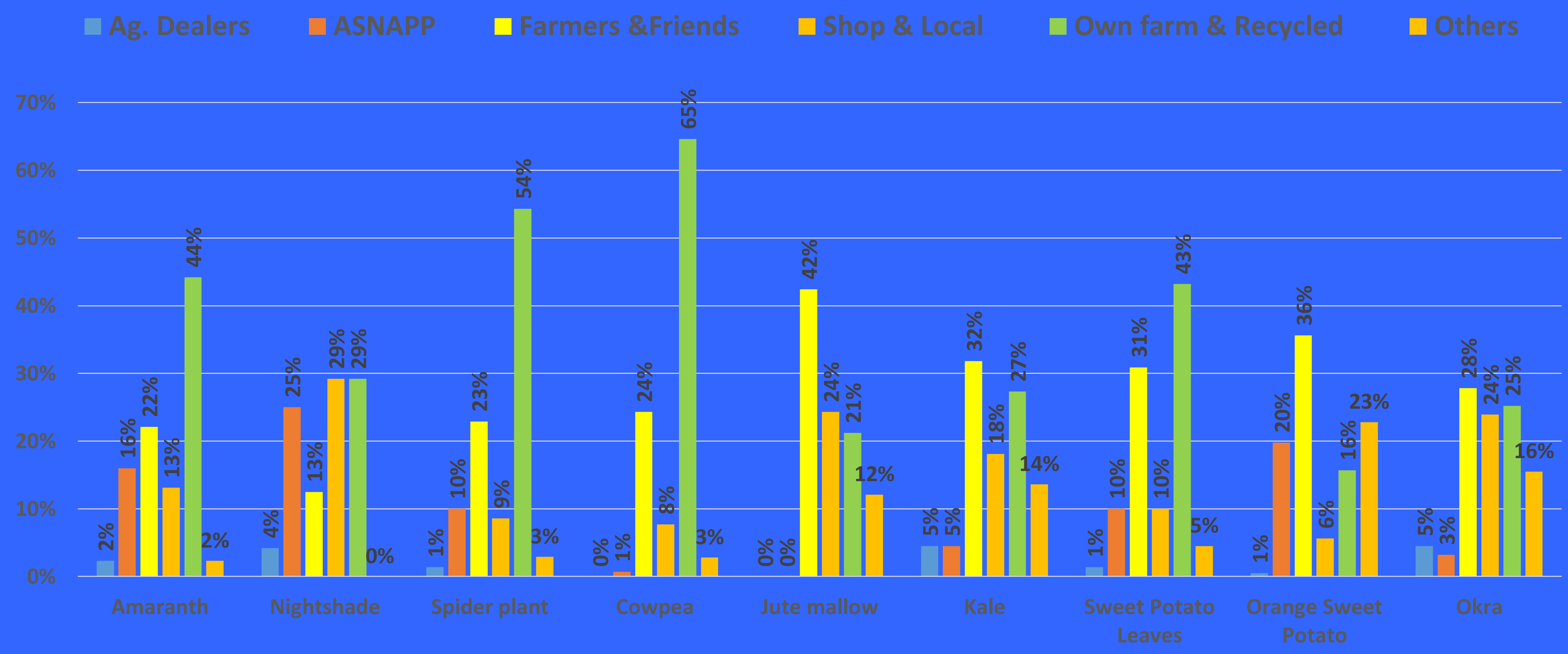
1=Rarely (once a month); **2**=Sometimes (1-2 times a week); **3**=Every day (6-7 times a week)

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

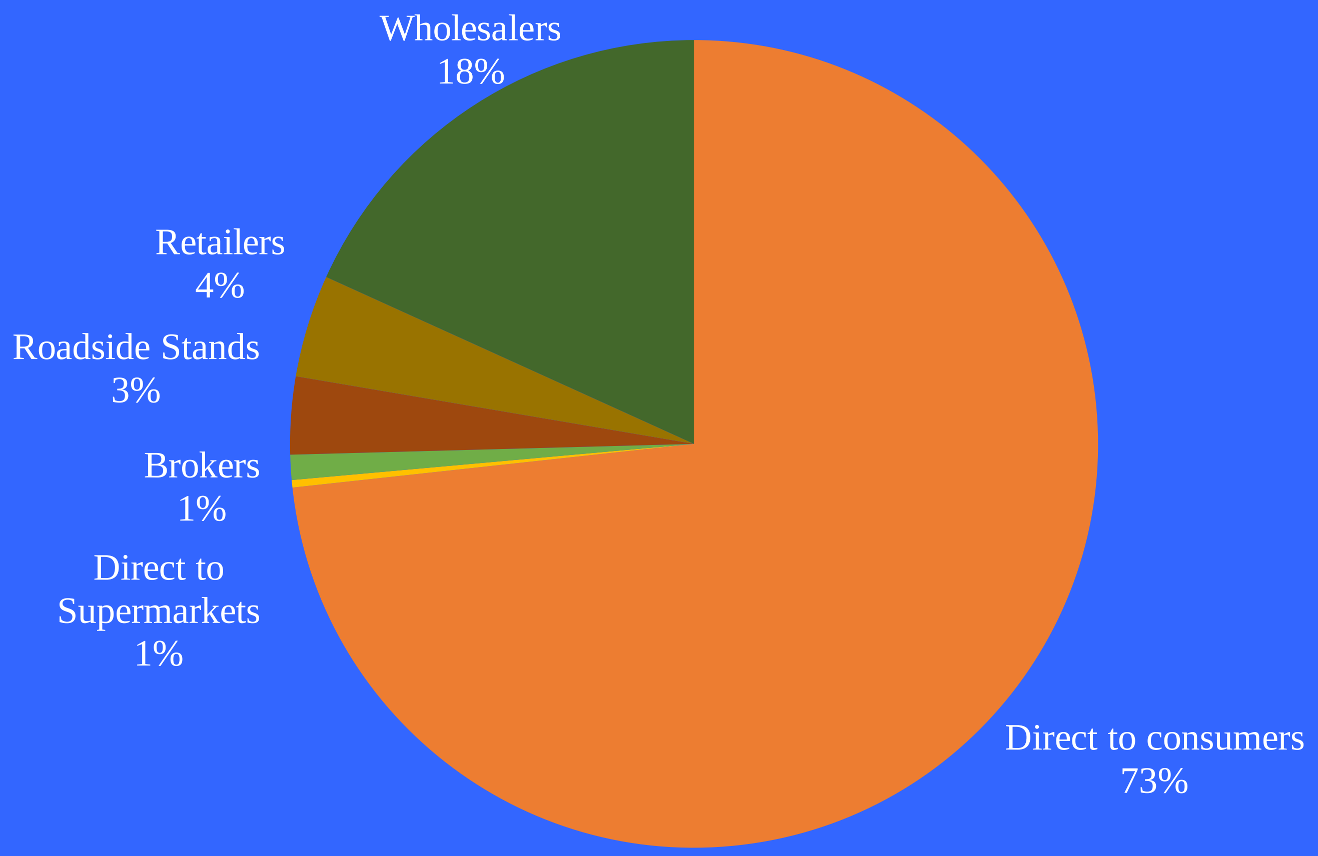


Production and Preferences of AIVs

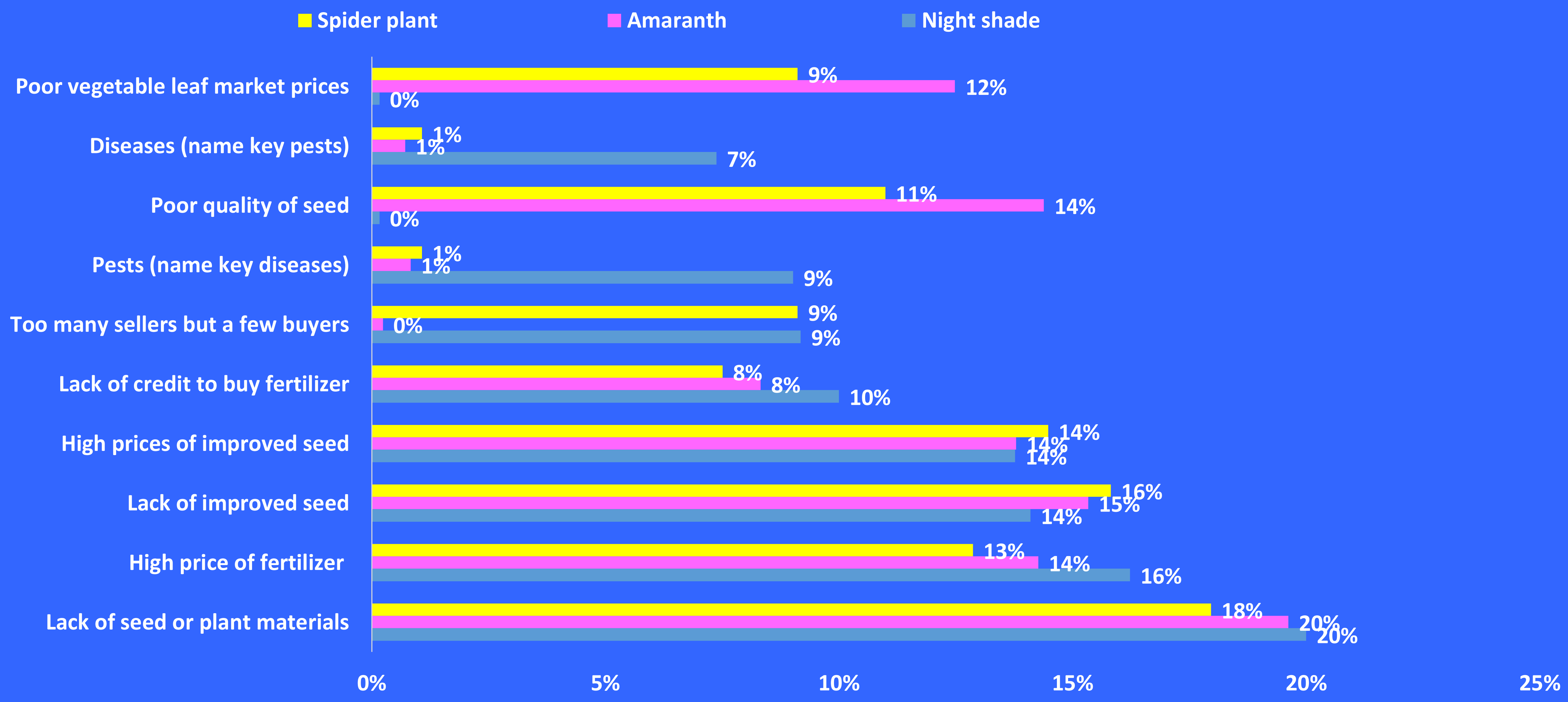
AIVs Seed Source



AIVs Trading Partners



Constraints in AIV Farming



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

- Survey results and participatory research to 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 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

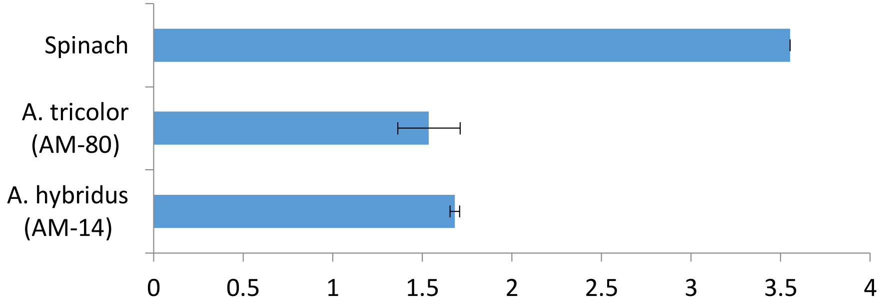
Vegetable amaranth field performance

Photo: David Byrnes

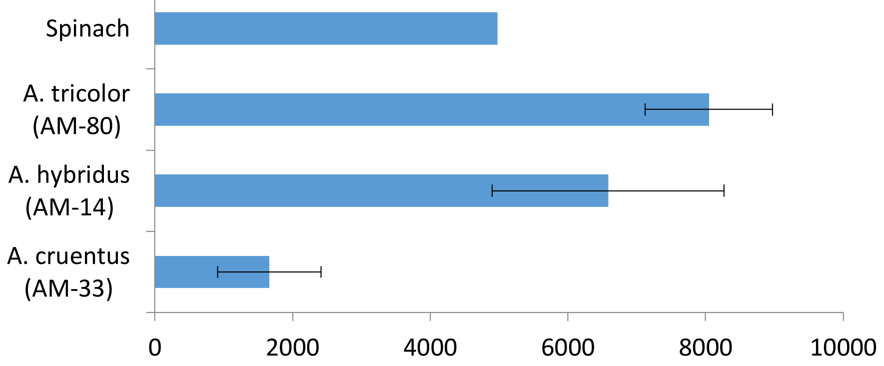
Genotype	Totyield	Totyield	height	height	spread	spread	market yield	market yield	market prop	market prop
AM8	1.3333	bcd	72.933	a	51.858	abc	0.7	bc	0.52705	bcd
AM14	1.7	abcd	80.133	a	52.036	abc	0.8333	bc	0.49076	cd
AM24	1.0167	cde	31.6	ghi	58.081	abc	0.7833	bc	0.77729	abc
AM27	0.8667	de	28.6	hi	42.757	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

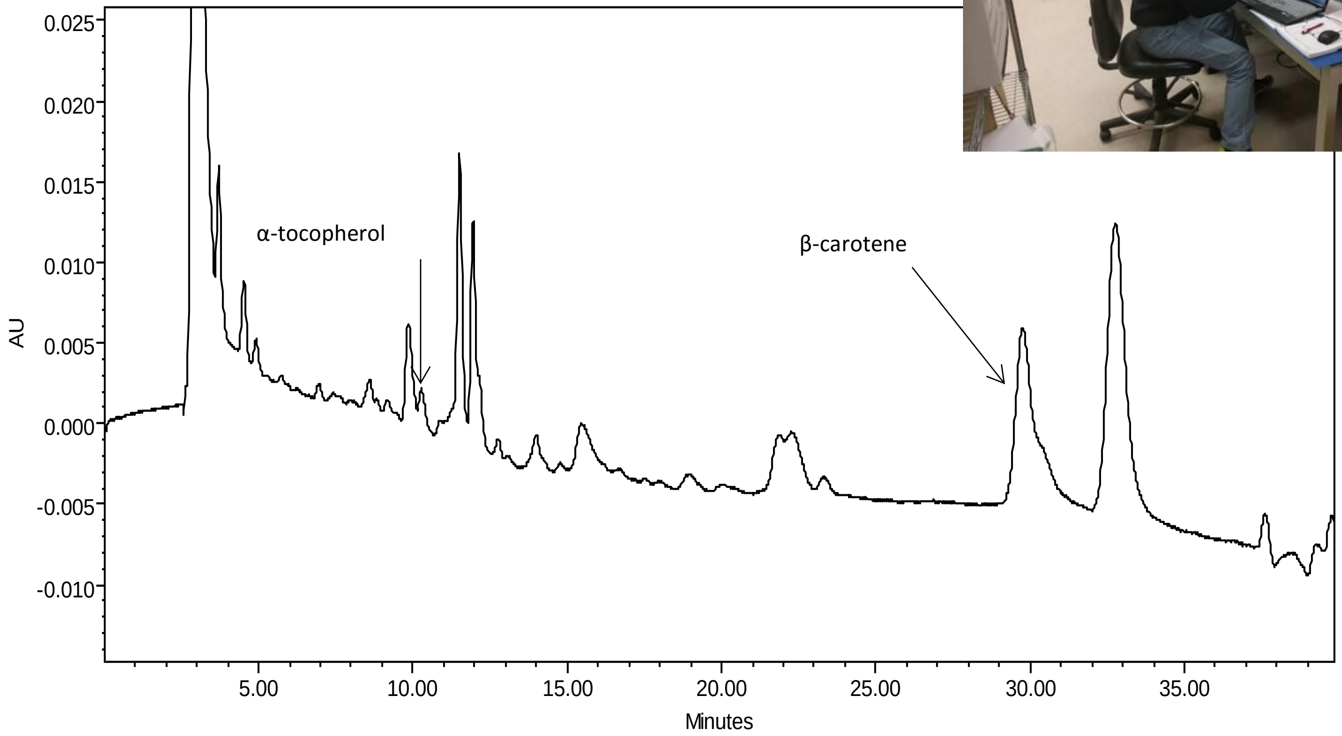
Amaranth spp.



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



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

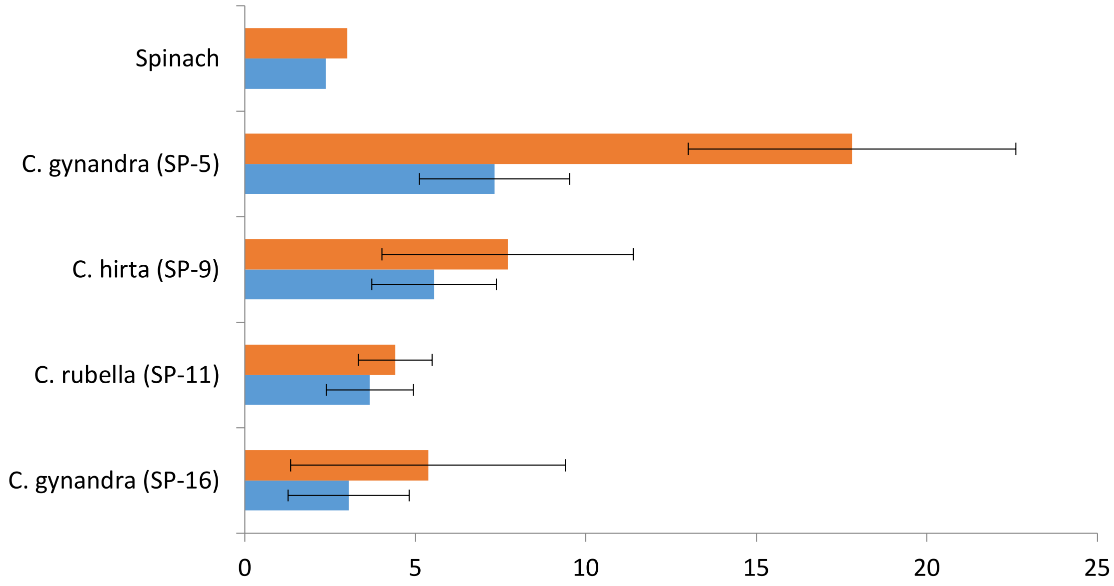


Representative HPLC chromatogram of *A. hybridus* (AM-14) at 290nm

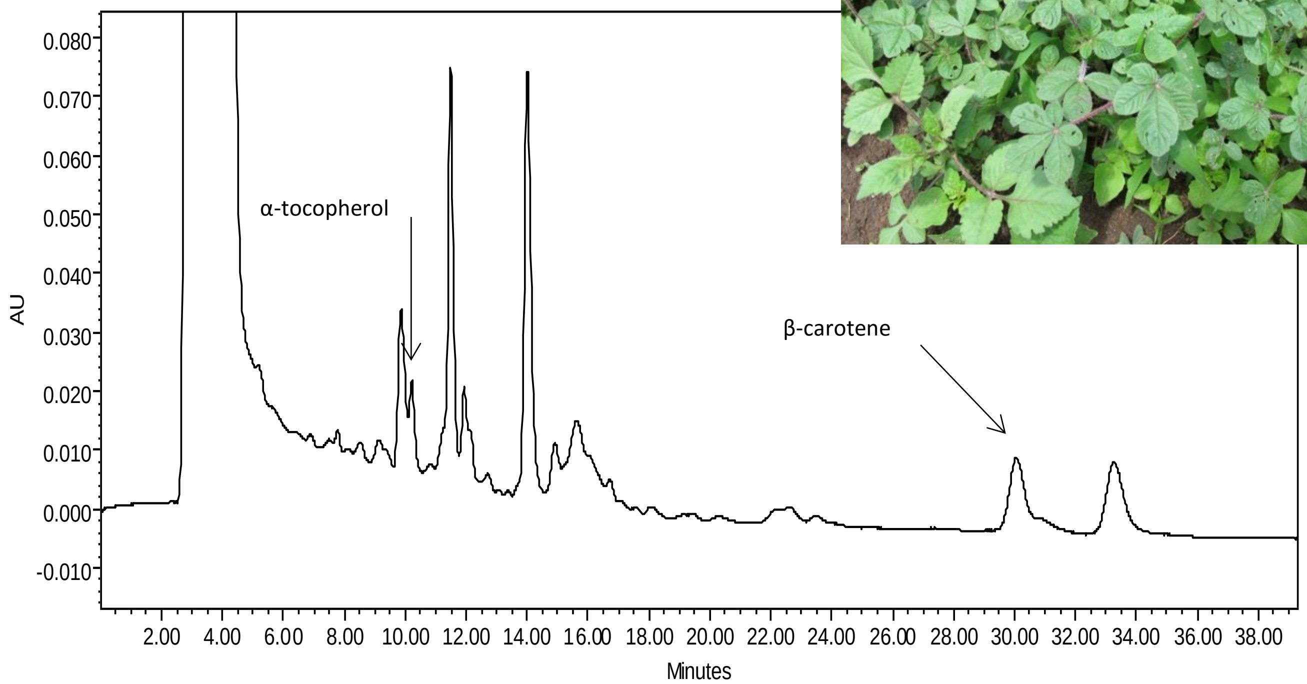
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
A. Cruentus (AM-33)	<0.517	1.00±0.45	<0.77	1659.91±750.14	2.21±0.39
A. Hybridus (AM-14)	1.13± 0.02	3.97±1.01	1.68±0.03	6585.15±1681.74	3.94±0.77
A. Tricolor (AM-80)	1.03± 0.12	4.85±0.56	1.54±0.17	8049.65±923.98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

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

Spiderplant (*Cleome* spp.)



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

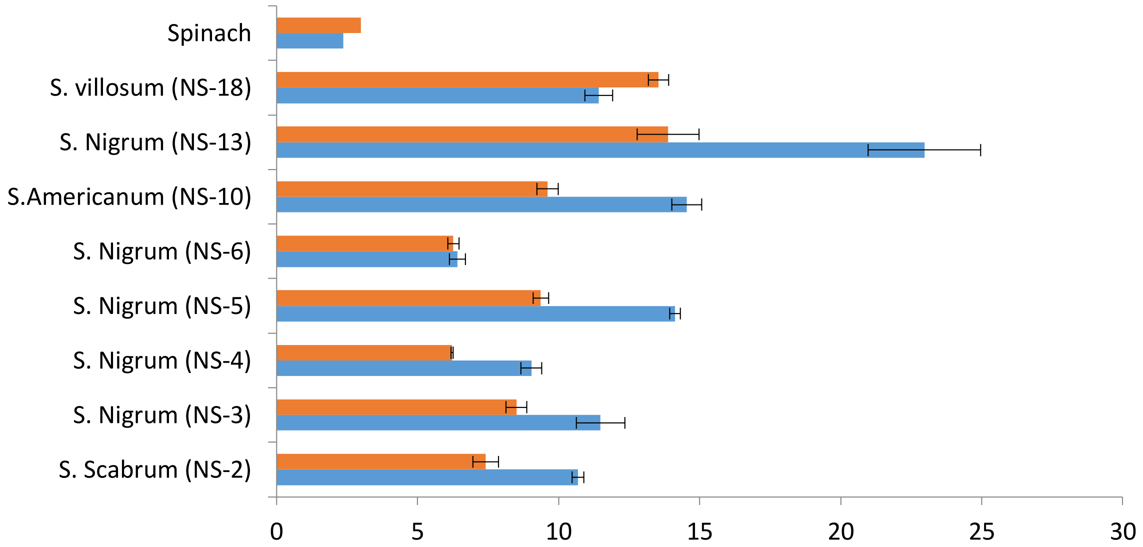


Representative HPLC chromatogram of *C. rubella* (SP-11) at 290nm

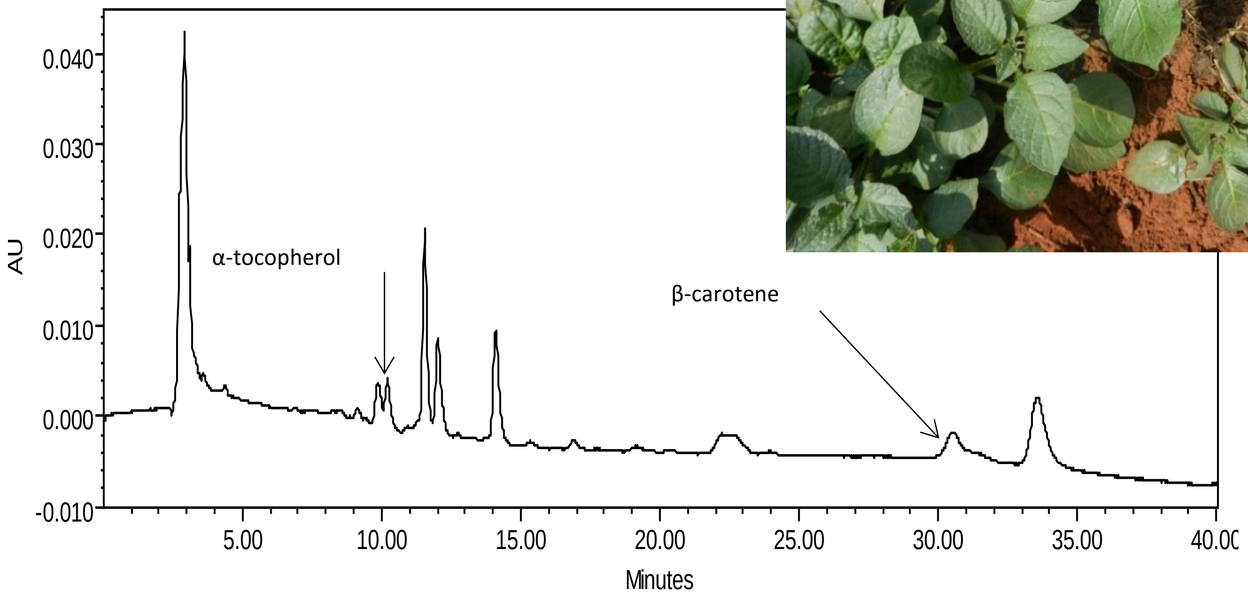
	mg α-tocopherol/100g	mg β-carotene/100g	IU α tocopherol/100g	IU β-carotene/100g	Polyphenols (GAE/gram)
C. gynandra (SP-16)	3.04±1.77	5.37±4.03	4.54±2.64	8924.00±6688.92	3.53±0.89
C. rubella (SP-11)	3.67±1.27	4.40±1.08	5.47±1.90	7313.15±1793.79	10.00±0.87
C. hirta (SP-9)	5.55±1.83	7.70±3.68	8.29±2.72	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
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 markd by "?". Molecular ions protonated in orange and adducted with acetonitrile in red, aglycone fragment in blue, fragment unidentified in green.

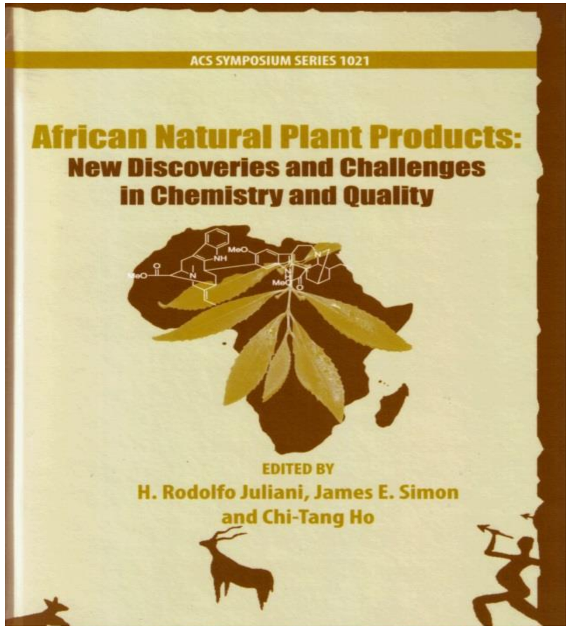
Nutritional Benefit of Moringa: Mineral Content Comparison

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

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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

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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

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

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