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Comparative nutritional analysis between African Indigenous Vegetables grown by urban farmers and those available for purchase in Kibera, Nairobi, Kenya: A Case Study

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Comparative Mineral Analysis between African Indigenous Vegetables Grown by Urban Farmers and Those Available for Purchase in and near Kibera, Nairobi, Kenya: A Case Study

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ABSTRACT

Informal settlements, commonly known as "urban slums", suffer from a number of health and economic concerns including limited access to and availability of affordable nutritious vegetables, exposure to air and water contamination and high rates of unemployment. These social and environmental conditions increase the risk of undernutrition and iron-deficiency anemia. Kibera is the largest informal settlement in Nairobi, Kenya in which most residents face such challenges. Research indicates that urban agriculture interventions can offer partial solutions to these challenges, particularly when incorporating locally recognized and valued produce such as African Indigenous Vegetables (AIVs). However, little is known about the nutritional value of these locally grown urban AIVs and about the adverse effects that the urban environment may have on soil quality, which may extend to plant and human health. This case study focuses on the implementation of an urban agriculture intervention among a group of women (n=36) living in Kibera as a means to provide the women with nutritious AIVs and a potential source of income. The objectives were to 1) analyze the nutritional value of the AIVs grown in urban gardens (sack gardens and small field plots) in terms of macro- and micronutrient levels, 2) compare the mineral content of AIVs grown in the urban garden to those locally available in the market and 3) analyze soil health. The AIVs grown in the urban gardens were found to have equal or higher levels of individual plant nutrients when compared to those available for sale in the local market. The soil used in these urban gardens was analyzed for mineral and heavy metal composition and found to be safe in regard to heavy metal

contamination. Results showed that the urban agriculture intervention was desirable amongst participants and is a promising growing system for income generation and in providing fresh and nutritious produce in a challenging environment.

INTRODUCTION

Urban informal settlements, or “urban slums”, are characterized by a lack of access to social amenities such as clean water, improved sanitation, security and durable housing. Moreover, residents often experience overcrowding, violence, unemployment, corruption, poverty and food insecurity (Gallaher et al., 2013a; Kyobutungi et al., 2008; Moreno, 2003). Urban informal settlements often arise near transportation systems, dumpsites, industrial areas and regions frequently at risk of devastation by natural disasters (Gallaher et al., 2013a; UN-Habitat, 2003). These conditions pose great environmental risk to the urban inhabitants as exposure to biological and chemical pollution is linked to many serious health issues and increased mortality (Gallaher et al., 2013a; Kyobutungi et al., 2008; Olack et al., 2014).

Sub-Saharan Africa has the highest prevalence of slums with 62% of their cities having informal settlements compared with North Africa (13%), Western Asia (25%), South Asia (35%), and Latin America and the Caribbean (24%; UN-Habitat, 2012). The percentage of people living in slums in Kenya in 2007 was estimated at 54.8%. About one third of this population resides in Nairobi, the nation’s capital (UN-Habitat, 2014). Kibera is a well-known informal settlement located in Nairobi, Kenya that faces the adverse social and environmental conditions typical of slums including poverty, food insecurity, hunger, poor nutrition and gendered power imbalance (Gallaher et al., 2013b; George et al., 2019; Harika et al., 2017a; Harika et al., 2017b; Mwambi, 2014; Ngesa and Swart, 2011; Pascal and Mwende, 2009; UN-Habitat, 2003).

A lack of access to affordable and nutritious vegetables is associated with micronutrient deficiencies, a major concern in Kenya and several other African countries, particularly for children and pregnant women. For example, iron-deficiency anemia is a result of a lack of iron in the blood from undernutrition and can lead to severe health complications if left undiagnosed or untreated. These complications including heart failure, developmental delays in children and birth complications (Allen, 2000; NIH, 2020). Harika et al. (2017a; 2017b) estimated that 25-53% of children, 32-62% of pregnant women and 19-61% of women of reproductive age in Ethiopia, Kenya, Nigeria and South Africa were anemic while Ngesa and Mwambi (2014) estimated that 28.8% of children between six months and 14 years in Kenya specifically were anemic.

Agriculture interventions, including sack gardening programs have been implemented to mitigate these issues by empowering women to grow nutritious foods for household consumption and sale. Local agricultural production can decrease household expenditures on food while generating income when surplus is sold (Gallaher et al., 2013b; Hoffman et al., 2018; Pascal and Mwende, 2009). Sack garden programs have shown to increase household dietary diversity, increase social capital and mitigate food shortages (Gallaher et al., 2013c; Weller et al., 2015).

African Indigenous Vegetables (AIVs) are beneficial crops to incorporate into agriculture interventions because they are nutrient-dense and more adapted to local environmental conditions and stressors. AIVs tend to be culturally desirable and preferable despite the social stigma of being ‘famine food’ (Hoffman et al., 2018). AIVs include leafy greens such as amaranth or terere (*Amaranthus* spp.), African nightshade or managu (*Solanum nigrum*), spider plant or sagaa (*Cleome gynandra*) and kale or sukuma wiki (*Brassica oleracea*). Though both amaranth and kale have their origins outside of Africa, they are described here as *indigenous* because they have been naturalized into traditional African culture (Macaskill, 2011).

Agriculture interventions in urban environments are not without challenges. The conditions of Kibera not only have a negative impact on living conditions, but also urban agriculture. Major health concerns for residents in Kibera related to crop growing conditions and handling have been found to include micronutrient deficiencies and heavy metal contamination, more so than food-borne illnesses (Gallaher et al., 2013a; George et al., 2019). Our case study examined the nutritional composition of crops grown by urban farmers in addition to the heavy metal composition and quality of their soil in order to assess health and safety concerns regarding urban agriculture near Kibera, Kenya.

This exploratory study sought to accomplish the following aims: 1) analyze the nutritional value of the AIVs grown in urban gardens (sack gardens and small field plots) in terms of macro- and micronutrient levels, 2) compare the mineral content of AIVs grown in the urban garden to those locally available in the market and 3) analyze soil health. This study was conducted to complement a larger initiative to promote the production and consumption of AIVs in Kenya and Africa. This data will inform with confidence that the soil used in this intervention is safe for plant propagation and that the vegetables are minerally comparable to those available in the market. These results will determine how the intervention could be strengthened and scaled up to increase household production and consumption of AIVs and provide an additional source of income for women in Kibera.

MATERIALS AND METHODS

Urban agriculture intervention. Participants were recruited through Mirror of Hope Community-Based Organization (CBO)'s Women Empowerment in Kibera, Nairobi, Kenya. Thirty-two women participated in the initial training in June 2018. Eleven women withdrew from the project, while four additional women were in the training process for a total of thirty-six women trained and twenty-five active members. Participants received sack garden training, which included construction of the sacks, caring for the sacks once planted (irrigation, pest management, replanting) and harvesting. The training took place over the course of two days and was led by an agronomist from Academic Model Providing Access to Health Care (AMPATH), Eldoret, Kenya and training was conducted in Swahili. In total, six sack gardens were initially planted. Small groups of women worked together to plant and care for the sack gardens. This case study report is part of a larger initiative funded through the Feed the Future initiative *Improving Nutrition with African Indigenous Vegetables.*

Growing conditions. The Urban Agriculture Intervention focused on sack garden preparation and maintenance; however, participants also grew vegetables in a small field plot adjacent to the sack gardens to maximize available growing area. For the purpose of this paper, vegetables grown in the sack gardens and those grown in small field plots were grouped together under the term "urban agriculture." Amaranth and kale were grown by urban farmers in the sack gardens (UFS) while nightshade and spider plant were grown by urban farmers in the field (UFF).The sack gardens and small field plots were established at the Mary Rice Centre, a school located on the outskirts of Kibera (1° 19' 08.3" S, 36° 47' 01.5" E).

Sack gardens were constructed by filling 90 kg grain sacks with rocks (1-3 cm) at the center core for water drainage and filling the remainder of the sack with a 3:2 mixture of soil and compost (Fig. 1). The soil was collected at the Mary Rice Centre. The compost was purchased from a local company and derived from animal manure. Approximately 70 holes (1.5 cm wide) were cut into the sides of each sack for the transplants. Holes were staggered and distanced approximately 15 cm. Plants (n=4) were also grown on the top of the sack. The same mixture of soil and compost was used as the growing medium in the field plots. The field plots varied in size, but created a total growing area of approximately 20 m x 1 m. The field plots ran along a fence line adjacent to the sack gardens.

All plants used in this project were purchased from a tree nursery near Embakasi Airport, Nairobi, Kenya. Purchased plants included kale, which were 15 cm suckers taken from a mature kale plants and transplanted into soil to establish roots, and spider plant, amaranth and nightshade seedlings (28-30 day old).

Participants harvested the plants regularly at the node of the plant stem for consumption and to promote growth. Additionally, new plants were established in the sack garden by propagating plugs either from rooted suckers or germinated seeds. Irrigation varied greatly by sack and plot with some participants reporting watering the sacks once a week while other reporting watering the sack two times a day. Participants noted the use of homemade pesticide made with *Pili* (ground hot peppers). Fertilizers or commercial pesticides were not applied. Growing conditions of the crops purchased from the market (M) were unknown by the vendors.

Soil analysis. Heavy metals, total nitrogen, pH, extractable phosphorus (Olsen P) and micromineral analyses were conducted on a soil core from a random sack garden by CropNuts Laboratory Services, Nairobi, Kenya. Soil Electrical Conductivity (EC) and pH were measured from potentiometric analyses. Nitrogen (%) and potassium content (ppm) were determined via colorimetry, while other plant-important elements (ppm) were determined via spectroscopy.

Sampling. An objective of this case study was to compare the mineral profile of the fresh produce grown in the urban agriculture intervention (sack gardens and small field plots) to those found in the local market. To accomplish this, amaranth, kale, African nightshade and spider plant were randomly harvested from the sack gardens and urban plots. For comparison, the same four vegetables (amaranth, kale, nightshade and spider plant) were purchased from the local market at four different locations: Toi Market (a large open-air market where many residents in Kibera buy their produce in bulk) and three different street vendors within Kibera (M). The AIVs available in the markets were sourced from commercial farmers producing the crops outside of Kibera and reflected the availability of such produce to Kibera residents. Purchasing dates coincided with harvest dates to represent the nutritional value of the produce if consumed on that day. At least five biological replicates were collected from each crop from each site and bulked into one sample. Sampling was conducted at the end of the dry season on March 18, 2019 and March 21, 2019 and at the end of the rainy season on July 10, 2019. Nightshade and spider plant grown by UFF were only grown by the women in one season and therefore were not replicated. Recognized limitations of this case study are the lack of control for the (i) specific AIV variety when purchasing from growers or the market and (ii) standardized growing conditions.

Plant mineral analysis. Leaves from each crop were sun-dried, ground and homogenized. Ground tissue (1g) was analyzed for elemental composition (P, K, Ca, Mg, S, Mn, Fe, Cu, B, Al, Zn and Na) via standard acid digestion and inductively coupled plasma mass spectrometry (ICP-MS) by Agricultural Analytical Services Laboratory at Pennsylvania State University. Crops were not examined for heavy metals as the soil was determined to only contain trace levels.

Dietary Reference Intake. Dietary Reference Intake (DRI) values were obtained from the Institute of Medicine Panel on Micronutrients (2001), the Institute of Medicine of the National Academies (2005), and Ross et al. (2011). Mineral content was determined as the average of the samples collected across seasons. These values were used to calculate the amount of leafy greens needed to be consumed daily to meet the DRI (g/d) for each nutrient analyzed assuming 90% water content in the leaves by dividing the DRI (mg/d) by the mineral content (mg/g). The DRI values are used to assess nutritional recommendations in the US and Canada, whereas other regions may use other references such as the Dietary Reference Values used in Europe.

Statistical analysis. Two-sample t-tests were conducted in cases of equal variance and Welch t-tests were conducted in cases of unequal variance to assess for differences between mean values of each crop grown by the urban farmers (UFS and UFF) and of that available for purchase at the local market (M). Significance could not be determined for nightshade or spider plant due to limited replications. Data were analyzed using the software package R with $p<0.05$ as the statistical significance level.

RESULTS AND DISCUSSION

Soil analysis. The soil was classified as Type A, silty clay. Generally, the levels of plant nutrients were within the optimal ranges. The pH of 6.8 was within the range of recommended guidelines for many fresh leafy vegetables. Results from the soil analysis showed optimal levels of macro- and microminerals including, phosphorous, potassium, calcium, manganese, sulfur, zinc, iron, sodium and trace levels of heavy metals including arsenic, cadmium, chromium, cobalt, nickel, and lead. The soil was low in copper, boron and total nitrogen, and high in magnesium and molybdenum. The trace levels of heavy metals indicate a low degree of soil contamination and therefore a low risk to overall plant health and human health (Tchounwou et al., 2014). Soil Cation Exchange Capacity (CEC) was calculated and found to be 14.5 meq/100 g, just below the recommended level of 15-30 meq/100 g. Magnesium and potassium content were high. The soil used was favorable for vegetable production but could be improved with fertilizer treatments or additional compost and by attaining more consistent porosity (Hoskins, 1997).

Plant mineral analysis. Macro- and micro-mineral levels were within range of other dried leafy greens (Bosnak and Pruszkowski, 2014; Van der Walt et al., 2009) and fresh leafy greens when assuming 90% water content (Gebhardt and Thomas, 2002).

Kale grown by the urban farmers was significantly higher in iron, aluminum, sodium, phosphorous, potassium and sulfur than the kale purchased from the market and comparable for all other nutrients (Figs. 2 and 3). These differences may be due to variations in soil composition, irrigation, crop variety or husbandry practices. Additionally, the difference in aluminum levels may be due to variation in crop storage, processing or transportation. While aluminum is not considered a nutrient necessary for human health, oral exposure is generally innocuous to human health (DTHHS, 2008). There was no significant difference in plant micromineral content (Fig. 2) or macro-mineral content (Fig. 3) between amaranth grown by the urban farmers and amaranth purchased from the local market. A lack of seasonal replication limits the analysis of nightshade and spider plant, but available data is included for elemental compositions and reference for future studies.

This analysis indicates that the vegetables grown by the participants are comparable to or higher in certain plant nutrients than those found in the market and therefore the intervention offers a source of nutritionally dense leafy greens to individuals who may otherwise have challenges accessing affordable greens.

DRI analysis. The average mineral content of each plant sample (Table 1) was used to calculate the amount of each AIV needed to be consumed to meet the DRI for each element assuming the AIV is the only source of that nutrient in the diet (Table 2). The mineral content of spinach, determined by Bosnak and Pruszkowski (2014), presented in the results were included solely as a reference of comparison, because spinach is a leafy green vegetable commonly known as a “high source” of essential vitamins and minerals such as iron (Yan, 2016) and is typically not available to participants. Sulfur, boron and aluminum were excluded from the analysis as there were no DRI values for these elements. Each AIV exhibited higher levels of phosphorous, potassium, calcium, manganese and iron and lower levels of sodium when compared to reported values in spinach (Table 1). Amaranth was higher than spinach in magnesium, but kale, nightshade and spider plant were lower. Nightshade was slightly higher in copper than spinach, while the other AIVs were comparable. Kale and nightshade were lower than spinach in zinc, but amaranth and spider plant were comparable.

High iron content in vegetables is of interest due to the high rates of anemia in Kenya and other sub-Saharan countries (Harika et al., 2017a; Harika et al., 2017b; Ngesa and Mwambi, 2014). The AIVs offer a good source of iron as compared to the spinach reference (Fig. 4). An individual would generally need to consume much less of the AIVs from this case study as compared to the spinach reference to meet their DRI for iron (Table 2). For example, a participant would meet the iron DRI for her 1-3 year-old child with an average of 73 g of her freshly grown amaranth, 121 g kale, 59 g nightshade and 88 g spider plant as compared with 264 g spinach. If she purchased her produce from the market instead of growing them in her urban garden, then she would need a statistically similar average amount of amaranth (72 g; $p>0.05$) and significantly less than double the amount of kale (216 g; $p<0.05$) to meet the same need for her child. Thus, her vegetables were comparable if not a better source of iron than those available at the market. These comparative values are presented to highlight that the AIVs used in this study are nutrient rich, and the values in nutrient composition from the sack garden and small field plots in Kibera matched the nutritional value of these same AIVs in the commercial marketplace.

It is important to note that these values are based on average nutrient contents across seasons and may be higher or lower with different growing conditions, environmental stresses and food processing methods. The amount of each individual AIV (g) needed to be consumed per day to meet the DRI is described in more detail in Table 2. These results are to provide insights into a theoretical amount of vegetables that would need to be consumed, by children and adults during reproductive years, and to allow for comparison to traditional European introduced leafy greens such as lettuce, spinach or cabbage that may not be accessible or customarily consumed by the participants.

Intervention impact. Barriers such as seasonal shortages and higher costs often prevent the women from consuming the desired AIVs. The sack gardens and urban plots offer reliable and affordable sources of these preferred, nutrient rich AIVs. Additionally, it is common for the women to sell excess food for additional income. If this urban agriculture intervention is scaled-up to meet household demand with surplus, an additional benefit of this intervention could be income generated from the direct sales of these AIVs.

Challenges observed in the course of this case study included the need for water storage capability during the dry season, security for the sack gardens themselves and the need for continual training in horticulture given these skills were new to many of the participants. Water storage systems and training programs are currently being explored. In addition, while the soil in this case study was found to be safe from heavy metals, production of fresh produce in urban environments must always consider the soil and water health in terms of the presence of heavy metals, microbial contamination and other environmental toxins. Participants stated eagerness to overcome these challenges and to scale the intervention to grow enough vegetables to meet household needs with excess for sale as added revenue.

This case study compared selected AIVs (amaranth, kale, African nightshade and spider plant) grown in an urban agriculture intervention (sack gardens and small field plots) to those purchased in the local market in Kibera, an informal settlement in Nairobi, Kenya. It was determined that the vegetables grown by the participants were equal or higher in individual elementals when compared to those available for purchase at the local market. Given barriers to market access, the urban gardens offered a source of minerally rich leafy vegetables, especially in terms of iron. The study also found the growing medium to be favorable and safe for vegetable propagation. These results indicate that, under monitored conditions, AIVs grown in an urban agricultural setting such as sack gardens or small field plots are nutritionally comparable if not a better source of fresh produce for household consumption. The participants in the study reported that the project was desirable, and they expressed interest and commitment to continue with the intervention. Further research is needed to determine how this intervention impacts other areas for the women such as income generation, household dietary diversity, and food frequency. Next steps will focus on scaling the intervention to facilitate the growth of more vegetables by more women in Kibera, Nairobi, Kenya.

Table 1. Mineral content in AIVs (mg/g) Grown by Urban Farmers or Purchased at the Market.

Crop/Source	P	K	Ca	Mg	S	Mn	Fe	Cu	B	Al	Zn	Na
Spinach (Ref)	4.8	26.6	15.0	8.6	4.4	0.08	0.27	0.01	0.04	0.20	0.08	17.4
Amaranth (UFS)	6.5	52.0	24.6	13.2	3.9	0.17	0.96	0.01	0.04	0.75	0.06	0.45
Amaranth (M)	5.8	47.2	33.0	12.4	4.0	0.35	0.97	0.01	0.04	0.87	0.09	0.46
Kale (UFS)	5.6	42.3	29.4	5.7	15.4	0.15	0.58	0.01	0.03	0.43	0.05	4.18
Kale (M)	3.4	35.0	31.3	4.3	9.5	0.13	0.32	0.01	0.04	0.20	0.07	1.22
Nightshade (UFF)	7.1	49.3	18.1	7.1	5.5	0.28	1.19	0.03	0.04	0.94	0.05	0.11
Nightshade (M)	4.9	39.7	22.4	6.9	5.1	0.19	0.62	0.01	0.04	0.46	0.04	0.60
Spider plant (UFF)	6.6	29.6	27.4	4.2	6.6	0.15	0.79	0.01	0.04	0.53	0.07	0.35
Spider plant (M)	**7.2**	**29.1**	**23.8**	**5.1**	**7.6**	**0.12**	**0.98**	**0.01**	**0.05**	**0.79**	**0.08**	**0.81**

*Spinach was not measured as part of this study but included as a reference for comparison (Bosnak and Pruszkowski, 2014). Urban farmers grew produce in sack gardens (UFS) or in field plots (UFF) and compared the mineral content was compared to that of the produce available for purchase in the market (M)

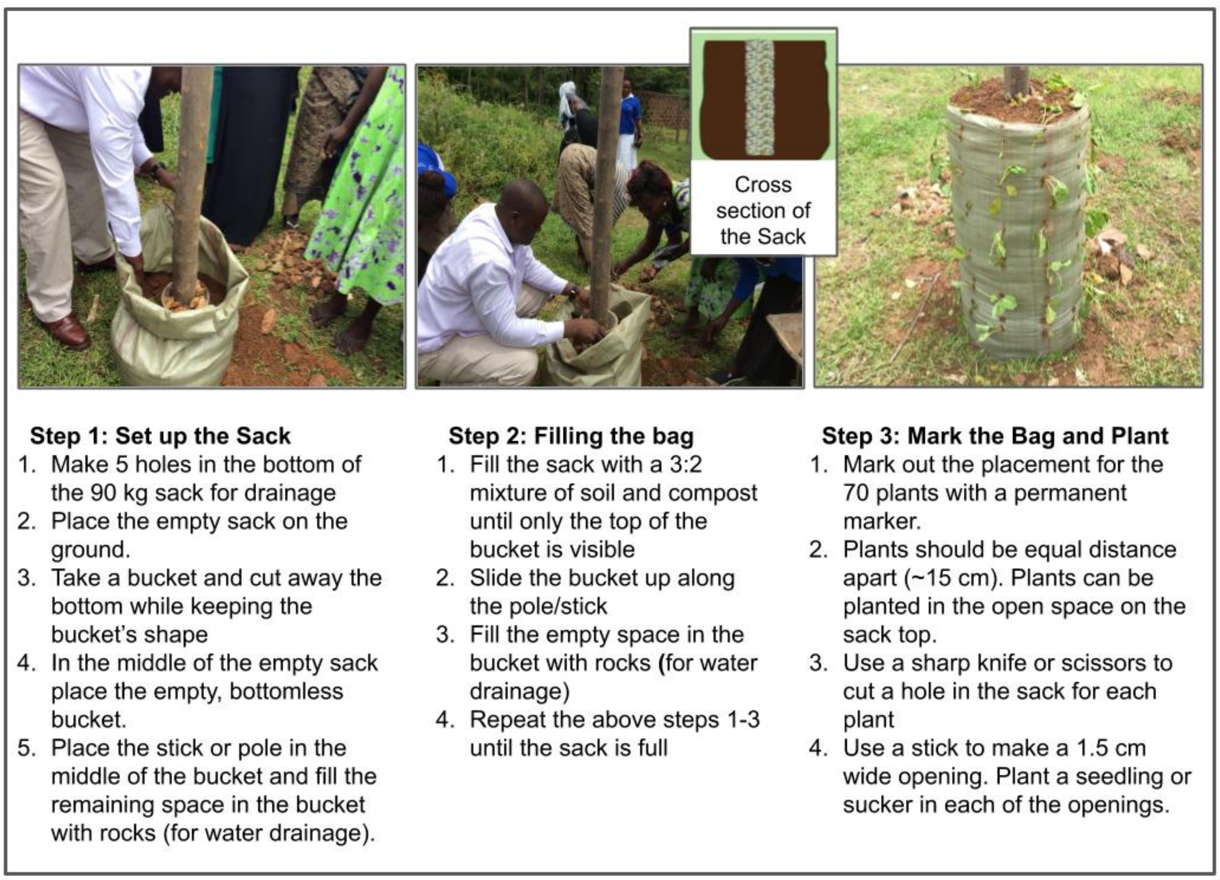

Figure 1. Sack Garden Construction Steps.

Table 2. Amount of AIVs (g) Needed to be Consumed Daily to Meet the DRI.

	Crop/Source	P	K	Ca	Mg	Mn	Fe	Cu	Zn	Na
1-3 y child	Spinach (Reference)	956	1128	465	93	154	264	293	375	576
	Amaranth (UFS)	707	577	284	61	69	73	289	527	22180
	Amaranth (M)	798	636	212	64	34	72	368	333	21593
	Kale (UFS)	819	709	238	141	80	121	551	637	2393
	Kale (M)	1360	857	224	186	94	216	566	425	8213
	Nightshade (UFF)	646	609	386	112	43	59	114	648	92167
	Nightshade (M)	944	756	313	116	65	112	380	702	16601
	Spider plant (UFF)	696	1013	256	191	78	88	296	418	28835
	Spider plant (M)	635	1031	294	155	96	71	382	378	12377
4-8 y child	Spinach (Reference)	1040	1429	665	151	193	377	379	625	692
	Amaranth (UFS)	768	731	406	98	86	104	374	879	26616
	Amaranth (M)	867	806	303	105	43	103	476	556	25911
	Kale (UFS)	890	898	340	229	100	172	713	1062	2872
	Kale (M)	1479	1086	320	302	118	308	732	708	9856
	Nightshade (UFF)	703	771	551	182	54	84	147	1079	110601
	Nightshade (M)	1026	957	447	188	81	161	492	1169	19921
	Spider plant (UFF)	756	1283	365	311	97	126	383	696	34602
	Spider plant (M)	690	1306	420	252	120	102	495	629	14852
9-13 y male	Spinach (Reference)	2599	1692	864	279	244	302	603	1000	865
	Amaranth (UFS)	1921	866	528	182	109	83	596	1406	33270
	Amaranth (M)	2169	954	394	193	54	83	757	889	32389
	Kale (UFS)	2225	1063	442	423	127	138	1135	1699	3590
	Kale (M)	3697	1286	416	557	149	247	1164	1132	12320
	Nightshade (UFF)	1757	913	717	336	69	67	234	1727	138251
	Nightshade (M)	2564	1133	581	347	103	129	783	1871	24901
	Spider plant (UFF)	1891	1519	475	574	123	101	609	1114	43253
	Spider plant (M)	1725	1546	546	466	153	82	787	1007	18565
9-13 y female	Spinach (Reference)	2599	1692	864	279	205	302	603	1000	865
	Amaranth (UFS)	1921	866	528	182	92	83	596	1406	33270
	Amaranth (M)	2169	954	394	193	46	83	757	889	32389
	Kale (UFS)	2225	1063	442	423	107	138	1135	1699	3590
	Kale (M)	3697	1286	416	557	126	247	1164	1132	12320
	Nightshade (UFF)	1757	913	717	336	58	67	234	1727	138251
	Nightshade (M)	2564	1133	581	347	86	129	783	1871	24901
	Spider plant (UFF)	1891	1519	475	574	104	101	609	1114	43253
	Spider plant (M)	1725	1546	546	466	128	82	787	1007	18565

Table 2 *Cont*. Amount of AIVs (g) Needed to be Consumed Daily to Meet the DRI.

	Crop/Source	P	K	Ca	Mg	Mn	Fe	Cu	Zn	Na
14-18 y male	Spinach (Reference)	2599	1692	864	279	205	302	603	1000	865
	Amaranth (UFS)	1921	866	528	182	92	83	596	1406	33270
	Amaranth (M)	2169	954	394	193	46	83	757	889	32389
	Kale (UFS)	2225	1063	442	423	107	138	1135	1699	3590
	Kale (M)	3697	1286	416	557	126	247	1164	1132	12320
	Nightshade (UFF)	1757	913	717	336	58	67	234	1727	138251
	Nightshade (M)	2564	1133	581	347	86	129	783	1871	24901
	Spider plant (UFF)	1891	1519	475	574	104	101	609	1114	43253
	Spider plant (M)	1725	1546	546	466	128	82	787	1007	18565
14-18 y female	Spinach (Reference)	2599	1767	864	419	205	566	767	1125	865
	Amaranth (UFS)	1921	904	528	273	92	157	757	1581	33270
	Amaranth (M)	2169	997	394	290	46	155	963	1000	32389
	Kale (UFS)	2225	1111	442	635	107	258	1442	1911	3590
	Kale (M)	3697	1343	416	836	126	462	1480	1274	12320
	Nightshade (UFF)	1757	954	717	504	58	126	298	1943	138251
	Nightshade (M)	2564	1184	581	521	86	241	995	2105	24901
	Spider plant (UFF)	1891	1587	475	862	104	190	774	1253	43253
	Spider plant (M)	1725	1615	546	699	128	153	1001	1133	18565
14-18 y female (pregnant)	Spinach (Reference)	2599	1767	864	465	257	1019	862	1500	865
	Amaranth (UFS)	1921	904	528	303	115	282	851	2109	33270
	Amaranth (M)	2169	997	394	322	57	278	1082	1334	32389
	Kale (UFS)	2225	1111	442	705	133	465	1621	2549	3590
	Kale (M)	3697	1343	416	929	157	832	1663	1698	12320
	Nightshade (UFF)	1757	954	717	560	72	226	334	2590	138251
	Nightshade (M)	2564	1184	581	579	108	434	1118	2806	24901
	Spider plant (UFF)	1891	1587	475	957	130	341	869	1670	43253
	Spider plant (M)	1725	1615	546	777	161	276	1124	1510	18565
19-30 y male	Spinach (Reference)	1455	1767	665	465	295	302	776	1375	865
	Amaranth (UFS)	1076	904	406	303	132	83	766	1933	33270
	Amaranth (M)	1214	997	303	322	66	83	974	1222	32389
	Kale (UFS)	1246	1111	340	705	153	138	1459	2336	3590
	Kale (M)	2070	1343	320	929	181	247	1497	1557	12320
	Nightshade (UFF)	984	954	551	560	83	67	301	2374	138251
	Nightshade (M)	1436	1184	447	579	124	129	1007	2572	24901
	Spider plant (UFF)	1059	1587	365	957	149	101	782	1531	43253
	Spider plant (M)	966	1615	420	777	185	82	1012	1384	18565

Table 2 *Cont*. Amount of AIVs (g) Needed to be Consumed Daily to Meet the DRI.

	Crop/Source	P	K	Ca	Mg	Mn	Fe	Cu	Zn	Na
19-30 y female	Spinach (Reference)	1455	1767	665	360	231	679	776	1000	865
	Amaranth (UFS)	1076	904	406	235	103	188	766	1406	33270
	Amaranth (M)	1214	997	303	249	52	186	974	889	32389
	Kale (UFS)	1246	1111	340	546	120	310	1459	1699	3590
	Kale (M)	2070	1343	320	720	141	555	1497	1132	12320
	Nightshade (UFF)	984	954	551	434	65	151	301	1727	138251
	Nightshade (M)	1436	1184	447	448	97	289	1007	1871	24901
	Spider plant (UFF)	1059	1587	365	742	117	227	782	1114	43253
	Spider plant (M)	966	1615	420	602	145	184	1012	1007	18565
19-30 y female (pregnant)	Spinach (Reference)	1455	1767	665	407	257	1019	862	1375	865
	Amaranth (UFS)	1076	904	406	265	115	282	851	1933	33270
	Amaranth (M)	1214	997	303	282	57	278	1082	1222	32389
	Kale (UFS)	1246	1111	340	617	133	465	1621	2336	3590
	Kale (M)	2070	1343	320	813	157	832	1663	1557	12320
	Nightshade (UFF)	984	954	551	490	72	226	334	2374	138251
	Nightshade (M)	1436	1184	447	506	108	434	1118	2572	24901
	Spider plant (UFF)	1059	1587	365	838	130	341	869	1531	43253
	Spider plant (M)	966	1615	420	680	161	276	1124	1384	18565
31-50 y male	Spinach (Reference)	1455	1767	665	488	295	302	776	1375	865
	Amaranth (UFS)	1076	904	406	318	132	83	766	1933	33270
	Amaranth (M)	1214	997	303	338	66	83	974	1222	32389
	Kale (UFS)	1246	1111	340	740	153	138	1459	2336	3590
	Kale (M)	2070	1343	320	975	181	247	1497	1557	12320
	Nightshade (UFF)	984	954	551	588	83	67	301	2374	138251
	Nightshade (M)	1436	1184	447	608	124	129	1007	2572	24901
	Spider plant (UFF)	1059	1587	365	1005	149	101	782	1531	43253
	Spider plant (M)	966	1615	420	816	185	82	1012	1384	18565
31-50 y female	Spinach (Reference)	1455	1767	665	372	231	679	776	1000	865
	Amaranth (UFS)	1076	904	406	242	103	188	766	1406	33270
	Amaranth (M)	1214	997	303	257	52	186	974	889	32389
	Kale (UFS)	1246	1111	340	564	120	310	1459	1699	3590
	Kale (M)	2070	1343	320	743	141	555	1497	1132	12320
	Nightshade (UFF)	984	954	551	448	65	151	301	1727	138251
	Nightshade (M)	1436	1184	447	463	97	289	1007	1871	24901
	Spider plant (UFF)	1059	1587	365	766	117	227	782	1114	43253
	Spider plant (M)	966	1615	420	621	145	184	1012	1007	18565

Table 2 *Cont*. Amount of AIVs (g) Needed to be Consumed Daily to Meet the DRI.

	Crop/Source	**P**	**K**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**Zn**	**Na**
31-50 y female (pregnant)	Spinach (Reference)	1455	1767	665	419	257	1019	862	1375	865
	Amaranth (UFS)	1076	904	406	273	115	282	851	1933	33270
	Amaranth (M)	1214	997	303	290	57	278	1082	1222	32389
	Kale (UFS)	1246	1111	340	635	133	465	1621	2336	3590
	Kale (M)	2070	1343	320	836	157	832	1663	1557	12320
	Nightshade (UFF)	984	954	551	504	72	226	334	2374	138251
	Nightshade (M)	1436	1184	447	521	108	434	1118	2572	24901
	Spider plant (UFF)	1059	1587	365	862	130	341	869	1531	43253
	Spider plant (M)	966	1615	420	699	161	276	1124	1384	18565
51-70 y male	Spinach (Reference)	1455	1767	665	488	295	302	776	1375	749
	Amaranth (UFS)	1076	904	406	318	132	83	766	1933	28834
	Amaranth (M)	1214	997	303	338	66	83	974	1222	28070
	Kale (UFS)	1246	1111	340	740	153	138	1459	2336	3111
	Kale (M)	2070	1343	320	975	181	247	1497	1557	10677
	Nightshade (UFF)	984	954	551	588	83	67	301	2374	119818
	Nightshade (M)	1436	1184	447	608	124	129	1007	2572	21581
	Spider plant (UFF)	1059	1587	365	1005	149	101	782	1531	37486
	Spider plant (M)	966	1615	420	816	185	82	1012	1384	16090
51-70 y female	Spinach (Reference)	1455	1767	798	372	231	302	776	1000	749
	Amaranth (UFS)	1076	904	488	242	103	83	766	1406	28834
	Amaranth (M)	1214	997	363	257	52	83	974	889	28070
	Kale (UFS)	1246	1111	408	564	120	138	1459	1699	3111
	Kale (M)	2070	1343	384	743	141	247	1497	1132	10677
	Nightshade (UFF)	984	954	661	448	65	67	301	1727	119818
	Nightshade (M)	1436	1184	536	463	97	129	1007	1871	21581
	Spider plant (UFF)	1059	1587	438	766	117	101	782	1114	37486
	Spider plant (M)	966	1615	504	621	145	82	1012	1007	16090

*Spinach was not measured as part of this study but was included as a reference for comparison (Bosnak and Pruszkowski, 2014). The mineral values assume that the indicated vegetable is the only source of that nutrient in the diet.

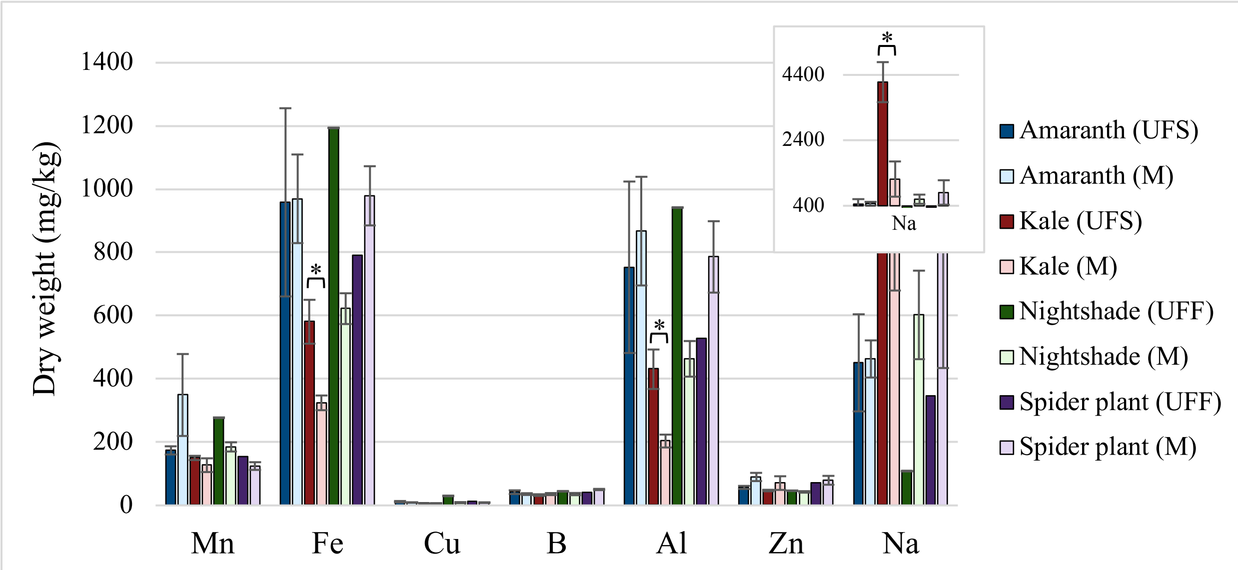

Figure 2. Comparison of Plant Micromineral Profiles between AIVs Grown by Urban Farmers and that of AIVs Available in the Market.

*Crops grown by urban farmers in either sack gardens (UFS) or the field (UFF) were comparable or higher in micromineral content to those available for purchase at the local market (M).

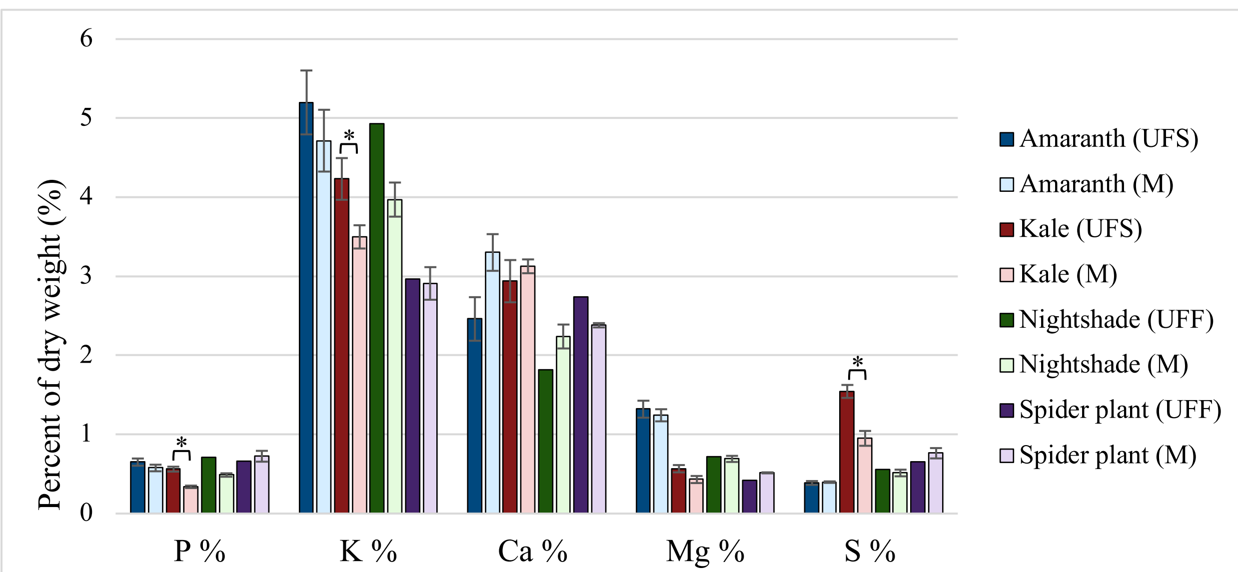

Figure 3. Comparison of Plant Macromineral Profiles between AIVs Grown by Urban Farmers and that of AIVs Available in the Market.

*Crops grown by urban farmers in either sack gardens (UFS) or the field (UFF) were comparable or higher in micromineral content to those available for purchase at the local market (M).

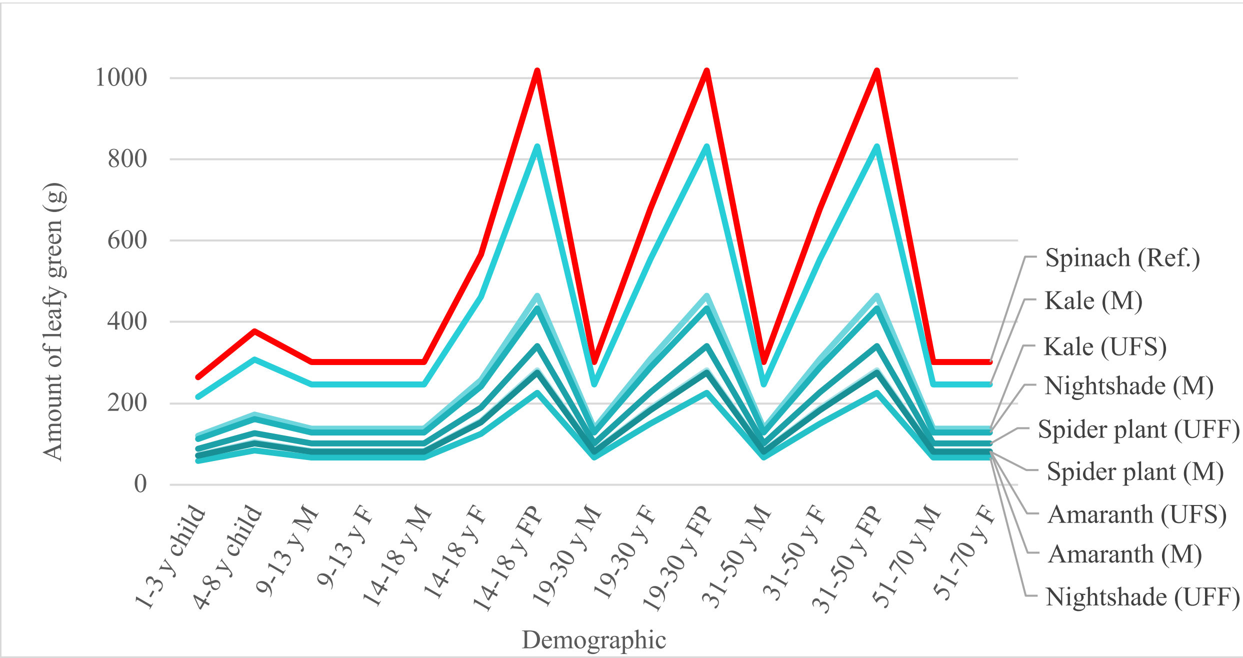

Figure 4. Amount of leafy greens needed to be consumed to meet the DRI for iron (Fe) for each demographic. Crops were grown by the urban farmer in either sack gardens (UFS), grown in the field (UFF) or purchased at the local market (M) and compared to a standard reference.

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REFERENCES

Allen, L.H. 2000. Anemia and iron deficiency: effects on pregnancy outcome. The American Journal of Clinical Nutrition 71: 280S-284S.

Bosnak, C., and Pruszkowski, E. 2014. The elemental analysis of spinach with the NexION 300/350 ICP-MS. PerkinElmer Inc., Waltham, MA. 1-4.

Division of Toxicology and Environmental Medicine (DTHHS). 2008. Public health statement: aluminum CAS #7429-90-5. Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

Gallaher, C.M., Mwankiki, D., Njenga, M., Karanja, N.K., and WinklerPrins, A.M.G.A. 2013a. Real or perceived: the environmental health risks of urban sack gardening in Kibera slums of Nairobi, Kenya. Ecohealth 10: 9-20.

Gallaher, C.M., WinklerPrins, A.M.G.A., Njenga, M., and Karanja, N.K. 2013b. Creating space: sack gardening as a livelihood strategy in the Kibera slums of Nairobi, Kenya. Journal of Agriculture, Food Systems, and Community Development 5(2): 155-173.

Gallaher, C.M., Kerr, J.M., Njenga, M., Karanja, N.K., and WinklerPrins, A.M.G.A. 2013c. Urban agriculture, social capital, and food security in the Kibera slums of Nairobi, Kenya. Agriculture and Human Values 30: 389-404.

Gebhardt, S.E., and Thomas, R.G. 2002. Nutritive Value of Foods. USDA, Agricultural Research Service, Nutrient Data Laboratory, Beltsville, Maryland.

George, N., Mildred, N., and Hudson, N. 2019. Health risk assessment on selected essential and non-essential elements in food crops grown in Kibera slum, Nairobi-Kenya. Food and Nutrition Sciences 10: 635-647.

Harika, R., Faber, M., Samuel, F., Mulugeta, A., Kimiywe, J., and Eilander, A. 2017a. Are low intakes and deficiencies in iron, vitamin A, zinc, and iodine of public health concern in Ethiopian, Kenyan, Nigerian, and South African children and adolescents? Food and Nutrition Bulletin 38(3): 405-427.

Harika, R., Faber, M., Samuel, F., Kimiywe, J., Mulugeta, A., and Eilander, A. 2017b. Micronutrient status and dietary intake of iron, vitamin A, iodine, folate and zinc in women of reproductive age and pregnant women in Ethiopia, Kenya, Nigeria and South Africa: a systematic review of data from 2005 to 2015. Nutrients 9(1096): 1-23.

Hoffman, D., Merchant, E., Byrnes, D.R., and Simon, J.E. 2018. Preventing micronutrient deficiencies using African Indigenous Vegetables in Kenya and Zambia. Sight and Life 32(2): 177-181.

Hoskins, B.R. 1997. *Soil testing handbook for professionals in agriculture, horticulture, nutrient and residuals management*, 3e. Maine Forestry & Agricultural Experiment Station, University of Maine, Orono, ME. 20-21.

Institute of Medicine (US) Panel on Micronutrients. 2001. *Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc*. National Academies Press (US), Washington (DC).

Institute of Medicine of the National Academies. 2005. *Dietary reference intakes for water, potassium, sodium, chloride, and sulfate*. National Academies Press (US), Washington (DC).

Ngesa, O., and Mwambi, H. 2014. Prevalence and risk factors of anaemia among children aged between 6 months and 14 years in Kenya. PLoS One 9(11): 1-10.

Kyobutungi, C., Ziraba, A.K., Ezeh, A., and Yé, Y. 2008. The burden of disease profile of residents of Nairobi's slums: results from a demographic surveillance system. Population Health Metrics 6(1): 1-8.

Macaskill, C. 2011. *The national agricultural directory 2011.* RainbowSA, South Africa.

Moreno, E.L. 2003. *Slums of the world: the face of urban poverty in the new millennium? monitoring the millennium development goal, target 11—world-wide slum dweller estimation.* United Nations Human Settlements Programme (UN-Habitat), Nairobi, KY.

National Institute of Health (NIH). 2020. Iron-deficiency anemia. National Heart Lung and Blood Institute, U.S. Department of Health and Human Services, Accessed May 1, 2020 at www.nhlbi.nih.gov/health-topics/iron-deficiency-anemia

Olack, B., Fieikin, D.R., Cosmas, L.O., Odero, K.O., Okoth, G.O., Montgomery, J.M., and Breiman, R.F. 2014. Mortality trends observed in population-based surveillance of an urban slum settlement, Kibera, Kenya, 2007-2010. PLoS One 9(1): e85913- e85913.

Pascal, P., and Mwende, E. 2009. A Garden in a Sack: experiences in Kibera, Nairobi. Urban Agriculture Magazine 21: 38-40.

Ross, A.C., Manson, J.E., Abrams, S.A., Aloia, J.F., Brannon, P.M., Clinton, S.K., Durazo-Arvizu, R.A., Gallagher, J.C., Gallo, R.L., Jones, G, Kovacs, C.S., Mayne, S.T., Rosen, C.J., and Shapses, S.A. 2011. The 2011 report on dietary reference intakes for calcium and vitamin D from the institute of medicine: what clinicians need to know. The Journal of Clinical Endocrinology & Metabolism 96(1): 53-58.

Swart, E. 2011. *Strategies for coping with gender-based violence: a study of young women in Kibera, Kenya* [Doctoral Dissertation]. University of Central Florida, Orlando, Florida.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K., and Sutton, D.J. 2014. Heavy Metals Toxicity and the Environment. Molecular, Clinical and Environmental Toxicology 101: 133-164.

United Nations Human Settlement Programme (UN-Habitat). 2003. *The challenge of slums: global report on human settlements 2003*. Global Urban Observatory, Nairobi, KY.

United Nations Human Settlement Programme (UN-Habitat). 2012. *State of the world's cities 2012/2013: prosperity of cities.* Global Urban Observatory, Nairobi, KY.

United Nations Human Settlement Programme (UN-Habitat). 2014. *The state of African Cities 2014: re-imagining sustainable urban transitions.* Global Urban Observatory, Nairobi, KY.

Van der Walt, A.M., Loots, D.T., Ibrahim, M.I.M., and Bezuidenhout, C.C. 2009. Minerals, trace elements and antioxidant phytochemicals in wild African dark-green leafy vegetables (morogo). South African Journal of Science 105: 444-448.

Weller, S.C., Van Wyk, E., and Simon, J.E. 2015. Sustainable production for more resilient food production systems: case study of African Indigenous Vegetables in Eastern Africa. Acta Horticulturae 1102: 289-298.

Yan, L. 2016. Dark Green Leafy Vegetables. USDA Grand Forks Human Nutrition Research Center, Grand Forks, ND.