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1. Introduction

The common bean, *Phaseolus vulgaris*, and white- or yellow-fleshed sweet potatoes, *Ipomoea batatas*, are widely grown in Uganda as both food and cash crops. Beans and sweet potatoes are common staples in Uganda, providing hearty, affordable nourishment to rural households. However, throughout the country, iron and vitamin A deficiency (VAD) remain high. Diets low in iron intake are a major cause of iron-deficiency anemia, which is associated with fatigue, decreased productivity, and reduced immune function. Childhood anemia is associated with impaired mental and physical development. Among pregnant women, anemia may lead to premature delivery and low birth weight (WHO 2008). VAD further impedes child growth, contributes to blindness, lessens immune function, and increases the morbidity and mortality of children and pregnant women (WHO 2009). According to data from the *Uganda Demographic and Health Survey 2011* (the most recent available), 49 percent of children ages six months to five years and 24 percent of women between the ages of 15 and 49 years suffer from anemia; for VAD, those statistics are 38 percent of children and 36 percent of women (UBOS 2012).

To combat malnutrition throughout the developing world, HarvestPlus and its partners use conventional breeding methods to develop staple food crops which have higher levels of micronutrients and minerals through a process known as biofortification. In particular, bean varieties with higher levels of iron content than other improved or local bean varieties and vitamin A orange sweet potatoes (OSP) have been bred. Partners in this breeding effort include the International Center for Tropical Agriculture (CIAT), the National Agricultural Research Organisation (NARO), and the International Potato Center (CIP). HarvestPlus seeks to disseminate high iron beans (HIBs) and OSP to help reduce micronutrient deficiencies in Uganda. Exhibiting agronomic and consumption features comparable to their local counterparts, HIBs and OSP present an opportunity to seamlessly weave much-needed micronutrients into the everyday Ugandan diet.

In 2011, in collaboration with the Diffusion and Impacts of Improved Varieties in Africa (DIIVA) project, HarvestPlus and its partners (CIP, CIAT, and Virginia Tech) conducted a varietal adoption study of beans and sweet potatoes in Uganda. The aim of this study was to explore the adoption and diffusion of improved bean and sweet potato varieties throughout the country to inform the delivery and marketing of these crops. Because approximately 80 percent of rural Ugandan farmers grow both beans and sweet potatoes (UBOS 2010), the study collected data on both crops. Uganda has two cropping seasons per year, and beans and sweet potatoes are grown in both seasons. The first cropping season occurs from March to June or July, while the second runs from August to December or January, depending on geographic location and climatic conditions. This study focused on the second cropping season. The results are nationally representative and provide macroregional observations specific to the Central, Northern, Eastern, and Western regions of Uganda. The results offer insight into the successes and limitations of past initiatives to introduce improved planting materials, including OSP varieties that were introduced in this country in 2006. Furthermore, the results serve as a baseline for continued efforts to introduce and scale up improved varieties in general and improved micronutrient-enriched varieties in Uganda.

2. Sampling Design and Survey Implementation

The sampling frame for this study is based on the existing framework of the Uganda Census of Agriculture, which was adjusted to include only districts in Uganda where beans or sweet potatoes are cultivated. The sample, which is nationally representative of bean and sweet potato household producers, includes 1,908 farming households distributed across 108 rural communities throughout Uganda. According to the most

recent agricultural census, in 2009, the total area under bean and sweet potato production was estimated to be 617,522 hectares (ha) and 440,256 ha, respectively (UBOS 2010).

Sample clusters were developed regionally across Central, Northern, Eastern, and Western Uganda. Clusters were proportionally allocated by region according to estimated bean and sweet potato acreage (UBOS 2010) and intensity of production per district. Ultimately, 19 districts were surveyed: 5 districts in the Central region (Masaka, Mubende, Sembabule, Mukono, Buikwe), 4 in the Eastern region (Kamuli, Busia, Budaka, Luuka), 3 in the Northern region (Oyam, Dokolo, Apac), and 7 in the Western region (Kabale, Kisoro, Ntungamo, Sheema, Isingiro, Mbarara, Kyegegwa). Within these districts, 108 communities were selected corresponding to 29, 21, 18, and 40 communities located in the Central, Eastern, Northern, and Western regions, respectively. In each community, trained enumerators interviewed 18 households.¹

The questionnaire,² which comprised 10 sections, gathered information about household composition and assets, social networks, farmer knowledge, and production characteristics. Specifically, information was obtained about knowledge and adoption of improved bean and sweet potato varieties, awareness of vitamin A and iron, the importance of and trust in media sources, sweet potato and bean farming practices at the plot level (including input use), market access and participation, access to agricultural services, and household food security.

Due to the length of the questionnaire and the desire to minimize recall bias, the survey was administered in two rounds. The first round took place approximately halfway through the second cropping season, from mid-October to late November of 2011. The second round took place after harvesting and marketing of the same season, between February and March of 2012.

3. Results

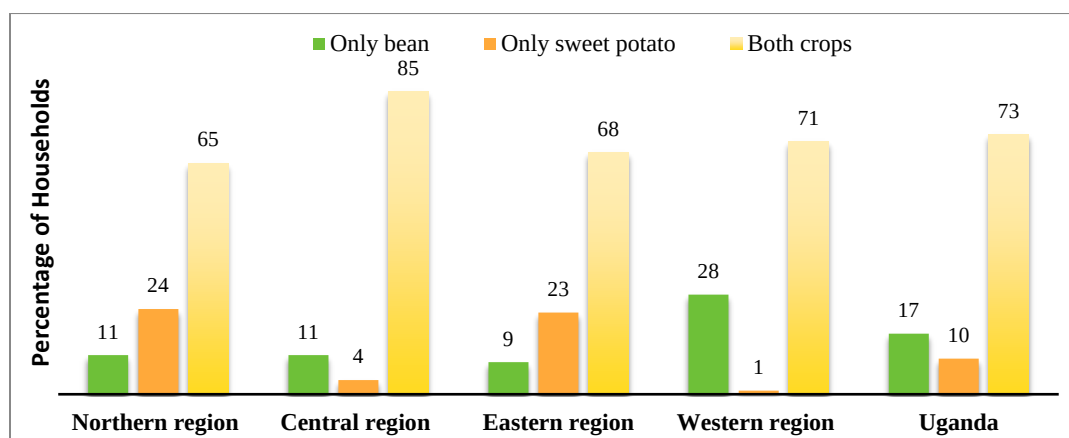
3.1. Agricultural Production

The majority of households in Uganda grow both beans and sweet potatoes (73 percent), while approximately 17 percent of households grow only beans, and 10 percent grow only sweet potatoes (Figure 1). A higher proportion of households in the Northern and Eastern regions grow sweet potatoes than beans, while the reverse is true in the Central and Western regions.

¹ The first round of sampling included 1,944 households; however, because not all households could be visited in the second round of sampling, the complete dataset was 1,908 households.

² The questionnaire was developed collaboratively by CIAT, CIP, Virginia Tech, and HarvestPlus.

Figure 1: Ugandan Household Bean and Sweet Potato Production by Region



Source: Authors.

3.2. Household Characteristics

Ugandan farming households are most commonly comprised of seven members (Table 1), with the largest households in the Northern region and the smallest in the Western region. Household heads are, on average, 45 years of age and have 4 years of education; between 16 and 21 percent of household heads are female, with a higher likelihood of female-headed households in the Central and Western regions. Heads of households have, on average, lived in their community for 30 years and have grown beans and sweet potatoes for 16–19 years. The social networks generated by such farmer communities, including the organized farmer groups (to which 42 percent of farmers belong), play a significant role in the dissemination of agricultural technologies (McNiven and Gilligan, 2011). Households growing only sweet potatoes show a lower participation in farmer organizations (29 percent) than farmers who grow only beans (45 percent) or who grow both crops (43 percent).

Table 1: Socioeconomic Characteristics of Surveyed Households

Variables	Northern	Central	Eastern	Western
Mean HH size	7.1*** (3.4)	6.4 (3.0)	6.6 (2.5)	6.0 (2.6)
HH head				
Female headed HH (%)	16.5**	21.0	16.0**	20.0
Mean age (years)	45.5 (13.6)	46.6 (13.6)	44.0*** (14.7)	46.7 (14.9)
Mean education (years)	3.9 (2.7)	4.1 (2.4)	4.8*** (3.1)	3.8* (2.7)
Farming experience				
Bush beans (years)	16.8*** (12.4)	19.7 (13.4)	19.2 (13.7)	19.7 (13.7)
Climbing beans (years)	0.1*** (1.3)	1.3 (4.2)	0.6** (3.2)	3.2*** (8.0)
Sweet potatoes (years)	18.2** (12.0)	19.7 (13.5)	19.2 (13.6)	18.4* (13.7)

Source: Authors.

Notes: HH = household. (1) Mean difference tests were performed across farmers in the four macroregions with a 95 percent level of confidence and using the Central Region as the base case for comparison. (2) Standard deviations are presented in parentheses. (3) *** significantly different at 1 percent; ** significantly different at 5 percent;

* significantly different at 10 percent.

Data on household assets were collected as proxy indicators of wealth (Table 2). Throughout Uganda, households growing both beans and sweet potatoes are more likely to have glass windows, have access to electricity, and own a larger number and greater diversity of livestock and durable goods than households growing just one crop. Among single-crop-growing households, housing characteristics vary by region. In the Northern region, households growing sweet potatoes or both crops are significantly more likely to have glass windows and electricity than households growing only beans.

Household members walk an average of 21 minutes to reach their main source of drinking or domestic water (Table 2). Protected boreholes are the most common source of drinking water (34 percent), followed by wells (26 percent). Protected boreholes are most common in the Northern (62 percent) and Eastern (69 percent) regions, whereas wells are more frequent in the Central (42 percent) and Western (26 percent) regions.

Table 2: Housing and Drinking Water Characteristics by Region and Farmer Groups

Regions	Distance to main drinking water source (minutes)			Main source of drinking water: Protected borehole (%)			Access to electricity (%)		
	Only bean	Only SP	Both crops	Only bean	Only SP	Both crops	Only bean	Only SP	Both crops
Northern	31.0 ²	26.9 ³	19.6 ^{2,3}	65.7	71.1 ³	57.6 ³	0.0	4.6 ¹	4.2 ²
Central	21.6	17.6	23.6	13.0 ^{1,2}	60.0 ^{1,3}	26.0 ^{2,3}	2.7	0.0 ³	5.3
Eastern	18.7	23.3 ³	17.4 ³	59.4	51.8 ³	75.2 ³	0.0	1.8	3.9 ²
Western	18.9	18.0	19.8	9.4 ¹	0.00 ^{1,3}	8.7 ³	4.0	0.0 ^{1,3}	5.5 ³
Uganda	20.6	24.0	20.5	21.05	59.14	33.3	3.0	2.5	4.9

Source: Authors.

Notes: SP = sweet potato. Means are statistically different at the 5 percent level (1) between households that grow only beans and those that grow only sweet potatoes, (2) between households that grow only beans and those that grow both beans and sweet potatoes, and (3) between households that grow only sweet potatoes and those that grow both crops.

Nationally, households cultivate an average of 1.52 ha of land. Land cultivation does not vary significantly among households growing only beans (1.40 ha), only sweet potatoes (1.51 ha), or both crops (1.54 ha). Nationally, of the 1.52 ha cultivated, approximately 17 percent is planted with beans, and 20 percent is planted with sweet potatoes. Farmers frequently intercrop beans with other crops such as maize, pea, eggplant, or bananas; intercropping is rare for sweet potato plots.

Only 25 percent of households have a market in their own village. More than half (56 percent) of farmers travel by foot from their house to the village or neighboring community market to sell their crops. Bicycles are the second most popular means of transport (24 percent) to reach the nearest village market and are used primarily by bean-producing households (34 percent). Motorbikes are more commonly used among sweet potato producers than bean producers (23 percent versus 6 percent, respectively), likely due to the bulky nature of the root crop. Furthermore, the data indicate that the cost to transport a 100 kg bag of produce to market is less than US\$2.00,³ on average.

³ All prices from this point forward are 2011 prices, calculated at 2,705 Ugandan shillings to 1 US dollar.

3.3. Information Sources and Trust

The media is an important source of information on agriculture, nutrition, and health in Uganda and is vital to awareness of and interest in new agricultural technologies, including biofortified crop varieties. Nationally, the most popular source of media is the radio, cited by more than three-quarters of households; this is followed by health clinics (cited by half of the households) and agricultural extension officers (cited by about one-fifth of households). Those interviewed have high levels of (“complete” or “a lot of”) trust in health clinics (92 percent) and extension officers (88 percent), most likely because these avenues allow for direct interaction with an expert; 84 percent of respondents had a high level of trust in radio.

In terms of use, radio is used daily by almost half (43 percent) of all households; almost one-fifth (16 percent) of households acquire information from local farming associations and 13 percent from other social groups. The least common sources of information are newspapers (8 percent) and television (3 percent), due in large part to availability. However, when individuals do have access to these resources, they typically use them on at least a weekly basis and place high value and trust in them.

3.4. Bean Production

Of the households interviewed, 93 percent reported growing beans in the second cropping season of 2011. Plots devoted to bean cultivation are frequently planted with several different bean varieties. Bean varietal diversity is high in Uganda, with 254 unique bean varieties being grown throughout the country. Table 3 lists the top 10 national varieties, ranked in terms of area; these varieties correspond to more than 60 percent of the total bean cropping area.⁴ Mwizaurahenda is the only climbing bean variety among the top 10; all the others are bush beans.

Of the bean farmers interviewed, 87 percent grow bush beans only, 5 percent cultivate only climbing beans, and 8 percent cultivate both bush and climbing beans. None of the Northern region farmers reported growing climbing beans. In the Central, Eastern, and Western regions, farmers devote, on average, half as much land area to climbing beans (0.13 ha) as they do to bush beans (0.26 ha), which is not surprising given the limited range of climbing varieties adapted to nontraditional growing areas, low investment in promotion of the technology, and technological barriers (the need for staking and being very labor intense).

Bean varieties can be categorized as local, selected, or improved. *Local* refers to landrace varieties. *Selected* refers to purified landrace varieties—that is, varieties selected by NARO and CIAT to emphasize desirable characteristics specific to a particular region. *Improved* refers to varieties that have been genetically enhanced using conventional breeding methods for such agronomic traits as yield, pest resistance, and others. Three improved varieties (K132, Nabe 4, and NAADS) and two *selected* varieties (K20 and Mwizaurahenda) are among the top 10 most frequent bean varieties grown in Uganda (Table 3). The remaining five varieties are local varieties.

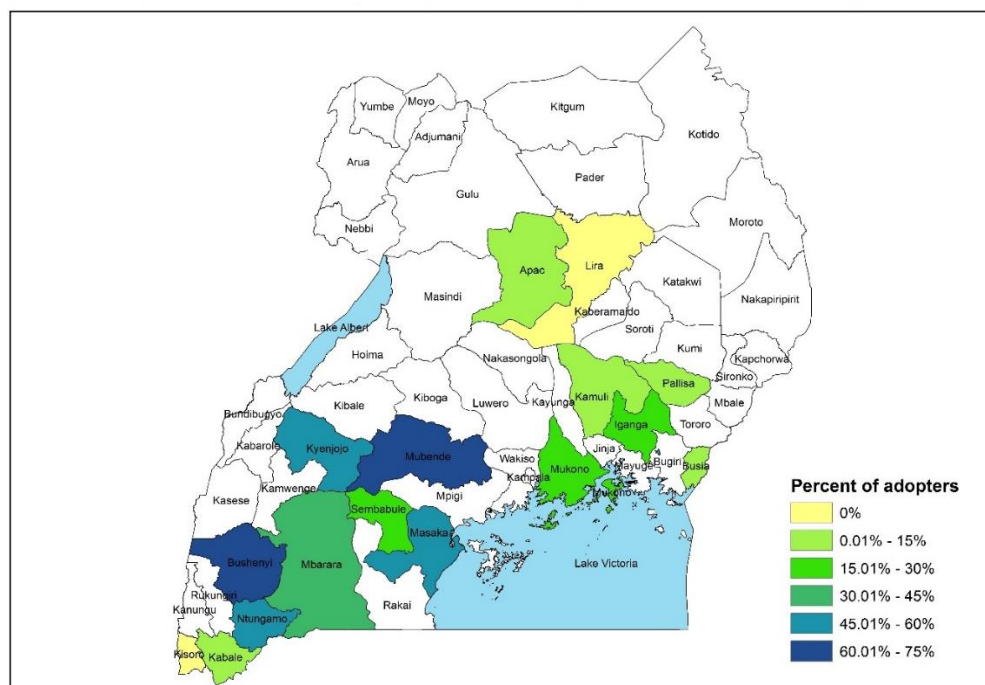
⁴ Numbers correspond to the second cropping season of 2011, which runs from August to December.

Table 3: Percentage Planting, Type, and Growing Patterns of the Most Popular Bean Varieties

Variety	Bean land planted in variety (%)	Bean type	Growing pattern
K132	16.43	Improved	Bush
Kanyebwa	13.26	Local	Bush
Yellow	11.32	Local	Bush
Nabe 4	9.69	Improved	Bush
Black Ocuc	4.26	Local	Bush
K20	4.25	Selected	Bush
Kahura/Kawule	4.11	Local	Bush
NAADS	2.15	Improved	Bush
White	2.01	Local	Bush
Mwizaurahenda	1.95	Selected	Climbing

Source: Authors.

Across Uganda, K132 beans occupy the greatest total cultivated area. This variety is popular in the Central and Western regions (Figure 2), whereas Kanyebwa is popular in the Eastern and Central regions. Yellow and Nabe 4 are primarily grown in the Central and Western regions, while Black Ocuc is preferred by farmers in the Northern region.

Figure 2: Adoption of K132 at the District Level During Second Cropping Season, 2011

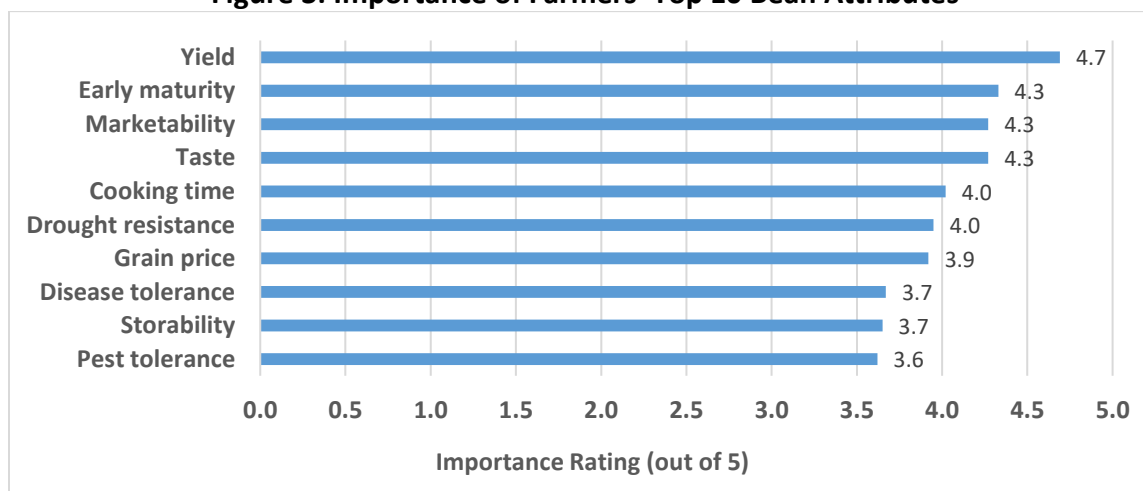
Source: Authors.

Variety Attributes and Performance

To assess how bean varieties were selected for planting, farmers were asked to score the importance of 16 bean attributes on a scale of 1 ("unimportant") to 5 ("extremely important"). As shown in Figure 3,

across Uganda, the most important bean attributes include yield, early maturity, marketability, taste, and cooking time. The least important attribute is palatability of the leaves. Scores are consistent across all regions.

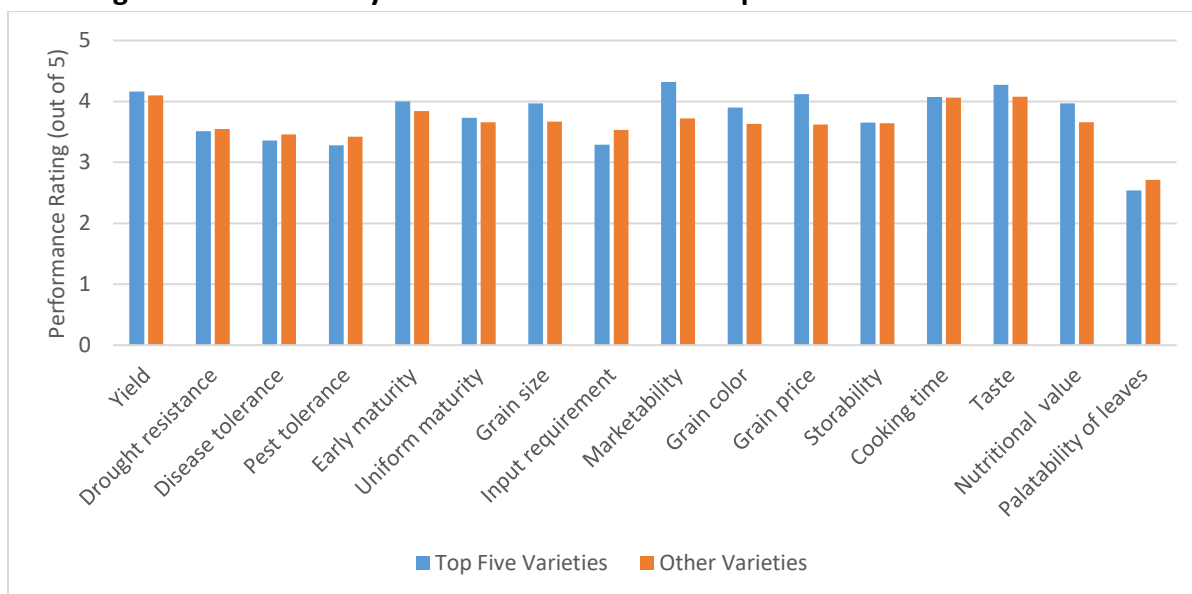
Figure 3: Importance of Farmers' Top 10 Bean Attributes



Source: Authors.

Farmers also evaluated the performance of the bean varieties they had grown in the past two seasons, scoring varieties according to the same 16 attributes on a scale of 1 (“extremely poor performance”) to 5 (“excellent performance”). The top five best performing bean varieties grown in Uganda, based on surveyed farmers, are Kanyebwa, K132, Nabe 4, Yellow, and Black Ocuc, with Black Ocuc having the highest average rating and K132 the lowest among the top five varieties. In comparison, although the average score among the top five bean varieties is above 4, the average score of bean varieties outside the top five is below 4, statistically different at the 1 percent significance level. The top five varieties outperform other varieties in the following attributes: grain yield, early maturity, uniformity in maturity, grain size, marketability, grain color, output price, taste, and nutritional value. However, the other varieties remain superior to the top five in terms of disease tolerance, pest tolerance, input requirements, and palatability of the leaves. There is no difference in drought tolerance, storability, and cooking time between the two groups.

Figure 4: Bean Variety Attribute Performance: Top Five Versus Other Varieties

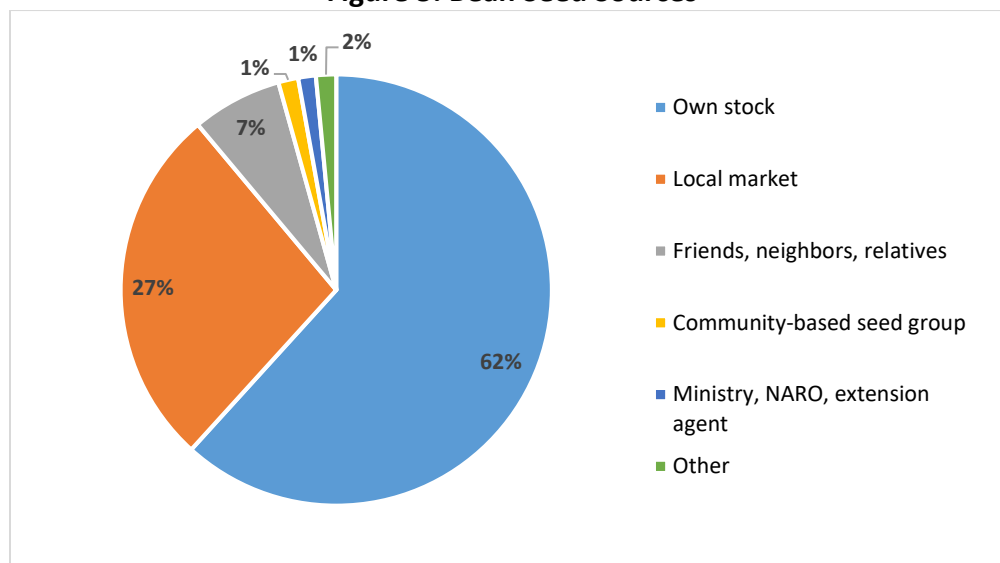


Source: Authors.

Seed Sources

Farmers acquire planting material for beans from a variety of sources (Figure 5). Nearly two-thirds use recycled seed (grain) from their own stock; the local market is the second most popular source of planting material, used by more than a quarter of bean farmers. Less than 10 percent of farmers receive bean planting material from friends, neighbors, and relatives. Very few households obtain seeds from emergency aid or development projects (fewer than 1 percent each). For those who purchase planting material, the majority (82 percent) pay in cash. On average, at the time of the study, the cost of a kilogram of bean seed was US\$0.57, though prices generally varied by about 20 percent, being highest in the Eastern region and lowest in the Western region. They also varied by bean variety and source. For example, the Mwizaurahenda and Kanye bwa varieties were the most expensive to buy, commanding 18 percent more than the average. NAADS seed purchased was cheaper than the average costs by 7 percent and was relatively stable in price. The cheapest variety, by far, was White, costing 25 percent less than the average and exhibiting little price variability.

Figure 5: Bean Seed Sources



Source: Authors.

Agricultural Inputs, Harvest, and Sale of Beans

Respondents were asked to report their use of chemical fertilizers (nitrogen, phosphorous, potassium [NPK] or diammonium phosphate [DAP]), organic fertilizers (urea, manure, compost), and pesticides in bean production. Neither NPK nor DAP are commonly used by bean farmers. NPK is used only in the Central region by approximately 2 percent of households, while DAP is used by less than 1 percent of households in the Northern, Central, and Eastern regions. Urea is more popular, being used by 10, 19, and 7 percent of households in the Northern, Central, and Eastern regions, respectively; none of the Northern households use urea. Nationally, about 4 percent of households use manure, which is partly dictated by livestock ownership; thus, it is more common (7 percent) in the Western region, where livestock ownership is greatest. Compost is used by 2.3 percent of households in the Western region, by less than 1 percent of households in the Northern and Central regions, and by none of the households in the Eastern region. Pesticide use is more common among households in the Central region (11.3 percent) compared with those located in the Eastern (1.4 percent), Western (0.7 percent), and Northern (0.4 percent) regions.

Land preparation, planting, and harvesting are primarily conducted by unpaid labor, including family labor and labor exchange among neighbors and friends. The type and duration of labor vary between cropping activities and regions. In addition, differences in labor are partly due to variation in plot size, cropping system, quantity harvested, and farmers' decision to supplement unpaid labor with paid workers. The total amount of unpaid labor (as measured in days worked) devoted to land preparation and bean planting is greatest in the Central region (approximately 43 days), roughly equal in the Eastern and Western regions (36 and 34 days, respectively), and least in the Northern region (24 days). Women devote significantly more unpaid labor days than men in preparing land and planting beans in the Central (21 days for women versus 12 days for men), Eastern (18 versus 11 days), and Western (21 versus 9 days) regions; women devote more days than men to harvesting in the Northern (5 versus 3 days) and Western (4 versus 2 days) regions. Both men and women are hired seasonally to help prepare, plant, and weed the land; however, harvesting and threshing are more often conducted by the family.

Harvested beans are sold throughout the four months following harvest, which ends in December or January, depending on geographic location. Per agricultural season, households harvest an average of 67

kg of dry beans and 13.5 kg of fresh beans. Usually, 60 percent of dry beans and nearly all fresh beans are consumed by the households. This implies that, everything else remaining the same, adoption of HIBs could have a significant impact on the health of these households. Of the remaining harvest (40 percent), approximately 43 percent is sold, and 57 percent is saved as seed stock for the following season.

The household head or spouse is the primary individual responsible for selling beans. Sales largely take place on the farm itself but also occur in local village markets, on the roadside, or at district markets. End consumers are an important share of bean buyers, especially in the Northern region, where they represent one-fifth and one-third of buyers in the first and second cropping seasons, respectively. Nationally, brokers purchase an additional 33 to 39 percent of beans, retailers purchase about 25 percent, and wholesalers purchase another 25 percent. A small portion (1 to 2 percent) of bean transactions occur between households and farmer groups.

3.5. Sweet Potato Production

Of the farmers interviewed, 83 percent grew sweet potatoes in the second growing season of 2011. This study found that, at the time of the study, more than 500 named varieties of sweet potatoes were grown throughout the country, depending on different agroecological conditions. Some of these varieties are local landraces and landraces from neighboring countries that have been evaluated by the Uganda National Sweet Potato Program and officially re-released and referred to as *selected* varieties. The same program has also conventionally bred several varieties of sweet potatoes and released them as *improved* varieties. Of the top 10 varieties most often grown by farmers surveyed, eight are local *landraces*, and one (Tanzania) is a selected Tanzanian landrace that was officially released in Uganda. One variety (NASPOT 1) is an improved variety bred and released by the Uganda National Sweet Potato Program in 1999.

The top 10 most popular sweet potato varieties represent 40.8 percent of surveyed farmers' total sweet potato acreage in Uganda. In addition to improved NASPOT 1 (6.0 percent) and selected Tanzania (3.0 percent), these varieties include Bungunduza (7.1 percent), Muwuulu (4.9 percent), Liralira (4.8 percent), Dimbuka (4.5 percent), Araka (3.4 percent), Kayebandula (2.5 percent), Kybiriki (2.3 percent), and Old Kawogo (2.3 percent).

No single sweet potato variety dominates in all growing regions (Table 4), and farmers tend to plant several different varieties in their fields. For example, in the Central region, NASPOT 1 is preferred, occupying 18.2 percent of regional sweet potato acreage. However, NASPOT 1 is not found in the Northern and Eastern regions, and it occupies just 0.06 percent of acreage in the Western region. Dimbuka and Tanzania are ranked second and third, respectively, in planting frequency in the Central region and occupy 12.9 percent and 6.8 percent of each region's total sweet potato acreage, respectively.

Table 4: Sweet potato acreage distribution of top five national varieties across regions

Variety	Northern (%)	Central (%)	Eastern (%)	Western (%)	National (%)
Bungunduza (landrace)	0	1.5	24.4	0.02	7.1
NASPOT 1 (improved)	0	18.2	0	0.06	6.0
Muwuulu (landrace)	0	0.1	18.1	0	4.9
Liralira (landrace)	26.2	0	0	0	4.8
Dimbuka (landrace)	0.9	12.9	0	0.4	4.5

Source: Authors.

Because farmers select sweet potato varieties specific to the agroecological conditions of their individual fields, few orange varieties released by the National Sweet Potato Program have gained traction at the district level. Nevertheless, the following orange varieties have been promoted: Kakamega was ranked fourth as the most planted variety in the Buikwe district, and VITA/NASPOT 9 ranked sixth in the Mukono district, both located in the Central region. Finally, a single orange variety, known both as Kipapali and Africare, ranked third in the Eastern district of Kamuli and third in the Western district of Kabale. However, none of these orange varieties have gained national popularity.

Variety Attributes and Performance

As in the bean portion of the study, sweet potato farmers were asked to score varieties based on 14 attributes on a scale of 1 (“unimportant”) to 5 (“very important”). The most important attributes recognized by Ugandan farmers are root yield, early maturity, high dry matter content, vine yield, drought tolerance, and ease of keeping vines.

In terms of varietal performance, the top six most popular sweet potato varieties scored significantly higher than the average ratings in terms of high dry matter, early maturation, vine yield, flesh color, marketability, root price, and nutritional value (Table 5). However, the top six varieties scored below average in the categories of root yield, drought tolerance, weevil resistance, virus tolerance, storability, and taste. Individually, Muwuulu, NASPOT 1, and Liralira varieties ranked highest overall. Liralira, a local variety, dominated in the Northern region and received the highest score in terms of vine yield, vine storability, drought tolerance, virus tolerance, high dry matter, taste, nutritional value, and marketability. NASPOT 1 ranked first in the categories of root yield, early maturation, root price, and marketability (tied with Liralira), yet scored low in drought tolerance, vine storability, and weevil resistance. Finally, Bungunduza scored highest in weevil resistance and flesh color, while Tanzania proved to be the most storable variety.

Table 5: Sweet Potato Attributes for the Most Popular Varieties (Score out of 5)

Attribute	RY	VY	EKV	DT	EM	HDM
Variety**	Avg. (Std)	Avg. (Std)	Avg. (Std)	Avg. (Std)	Avg. (Std)	Avg. (Std)
Bunduguza (local)	4.26 (0.96)	3.96 (1.01)	3.74 (1.01)	3.70 (1.18)	4.30 (0.93)	3.95 (1.03)
NASPOT 1 (improved)	4.51 (0.83)	3.78 (1.11)	2.68 (1.17)	2.41 (1.15)	4.63 (0.63)	4.05 (1.01)
Muwuulu (local)	4.40 (0.90)	4.13 (0.84)	3.87 (0.98)	3.80 (1.11)	3.94 (1.02)	4.03 (1.04)
Liralira (local)	4.26 (0.86)	4.15 (0.83)	4.16 (0.93)	4.01 (1.05)	4.19 (0.84)	4.61 (0.72)
Dimbuka (local)	4.21 (0.94)	3.66 (1.04)	3.31 (1.15)	2.97 (1.20)	4.40 (0.79)	3.33 (1.09)
Tanzania (selected)	4.05 (0.99)	3.76 (1.02)	3.57 (1.05)	3.37 (1.13)	3.60 (1.11)	4.10 (0.98)
Average, top six varieties	4.27* (0.92)	3.91** (0.99)	3.60 (1.13)	3.42** (1.25)	4.20** (0.95)	3.98* (1.06)
Average, all varieties	4.33 (0.91)	3.82 (1.05)	3.63 (1.08)	3.64 (1.17)	4.13 (1.02)	3.94 (1.11)

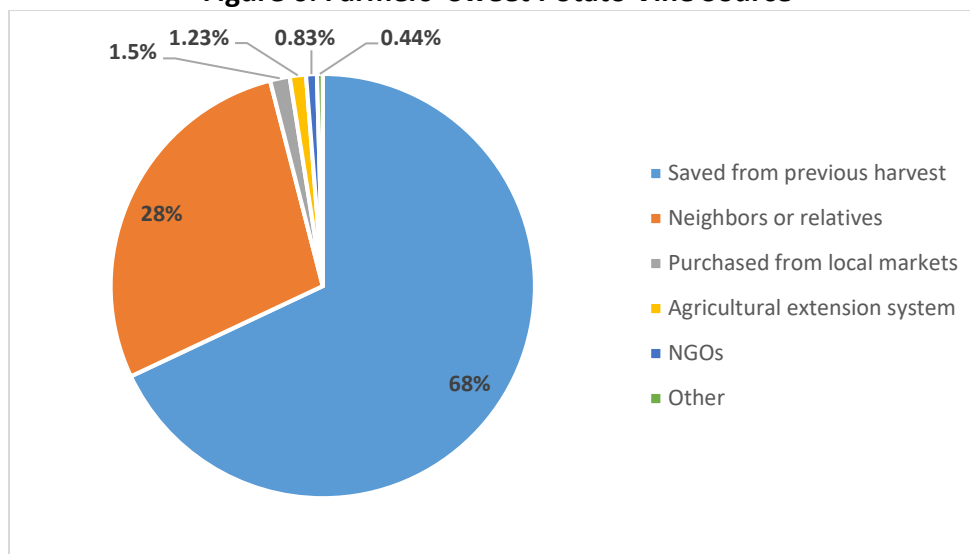
Source: Authors.

Notes: RY = root yield; VY = vine yield; EKV = easy to keep vines; DT = drought tolerance; EM = early maturity; HDM = high dry matter. Mean difference t-test of comparison of the average of top six varieties and average of all varieties (* significant at 10 percent level, ** significant at 5 percent level).

Vine Sources

Sweet potatoes are typically grown by the vegetative propagation of vines, not by seed. Throughout Uganda, subsistence farmers usually source sweet potato vines from their own community. More than two-thirds of surveyed farmers use their own planting material, saved from the previous cropping season (Figure 6). More than a quarter of them obtain vines from neighbors or relatives, exchanged in-kind. Very few farmers (1.5 percent) purchase planting materials in local markets—typically, at a cost of \$US0.55 per 5 kg. Other sources of planting materials include the national agricultural extension system and nongovernmental organizations (NGOs), with about 1 percent of sweet potato farmers acquiring vines from each of these sources.

Figure 6: Farmers' Sweet Potato Vine Source



Source: Authors.

Agricultural Inputs and Harvest of Sweet Potatoes

Sweet potato farmers plant an average of 10 sweet potato vines bundles per hectare. Farmers rarely use fertilizers: 3 percent reported using NPK, and 1 percent used DAP. Organic fertilizers are slightly more popular than inorganic fertilizer, with 17 percent of farmers reporting using manure; 5 percent, urea; and 5 percent, compost. In addition, 25 percent of farmers apply chemical pesticides to their sweet potato fields.

As in bean production, land preparation, planting, and harvesting are primarily conducted by unpaid laborers, including family labor and labor exchanged among neighbors and friends. Paid labor is restricted to land preparation and weeding; during the second growing season of 2011, it averaged approximately half a day of hired adult labor per household, with minor assistance from children. Hired labor is slightly more likely to be performed by women (0.67 labor days) than men (0.53 labor days) in sweet potato production.

3.6. Constraints to Bean and Sweet Potato Production in Uganda

Interviewed farmers reported that drought is the most significant constraint of both bean and sweet potato production in Uganda. Drought limits a farmer's ability to begin cultivation at the appropriate time; reduces yield; and, when prolonged, results in difficulties in accessing planting material. Across Uganda, three-quarters of the bean-producing households and almost two-thirds of sweet potato-producing households reported experiencing a severe drought in the past five years. More than 80 percent of bean farmers in the Eastern, Northern, and Central regions cited drought as the most significant challenge. Bean growers experiencing droughts over the past five years reported, on average, almost two (1.7) severe droughts during the period.

Following drought, the second major growing constraint, as indicated by bean households, is seed shortage, which was experienced by almost a third of all households. Seed shortage is highest in the Northern region (59 percent) and lowest in the Western region (17 percent). In terms of socioeconomic limitations, bean farmers indicated that the high price of improved seeds is the main constraint to their

adoption. Other restricting factors include timely availability of seed, the ability to generate a market surplus, low market price, and lack of land.

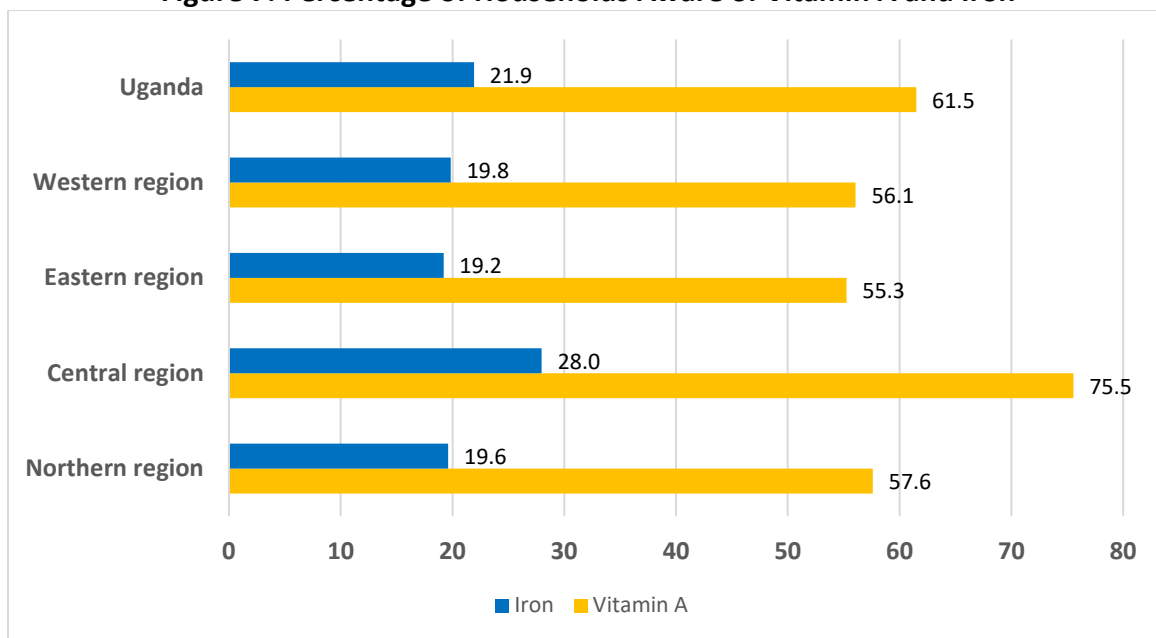
Following drought, sweet potato–producing households indicated that vine shortage is the most serious problem. On average, 16 percent of all sweet potato–producing households reported experiencing a vine shortage during the past five years, with the highest occurrences reported in the Northern region (36 percent). Despite large-scale efforts to distribute sweet potato vines in mass quantities in the Northern region in 2010, availability of planting material remained a challenge at the time of the survey.⁵ Vine shortage is particularly problematic at the beginning of the rainy season, and local growers struggle to keep vines over a long period (Labarta 2015). Approximately 63 percent of sweet potato farmers indicated that the main biophysical constraints that affect crop production are low soil fertility and erosion. Other constraints cited by sweet potato farmers are flooding, pest damage, limited land availability, the ability to generate production surplus, and the high costs of bringing their crop to market.

3.7. Nutritional Awareness

In addition to being asked about their farming practices, respondents were asked if they had ever heard about vitamin A or iron. Although almost two-thirds of respondents reported having heard of vitamin A, less than a quarter were aware of iron (Figure 7). Awareness of both micronutrients is greatest among respondents in the Central region, where 75 percent have heard of vitamin A and 28 percent are aware of iron. In the Northern, Eastern, and Western regions, an average of 56 percent of households reported an awareness of vitamin A, and an average of 19.5 percent reported an awareness of iron. Respondents familiar with vitamin A and iron first gained awareness from either a health clinic (approximately 32 percent for vitamin A and 22.5 percent for iron) or a schoolteacher (29 percent for vitamin A and 48.6 percent iron). The national radio and friends were also cited as initial sources of micronutrient information, especially in the Western region.

⁵ The large-scale efforts refer to the sweet potato vine distributions implemented by various NGOs during the peace agreement, which began around 2007 and continued beyond 2010 (Labarta 2015).

Figure 7: Percentage of Households Aware of Vitamin A and Iron



Source: Authors.

Of those who had heard of vitamin A or iron, when asked to list specific foods high in vitamin A or iron, roughly 20 percent of individuals cited OSP as a source of vitamin A, and about 13 percent of households reported beans as a source of iron. Awareness of sweet potatoes as a source of vitamin A is lowest in the Northern region (10.5 percent) and highest in the Central (26 percent) and Eastern (24 percent) regions. Awareness of beans as a source of iron is lowest in the Western region (4 percent) and highest in the Eastern region (22 percent).

Other foods reported as a good source of vitamin A and iron include other pulses not including beans (18.6 percent for vitamin A and 6.6 percent for iron), fruits (12.7 percent for vitamin A and 6.4 percent for iron), and dark green leafy vegetables (12.7 percent for vitamin A and 11.4 percent for iron). Yet, an average of 24 percent and 45 percent of households were unable to name a single food containing vitamin A or iron, respectively. Overall, respondents had fewer difficulties correctly identifying foods with high levels of vitamin A than those with iron.

Using an open-form question, households were asked to describe symptoms of vitamin A and iron deficiency. Nationally, 42.5 percent of households correctly identified symptoms of both micronutrient deficiencies, with results consistent across regions. The most frequently reported symptoms of vitamin A deficiency are poor health (40.5 percent), bad eyesight (8.1 percent), and low immunity (7.4 percent). The most frequently reported symptoms of iron deficiency are poor health (24.4 percent) and low immunity (10.6 percent). Despite these figures, approximately 34 percent of respondents could not name specific symptoms of vitamin A deficiency, and 50.5 percent of respondents were unaware of iron-deficiency symptoms.

4. Conclusions

HarvestPlus and its partners are developing HIBs and vitamin A OSP varieties to combat malnutrition in Uganda and other countries throughout the world. To facilitate delivery and marketing of these crops,

and to later monitor adoption trends, a varietal adoption survey was conducted in collaboration with DIIVA in Uganda in 2011.

The study revealed important bean and sweet potato varietal diversity. More than 200 bean varieties are grown by small landholders in Uganda, and more than 500 sweet potato names were used to describe the varieties grown. Although the true number of sweet potato varieties is unclear (local varieties can be given two or three and sometimes more names), it is obvious that sweet potato varietal diversity is high in Uganda. The 10 most frequently planted bean varieties include three improved varieties (K132, Nabe 4, and NAADS) and two selected (purified landrace) varieties (K20 and Mwizaurahenda). The top 10 most popular sweet potato varieties include the improved variety NASPOT 1 and the selected variety Tanzania. The remaining varieties are local.

Given that no bean or sweet potato variety predominates throughout the country and that farmers select varieties according to their specific and localized agroecological conditions, several micronutrient-dense varieties should be developed and disseminated to ensure wide adoption. Alternatively, researchers could focus on developing a few varieties that perform well in regions where micronutrient deficiencies are the greatest.

The most important attributes farmers reported for both beans and sweet potatoes are high yield and early maturity, which is consistent with typical findings of breeders during participatory variety selection methods. Therefore, incorporating these traits, which are already prioritized by breeders, in addition to high levels of iron and vitamin A, should facilitate producers' acceptance of these new varieties. In addition, breeders could seek to incorporate drought resistance as an additional trait to the micronutrient-dense bean and sweet potato varieties, because drought is the number one biophysical constraint in bean and sweet potato production. Dissemination efforts could also aim to alleviate some of the socioeconomic barriers to farmers' adopting improved varieties, such as the high price of improved bean seed and the unavailability of sweet potato planting material.

In addition to being widely grown, micronutrient-dense varieties must be consumed in large quantity in order to improve the nutrition and health of the rural population. Well-targeted educational initiatives on agriculture and nutrition through a variety of channels should help in this regard, given that micronutrient awareness throughout the country is mixed. Roughly two-thirds of Ugandan households are aware of vitamin A's importance to the body, but less than one-third are familiar with iron. While 20 percent of the individuals surveyed recognize OSP as a source of vitamin A, 25 percent could not name a single food source of vitamin A. Similarly, just 13 percent of households reported beans as a source of iron, while 45 percent could not name any iron-rich foods. When asked to name specific symptoms of vitamin A deficiency, 34 percent knew none. Just over half of the respondents (51 percent) were unaware of iron-deficiency anemia.

Ugandan farmers acquire the majority of agriculture, nutrition, and health information from the radio, though they place the greatest amount of trust in in-person interactions with health clinics and agricultural extension officers. Respondents indicated that health clinics, schoolteachers, national radio, and friends typically serve as initial sources of information about vitamin A and iron in Uganda. These channels are thus recommended as future marketing channels for nutrition and agriculture information campaigns in Uganda about OSP and HIBs.

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