Chapter 16
Sweetpotato in Sub-Saharan Africa

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Historical Background

Botanically sweetpotato is called *Ipomoea batatas* (L.) Lam and belongs to the morning-glory family (*Convolvulaceae*) and originated from Latin America. The exact date of arrival of sweetpotato on the continent of Africa is unknown. Evidence indicates that slave traders brought it into the region and since its introduction it has been displacing the true yam in tropical Africa (Davidson, 1999). Given that it has been in the food system for several hundred years, whereas round, Irish, or solanum potato (*Solanum tuberosum*) was introduced in the late 1800s, sweetpotato is often falsely considered by African farmers to be an indigenous crop and is often referred to as the "local" or "traditional" potato in most Sub-Saharan African countries.

Importance of Sweetpotato in the Sub-Saharan African Region

Sweetpotato is one of the most widely grown root crops in sub-Saharan Africa (SSA), covering around 2.9 million hectares with an estimated production of 12.6 million tons of roots in 2007 (FAOSTAT, 2008 and national surveys). It is predominantly grown in small plots by poorer farmers, hence it is known as the "poor man's food" (Woolfe, 1992). However, as women predominate in sweetpotato production, "poor person's food" would be more accurate.

The crop is particularly important in countries surrounding the Great Lakes in Eastern and Central Africa; Malawi, Angola, Mozambique, and Madagascar in Southern Africa, and Nigeria in West Africa (Woolfe, 1992). It is expanding faster than any other major food crop in SSA (Fig. 16.1). It can be found from sea level up to 2500 m. Sweetpotato generates large amounts of food per unit area per unit time (Woolfe, 1992), superior to other major staples (Table 16.1). It tolerates occasional dry spells and yields even on less fertile soils in contrast to other crops such as

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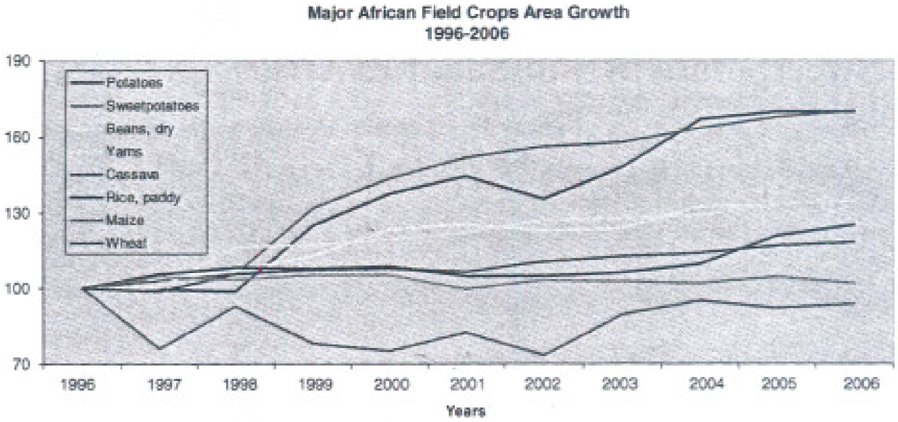

Fig. 16.1 Growth in area in Sub-Saharan Africa under major field crops: 1966–2006. Source: FAOSTAT (2008)

maize (Ewell, 1990). Compared to other crops, sweetpotato requires few inputs and relatively less labor.[1] The rapid growth of sweetpotato area in sub-Saharan Africa during the past decade is due to three major factors: (1) changes in cropping patterns, (2) unstable economies and (3) the increasing commercialization of production.

Area under sweetpotato has grown in different locales as farmers have changed cropping patterns as other traditional crops become difficult to cultivate for a variety of reasons. Perhaps the most important factor explaining change in cropping patterns affecting the area of sweetpotato is the spread of cassava and banana diseases especially in the Lake Victoria region. Numerous studies have identified the

Table 16.1 Comparative energy yields of sweetpotato and other major crops

Crop[a]	Average Tropical Yield (Tons/ Hectare)	Edible Energy Value (MJ/kg)	Proportion of Edible Energy (%)	Edible Energy per Hectare (10^3 MJ)	Mean Growth Period (Days)	Edible Energy (MJ/ha/ day)
Sweetpotato	7	4.8	88	27.2	140	194
Cassava	9	6.3	83	45.6	330	138
Yam	7	4.4	85	26.2	280	94
Banana	13	5.4	59	41.4	365	113
Rice[b]	2	14.8	70	20.8	140	149
Maize	1	15.2	100	18.8	130	145
Sorghum	< 1	14.9	90	11.1	110	101
Millet	< 1	15.0	100	8.2	100	82

Source: Woolfe (1992), p. 4 Notes: Based on de Vries et al. 1967.
[a] Cereals, air-dry; roots/tubers/bananas fresh.
[b] Paddy Rice.

[1] Average energy output/input ratios for rice and sweetpotato on Fijian farms were 17:1 and 60:1, respectively (Norman et al., 1984).

serious and spreading epidemic of cassava brown streak virus. There are 12 million hectares of cassava in SSA. Frequently sweetpotato and cassava are grown on the same farm or the same region. When cassava fails, farmers frequently switch to sweetpotato to substitute for the energy delivered by cassava. Another important reason driving changing cropping patterns is that cultivable land has declined in size in many countries due to increasing population. Farmers respond by growing more root and tuber crops that give higher yields per unit area than grain crops, among which sweetpotato is a significant choice.

A second important source for cropping pattern change is the decline in support for maize production. In the postcolonial era, sub-Saharan African governments seeking food self-sufficiency created a diverse set of policies that encouraged an excessive reliance on maize. During the last decade, especially in southern Africa, governments have recognized the high cost of the policies and began to dismantle some of the supports. Reduced subsidies of irrigation, fertilizer, seed and marketing costs led to declines in maize area. As farmers seek alternatives, the robust, low cost sweetpotato is often included. Soaring grain prices, resulting from the recent food crisis, have led to increased investments in inputs and staple food sectors, but the important food security role of root and tuber crops is now widely recognized.

A third important source for cropping pattern change is the impact of HIV/AIDS (Jayne et al., 2004). Now in its third decade as an epidemic, death rates in rural areas have climbed sharply. That HIV/AIDS kills those between 20 and 50 is well documented. The family and farm level impacts of the illness and death of farm family parents is being better documented. Farm families de-capitalize as savings, equipment and livestock are sold to care for the sick. In many cultures, funeral customs create additional expectations for capital expenditures to finance the ceremony. Farm families lose labor and management skills. One impact of the impoverishment, labor loss and skills loss is that the remaining farmers –typically a single parent or orphan headed households – shift to lower labor, lower cost and lower risk crops (Kennedy, 2002). Sweetpotato is a crop that answers all these needs. Rugalema (1998) showed in Bukoba District, Tanzania a shift from the intensively managed bean/coffee/banana cropping system to a simpler, extensive and low cost system based on cassava and sweetpotato.

As agriculture becomes more market-oriented, sweetpotato is one of several crops that farmers can produce to obtain cash income in addition to subsistence food security. Supply and demand factors are therefore increasingly important in determining the role sweetpotatoes will play in a more market-oriented smallholder farm sector. Markets for fresh roots and vines do exist, but with few exceptions (e.g. Uganda) are not large and, like cassava, consumption of fresh sweetpotato roots tends to decrease with urbanization, due to shifts in diets related to factors such as price, convenience and status. Enhancing the unrealized potential of sweetpotato by improving its marketing system (Ndunguru et al., 1998; Tomlins et al., 2000) and increasing demand for fresh roots and value-added sweetpotato-based products would contribute to improved productivity and well-being among rural producers, especially women, and help meet ever increasing urban food demand (Best et al., 2006; Omosa, 1997; Gakonyo, 1993).

Sweetpotato does have some "points of difference" with other root crops that justify efforts to maximize its role in rural and urban diets as well as in enhancing rural incomes and nutrition (Wheatley and Loechl, 2008):

- Orange-fleshed sweetpotato varieties (OFSP) exist that have high levels of beta-carotene, the precursor to vitamin A, in the roots. In 2005, an estimated 43 million children in SSA under 5 years of age were at risk of vitamin A deficiency (VAD) (Aguayo and Baker, 2005). The causal link between compromised vitamin A status and increased child mortality is well established.[2] Only 125 g of most OFSP varieties can supply the recommended daily allowance of vitamin A for children and non-lactating women (300–700 μg retinol activity equivalents). Most varieties in SSA are white, cream or yellow-fleshed. Hence, due to the urgency of addressing the VAD problem, sweetpotato varietal development programs have focused since the late 1990s first on adaptive testing of introduced orange-fleshed varieties, then on breeding for orange-fleshed varieties more adapted to specific agro-ecologies.
- Sweetpotato roots (orange and non-orange) are a valuable source of vitamins B, C and E. Moderate levels of iron and zinc are often found in association with high beta-carotene content.
- Vine tops have excellent micronutrient contents and adequate protein content (3–4%) (quantity and quality) for use as feed or food.
- The existence of early maturity varieties 3–4.5 month growth periods, with the potential to produce relatively high fresh and dry matter yields (of roots and vines) in less fertile conditions from sea level to 2200 m, means sweetpotato can be a component of sustainable multiple cropping systems in a broad range of agro-ecologies.
- A wide range of varieties/cultivars offering potential for many different types of utilization, including: (1) Flesh colors from white, cream, yellow, orange and purple; (2) High and low dry matter and starch contents; and (3) High and low sugar contents (sweet and non-sweet varieties).
- Unique starch properties of interest to the food industry (well-exploited already in Asia but not yet in SSA).

On the other hand, some less positive characteristics of the crop exist, but are amenable to either genetic improvement and/or post-harvest management, including:

- A lower dry matter and starch content than cassava (in general) reducing competitiveness for uses dependent on dried root chips/flour.
- Presence of anti-nutritional factors (trypsin inhibitors), complicating use of raw (either fresh or dried) roots for animal feed.

Pilot efforts in SSA have shown the potential for sweetpotato to be an excellent vehicle for creating value-added, income generating opportunities in rural villages and towns (Best et al., 2006; Wheatley et al., 1995; Kapinga et al., 2000;

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[2] Very high mortality rates (60%) are associated with severe vitamin A deficiency and even subclinical deficiency is associated with a 23% increase in pre-schooler mortality (McGuire, 1993).

Westby et al., 2004). For value-added products to succeed, adequate farm productivity is needed to ensure low raw material costs for processors (Walker and Fuglie, 2006). Given its potential, sweetpotato has been underinvested in SSA because: (1) it is perceived as a food crop cared for by women, whose needs are often under addressed; (2) its association with "bad times" as it is heavily relied on when other crops fail; (3) its image as a crop of the poor eaten by those who cannot afford the "modern" luxuries of bread and rice; (4) lack of awareness of nutritional qualities especially of OFSP varieties and their potential contribution to combating vitamin A deficiency; (5) its bulky nature and seasonal availability which constrains market development; (6) lack of awareness and expertise concerning how to produce and market sweetpotato-based processed products and animal feeds and the potential return from these investments; (7) the difficulty of capturing production of a "piecemeal" harvest crop, and hence widespread underreporting of production in official statistics, hampering its status and resultant financial support relative to other crops, and (8) the perception that it is difficult to find appropriate resistant cultivars and agronomic practices to control major pests and disease problems. As a consequence, most under-resourced SSA national research programs have few people engaged full-time on sweetpotato research as outside funding opportunities have focused on cereals, crops with severe disease problems (e.g., cassava), and high-value crops with export potential.

Major Growing Areas, Acreage, Yields, Varietal Development and Potential Economic Impact

A. Area Under Cultivation and Yields

According to available FAO and national survey data, twenty-three countries produce 99% of all sweetpotato in SSA that is currently captured in official statistics and representative surveys (Table 16.2). Uganda and Nigeria dominate in terms of overall sweetpotato production, accounting for 33% of total reported SSA production. Per capita sweetpotato production figures are positively correlated with population density ($r = 0.75$) among these countries. This is part of a more general trend worldwide: as population increases, fertile arable land per capita diminishes and farmers turn increasingly to crops which yield a large amount of food per unit area per unit of time. Sweetpotato production per capita is over 85 kg per person in four countries: Uganda, Rwanda, Burundi, and Malawi. Seven countries (DR Congo, Ethiopia, Ghana, South Africa, Côte dÍvoire, Niger and Burkina Faso) have low production per capita levels on a national basis (less than 6 kg per capita) because sweetpotato production is concentrated in certain parts of the country and marketing channels are inadequately developed. Seven countries in Eastern and Central Africa account for half of total production, six Southern African countries 26%, and ten West African countries 21% (Fig. 16.2).

Table 16.2 Status of sweetpotato production in sub-Saharan Africa (2005–2007)

Country	Sweetpotato production ("000 Metric tons)	% of total sweetpotato grown in SSA	Sweetpotato production per capita (kgs/ person)	Population density in 2007 (persons/ sq km)	Area (Ha)	Est. yield (Tons/ ha)
Uganda	2,591	20.5	90.9	141	578,000	4.5
Nigeria*	1,578	12.5	10.9	145	464,000	3.4
Malawi*	1,146	9.1	87.5	138	159,227	7.2
Tanzania	960	7.3	24.8	42	505,000	1.9
Madagascar	874	6.9	47.8	32	123,952	7.1
Rwanda	872	6.9	93.7	346	148,996	5.9
Burundi	838	6.6	98.5	315	125,000	6.7
Kenya	769	6.1	20.8	61	70,000	11.0
Angola	689	5.4	42.2	10	143,468	4.8
Ethiopia	409	3.2	5.3	67	49,656	8.2
Mozambique*	388	3.1	19.0	25	97,000	4.0
DR Congo	228	1.7	3.6	28	45,649	5.0
Guinea	215	1.8	21.3	39	69,000	3.1
Cameroun	189	1.7	10.3	37	43,000	4.4
Mali	185	1.5	14.8	19	10,000	18.5
Zambia*	138	1.4	12.0	16	39,493	3.5
Ghana	91	0.7	4.0	97	65,250	1.4
Burkina Faso	72	0.6	4.8	51	8,550	8.4

Table 16.2 (continued)

Country	Sweetpotato production ("000 Metric tons)	% of total sweetpotato grown in SSA	Sweetpotato production per capita (kgs/ person)	Population density in 2007 (persons/ sq km)	Area (Ha)	Est. yield(Tons/ha)
Chad	65	0.5	6.0	8	25,500	2.5
Benin	56	0.4	6.2	71	11,293	5.0
South Africa	46	0.4	1.0	36	15,438	3.0
Cote d'Ivoire	45	0.4	2.2	56	20,000	2.3
Niger	44	0.3	3.1	10	2,983	14.8
Sub-Regions (No. of countries)						
East & Central (7)	6,667	52	338		1,522,301	4.4
Southern (6)	3,281	26	210		578,578	5.7
West (10)	2,540	21	84		719,576	3.5
All Countries (23)	**12,488**	**99**	**631**		**2,820,455**	**4.4**

All production and area data not marked with * are from FAOSTAT 2008 (accessed October 2008). Where variation is less than 10% across adjacent years, values are weighted: ((3 × 2007 values) + (2 × 2006 values) + (1 × 2005 values))/6. Where consistent trends are apparent, most recent data (2007) are utilized. Area data for Malawi from FEWSNET (Early Warning System database); yield estimates considered to be too high (14.2 t/ha) so 50% of that value used to estimate production (7.1 t/ha). Data for Mozambique from TIA (national agricultural survey), 2005. Data for Zambia from (Central Statistical Office, 2003/2004). Data for Nigeria from the National Food Reserve Agency, 2007.

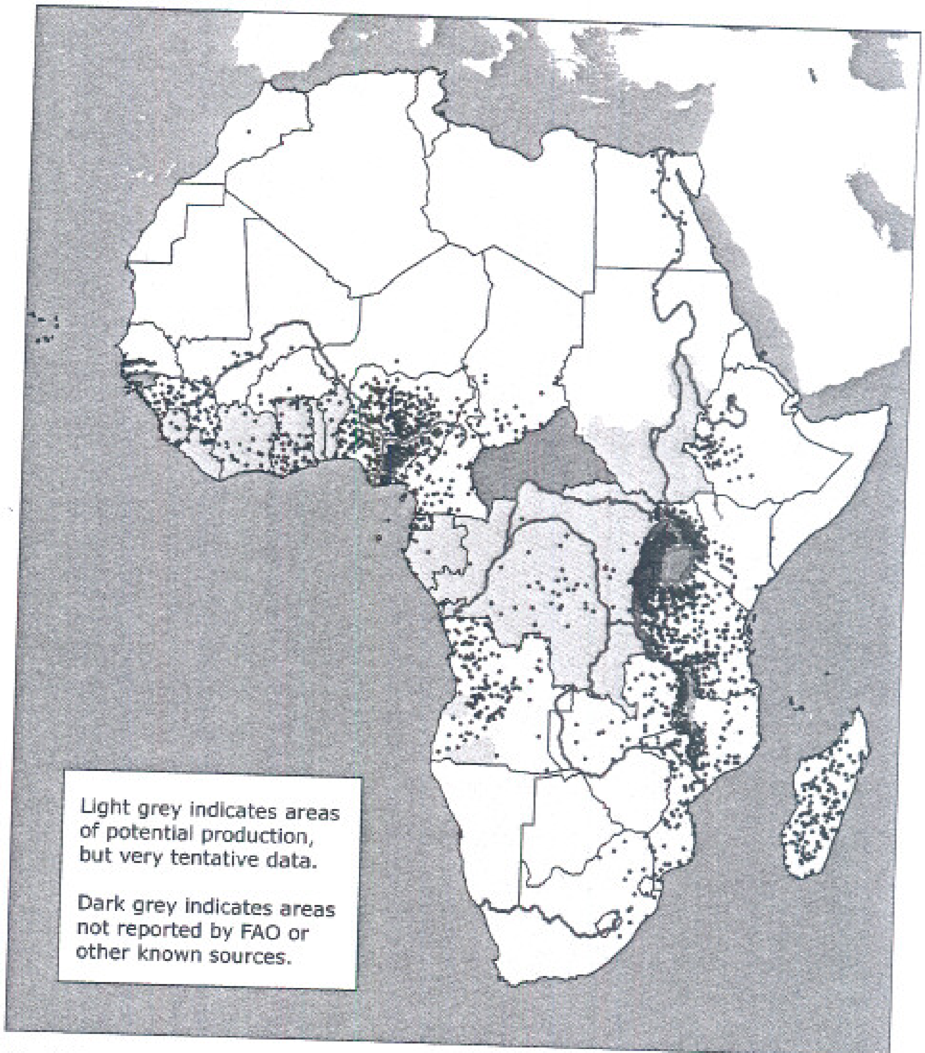

Fig. 16.2 Area under sweetpotato cultivation in sub-Saharan Africa (2007) estimates. (Each dot represents 1,000 hectares of sweetpotato cultivation)
Source: World Sweetpotato Atlas (2008).

FAO data indicate very low average sweetpotato yields (4.4 t/ha) for SSA. Given the difficulty in collecting accurate data on piecemeal harvested crops like sweetpotato and cassava, we suspect that due to underreporting actual yields on average may be higher (6 t/ha). Almost all smallholders produce sweetpotato under rainfed conditions. In contrast, commercial sweetpotato growers in South Africa who have access to irrigation, fertilizers, and credit achieve yields ranging from 50 to 70 t/ha (Niederwieser, 2004). A discussion of the factors underlying the "yield gap" between smallholders and commercial sweetpotato producers in SSA is presented in a section below.

B. Role of Sweetpotato in the Diet, Varietal Preference and Development, and the Potential Contribution of Orange-Fleshed Sweetpotato

Sweetpotatoes are principally grown in food systems in Eastern and Southern Africa dominated by root crops and bananas/plantains and secondarily grown in maize-based systems. In the root crop belt of West Africa sweetpotatoes complement the supply periods of cassava and yams, the two principal crops in those food economies. Sweetpotatoes are a strategic and flexible part of these food systems. Early maturing varieties of around three months are first to come into production to end the "hunger season" and these are often improved materials. Due to their flexible planting times and range of maturity periods farmers can manage the supply period if not constrained by an extended dry period. This helps ensure continuity of staple food supply, both for home consumption and market, so that producers can take advantage of generally higher staple food prices early in the growing season.

In countries with two rainy seasons (for example, Rwanda, Burundi and Uganda) sweetpotato is available 11 months of the year and is a primary staple. Elsewhere in SSA, where there is only one main growing season, sweetpotato is available 4–8 months of the year and it is a secondary staple consumed 2–4 times per week when in season.

With the exception of South Africa, sweetpotato production is dominated by smallholder producers. Those countries relying on sweetpotato as a food security crop tend to cultivate many varieties that have a range of maturing periods of 4–7 months and often distinct characteristics. Varieties are often mixed in the field. In SSA, white and creamed fleshed varieties predominate, and there are many popular yellow-fleshed varieties in certain countries. Adults in East and Central Africa are known to have strong preferences for floury textured varieties with dry matter contents 30% and above; those in Southern Africa also accept and often prefer varieties in the 26–30% dry matter range. In locations where commercialized sweetpotato production has emerged (e.g. Western Kenya, Eastern Uganda), distinct varietal preferences have also emerged and the number of predominant varieties has been reduced to the 2–3 demanded by the market. In the case of East Africa, many of the most highly marketed varieties are red-skinned and white-fleshed; however, during the past decade one early maturing (3 months), high dry matter (30–33%) variety SPN/O (also known as Simama, Tanzania, Kenya or Chingova depending on the country) that is white-skinned and yellow-fleshed has emerged as an important marketed variety in Uganda, Kenya, Tanzania, and Malawi.

Since the mid-1990s, the focus of adaptive testing and breeding programs in East and Southern African has been on the testing and promotion of orange-fleshed varieties. Unlike white-fleshed varieties, orange-fleshed sweetpotatoes contain B-carotene, the major provitamin A carotenoid. Vitamin A deficiency (VAD) is widespread among young children in the developing world; globally, 127 million children under six years of age are estimated to be affected (West, 2002). Sub-Saharan Africa and India have the highest estimated prevalence rates of sub-clinical vitamin A deficiency. VAD can limit growth, weaken immunity, cause xeropthalmia leading to blindness, and increase mortality (Sommer and West, 1996).

There are two types of vitamin A available in foods: (1) preformed retinol (vitamin A itself) typically found in animal foods such as eggs, liver, and milk; and (2) provitamin A carotenoids found in plant foods such as dark green leafy vegetables, yellow and orange vegetables and fruits, and orange-fleshed sweetpotato (McLaren and Frigg, 2001).

Poor households typically cannot afford to consume the highly bioavailable animal foods on a regular basis. High rates of deficiency in the major micronutrients (vitamin A, iron, and zinc) are common among poor populations that consume plant-based diets (Hess et al., 2005). Many plant sources of vitamin A are seasonal, and after provitamin A carotenoids are absorbed into the body, they must be converted into retinol for the body to be able to make use of them. Rates of conversion vary among carotenoid containing plant foods (up to five fold) and also depend on what else is consumed at the same time (for example, fat increases absorption) and the health status of the individual (e.g. more deficient individuals absorb and/or convert at higher rates than replete individuals). Heat processing may also increase conversion rates compared to the raw product, depending on the plant matrix (Hess et al., 2005). Current guidelines recommend that provitamin A activity be expressed in Retinol Activity Equivalents (RAE). The RAE definition is based on the assumption that 16.7% of the ingested beta-carotene is absorbed and 50% is converted to retinol. This results in an average conversion factor of 12 units of beta-carotene to form 1 RAE. Many dark green leafy vegetables are probably less bioavailable than this, while palm oil is far superior (2:1 conversion factor). In contrast, the conversion factor for preformed retinol from animal sources is 1:1 and for other provitamin A carotenoids 24:1 (Institute of Medicine, 2001).

During the past five years, convincing evidence has been obtained regarding the impact of OFSP on young child vitamin A status. A South African study demonstrated that OFSP is bioavailable and efficacious in improving vitamin A status in children (Jaarsveld et al., 2005) and significant improvements in vitamin A intake and serum retinol concentrations (a proxy for vitamin A status) were obtained from an action-research study of an OFSP-based integrated agriculture-nutrition-market intervention in a very resource poor setting in Central Mozambique (Low et al., 2007a). The latter study emphasized the importance of having all three components (agriculture, nutrition and market interventions) to ensure improvement in young child vitamin A intakes and sustained adoption of the new material. A third study (Haskell et al., 2004) using the isotopic tracer deuterated retinol to estimate total vitamin A stores in 14 Bangladeshi men determined a conversion factor of 13:1 for orange-fleshed sweetpotato when it was cooked pureed with a small amount of oil.

Orange-fleshed sweetpotato as a staple food has an advantage over most vegetables in that it can supply significant amounts of vitamin A and energy simultaneously – thus helping to address both VAD and undernutrition. OFSP is an example of a *biofortified* crop in which the micronutrient status of staple foods is enhanced through plant breeding to the point where impact on micronutrient status can be achieved (Bouis, 2002). Since the poorest households typically obtained over 60% of their energy needs from food staples, this strategy is particularly suited to poor rural households that cannot access purchased fortified food products but could grow OFSP.

The intensity of the orange color reflects the amount of beta-carotene present in the sweetpotato. In most of SSA, white-fleshed varieties dominate and contain no beta-carotene. On a fresh weight basis (fwb), light orange varieties contain at least 250 RAE/100 g (30 μg/g), medium-intensity varieties at least 458 RAE/100 g (55 μg/g) and dark orange-varieties at least 833 RAE/100 g (100 μg/g). To put things into perspective, the recommended daily intake for healthy two and five year old children is 400 RAE and 500 RAE, respectively (Institute of Medicine, 2001). Depending upon the color intensity of the OFSP variety used and taking losses during cooking into account (approximately 20% through boiling) (Jaarsveld et al., 2006), 1/4 to 1 cup of boiled and mashed orange-fleshed sweetpotato meets the intake requirements of a young child.

In the late 1990s, the regional potato and sweetpotato network for Eastern and Central Africa, PRAPACE, began supporting research to on OFSP varietal development and value addition. In 2001, the International Potato Center launched the Vitamin A for Africa Initiative (VITAA) to provide a platform for bringing experts from different disciplines (especially agriculture and health) together to develop strategies and share experiences concerning the promotion of OFSP with a focus on young children and women of reproductive age (Kapinga et al., 2005). As of 2008, there are eleven African countries participating in this initiative and 38 OFSP varieties officially released (Table 16.3).

C. Potential Economic Impact of Key Interventions

Recent survey evidence indicates that the lack of sustainable seed systems is one of the key constraints to improving sweetpotato productivity in SSA. For example, a CIP survey of national agricultural research system (NARS) priorities in 2005 reported that "virus management, seed quality and supply systems" were ranked as the highest priority for future R&D against all other listed sweetpotato technologies by 91 respondents from 34 developing countries (Fuglie, 2006). CIP pro-poor research targeting further indicates that research on virus control in sweetpotato through provision of clean planting material alone could yield rates of return of between 56–84% depending on rate of adoption and adoption ceiling. The anticipated aggregate impact of the technology (assuming a *status quo* adoption ceiling) was calculated to be $74 million per annum with annual benefits to the rural poor calculated to be $49 million p.a. The maximum potential aggregate benefits and benefits to the rural poor for SSA (assuming adoption on all affected areas i.e. no adoption constraint) were calculated to be $434 million per annum and $287 million per annum, respectively (Fuglie, 2007).

Table 16.3 Status of membership in VITAA platform, and the number of sweetpotato varieties released from 2004–2007 by type, the number of Orange-fleshed Sweetpotato (OFSP) varieties likely to be released in 2008–2009

Sub-region (Country)	Member of VITAA Platform	# non-OFSP varieties released 2004–2007	# of released OFSP varieties 2004–2007	# OFSP varieties to be released in 2008–2009
East & Central				
Uganda	Yes	3	4	0
Kenya	Yes	3	4	5
Tanzania	Yes	1	0	3
Rwanda	Yes	0	4	5
Burundi	No	0	0	0
Ethiopia	Yes	4	5	3
DR Congo	No	0	2	0
Southern				
Mozambique	Yes	0	9	3
Malawi	Yes	0	0	2
Zambia	Yes	0	3	4
Madagascar	No	1	2	2
Angola	No	0	0	2
South Africa	Yes	2	3	1
West				
Ghana	Yes	2	2	4
Nigeria	Yes	0	0	2
Burkina Faso	No	0	0	2
Niger	No	0	0	2

Compelling evidence is available of the potential contribution of OFSP to improved nutrition. To evaluate potential health and economic impact, economists estimate the number of vitamin A deficiency (VAD)-related Disability-Adjusted Life Years (DALYs) that could potentially be saved through the use of biofortified sweetpotato. Results indicate that just by replacing white-fleshed varieties with orange-fleshed ones could reduce the VAD burden by 15 to 22% in 17 SSA countries where sweetpotato is widely grown (Stein et al., 2005; Fuglie and Yanggen, 2007). *Ex-ante* analysis determined that if OFSPs were adopted by one-in-six Ugandan households within 10 years of becoming available, the effort would achieve an estimated internal rate of return between 16 and 30% and yield a net present value between $23 million and $67 million (Fuglie and Yanggen, 2007).

Cultural Methods

During the past 15 years, several surveys have been conducted to better understand existing cultural practices among smallholder farmers in SSA (Bashaasha et al., 1995; Kapinga et al., 1995; INIA/SARRNET, 2003; Tewe et al., 2003). Subsequent research to improve those practices and investment in developing farmer field schools in Uganda from 2002 onwards led to the development of a useful manual that summarizes existing and recommended practices for integrated sweetpotato production and pest management (Stathers et al., 2005). Niederwieser (2004) provides useful guidelines for maximizing sweetpotato production under high and low input conditions in South Africa and provides an excellent overview of the major commercialized sweetpotato production system in SSA. These sources provide the background material for this section.

A. Smallholder Production

Most smallholder sweetpotato production occurs in rainfed systems. In systems where sweetpotato is principally grown for home consumption, priority is given to planting cereals or other cash crops at the beginning of the rains. Sweetpotato is planted 1–2 months later when sufficient moisture is still available to ensure establishment. In countries with reliable and well-distributed rainfall this approach still results in good yields. However, in Southern and many drier parts of East Africa, planting late can significantly expose sweetpotato to drought, especially at the critical time of root formation (6–8 weeks after planting) and weevil damage (as the production period extends in into the dry season). In such cases, sweetpotato production figures show considerable annual variation.

For most field work in sweetpotato, women dominate in terms of labor contribution. Men are most involved in land preparation, especially when land needs to be cleared or soils are heavy and in marketing, particularly where sweetpotato is a significant cash crop. In many areas, men also significantly contribute to weeding and harvesting, particularly when sweetpotato is intercropped.

Land Preparation

Sweetpotato is most commonly grown on mounds or ridges, and occasionally on raised beds or on the flat. Deep cultivation enhances root growth and bulking of the sweetpotato root, and production on the flat tends to be found only on sandier soils. Mounds and ridges also permit adequate drainage and can ease harvesting. Mounds are made by hoeing the soil together from the surrounding areas, and consequently are rarely in straight lines. In Uganda, mounds are approximate 100 cm wide and 60 cm tall. When mounds are used, three vine cuttings are planted singly in a triangular pattern below the tip of each mound, giving a plant population of about 33,300 plants per ha.

Farmers report that mounds are easier to make than ridges, and such systems dominate in countries like Uganda. Ridges, however, are the norm when animal traction is used and their use is increasing, as it is often the approach advocated by extension personnel. Recommended spacing varies from 70–100 cm between rows and 30 cm between plants. Raised beds are most often found in wet areas near Lake Victoria, a major sweetpotato growing zone. In this system, weeds are gathered from the surrounding area, spread on the field and then soil is pulled up to create the beds and cover the organic matter.

Traditional farmer practice varies in terms of the placement of vines on mounds and the number of vines planted per hole. In drier parts of Mozambique, it is common for 2–3 vine cuttings to be placed in a hole as farmers feel there should be a reserve plant available in case one dies. However, to maximize the use of planting material, extensionists recommended planting one per hole and replacing lost plants if they fail to establish. If single vine cuttings spaced 30 cm apart are planted on ridges, the same plant population of 33,300 plants per hectare is obtained. About 2/3 of a 25–30 cm cutting is placed below the surface at an angle.

Detailed data from 5 of 6 production zones in Tanzania (Table 16.4) serve as an example of how sweetpotato is typically grown by SSA smallholders at all altitudes, on all kinds of soils, and especially in areas where rainfall varies between 800 and 1400 mm per year. In most zones, ridges were the commonest type of seedbed, but in the Lake Zone ridges were the least common option, with the sample of farmers almost evenly divided between using mounds, raised beds, or planting on the flat.

Sources of Planting Material

Most smallholder farmers rely on their own sweetpotato fields as a source of planting material or obtain vines from their neighbors or less commonly, from extension personnel. Apical cuttings taken from disease-free mature vines make the best planting material. However, limited availability of planting material at the beginning of the rains often means that middle to lower parts of the vines are used; cuttings from the base of the vine are more likely to be infested with sweetpotato weevil.

The availability of water during the dry season, through access to lowland areas with residual or permanent moisture or access to irrigation determines the options smallholders have to draw on. In areas with dry periods lasting 4 months or longer, lack of sufficient planting material often emerges as a major constraint to expanding sweetpotato production. Namanda (2007) describes six distinct traditional practices for sourcing vines in two drier districts of Uganda (Table 16.5).

In areas where rainfall is not a major constraint, Ugandan farmers cut vines from existing fields either prior to harvest or at harvest time to plant their new field. In this study, 26% of households engaged in that method. Farmers with access to lowlands with permanent or sufficient residual moisture often obtain their vines from such plots. Lowland sites in drought prone areas are often at risk, however, of animal or pest attack and in some countries such as Mozambique are at risk of flooding if the first rains are heavy. In the Uganda study, farmers had limited access to lowland areas for maintaining their vines (only 9%). Vines maintained in the backyard often require care. In Malawi, many families place such plots near washing areas and use so-called gray water to maintain plots during the dry season.

When conditions are very difficult for maintaining vines, then SSA farmers exploit sprouts which emerge from the roots themselves. There are two sources of roots: those which just were not harvested from the field and re-sprout when the rains come (28% of cases in the Ugandan example); and those from plots which

Table 16.4 Cultural practices in five major sweetpotato producing zones of Tanzania

	Lake	Central	Eastern	Southern	Southern Highlands	Total
Sample Size	186	109	238	200	95	828
Description						
Population Density (persons/sq km)	> 50	< 50	< 50	< 50	< 50	
Number dry months	most 4–6	6–9	5–6	6–9	most 4–6	
Climate Class	Lowland semi-humid	Lowland semi-arid	Lowland Humid	Lowland semi-arid	Highland continental	
Altitude Range (m)	1000–1300	1000–1300	0–1100	0–900	1000–2500	
Cultural Practices						
% Using bed type:						
Ridges	11	90	85	93	83	72
Mounds	33	6	0	2	7	10
Raised beds	27	0	0	0	10	7
Flat	29	4	15	5	0	11
Sources of planting material (%):						
Own field	43	47	88	37	56	54
Purchase	19	28	8	2	4	12
Neighbors or others	38	25	4	61	40	34
% Intercropping	96	88	16	19	29	50
Weeding Frequency						
% Not Weeding	0	20	6	5	0	6
% Weeding once	95	70	78	50	50	69
% Using inorganic fertilizer	3	1	8	9	4	5

Source: Kapinga et al. (1995). Note that sample sizes for individual questions can vary up to 15% due to missing values.

Table 16.5 Sources of vines for smallholder sweetpotato producers in Bukedea and Kamuli districts, Uganda (2007)

Source of vines	Frequency	Percent
Sprouting roots from previously harvested fields	45	28
Sprouting roots from previously unharvested fields	15	9
Cutting from plants grown in swamps	15	9
Cutting from plants grown in backyard	35	22
Cutting from plants grown in shade	10	6
Cutting from existing plants already harvested piecemeal	42	26
Total	162	100

Source: Namanda (2007). Understanding Farmer's Traditional Knowledge in Vine Management in Bukedea and Kamuli Districts. Unpublished report.

were not harvested, with the specific purpose of obtaining sprouts from these roots for the next season (9%). Sprouting from unharvested roots begins with the onset of the rains. Hence, valuable time is lost while farmers wait to accumulate sufficient planting material and as a consequence, delayed planting (in terms of yield maximization) is the norm (Namanda, 2007).

Crop Management

Purchased fertilizer and chemical use is minimal and the use of organic manure varies depending on household livestock assets and the presence of other crops that are valued higher than sweetpotato. For example, in Tanzania only 5% of households used inorganic fertilizer on sweetpotato (Table 16.4). Monocropped plots of sweetpotato are common, but intercropping with maize, cassava, beans, pigeon pea, and occasionally other crops also occurs. Intercropping is especially common when land is scarce (e.g. Western Kenya) or labor for constructing ridges is limited (e.g. Mozambique). Practices can vary considerably within a given country as seen in the Tanzanian example in Table 16.4. In the Lake Zone, known for land shortages, intercropping is the norm. In the Eastern and Southern zones, less than 20% of households intercrop. Sweetpotato is also found grown under the shade of young perennials such as coconut and banana and under tree crops such as mango. Sweetpotato can take advantage of residual fertilizer when intercropped with fertilized maize.

Most smallholder farmers weed their sweetpotato only once (for example, Table 16.4 for Tanzania), usually within the first 2 months of planting. Many extensionists advocate a second weeding to maximize yields.

B. Commercial Production

Commercially oriented sweetpotato production, with larger amounts of land (at least one quarter of a hectare) under production as a cash crop is still limited in SSA. Two different types exist: (1) medium-scale farmers using animal traction to enable larger-scale production in Western Kenya and parts of Eastern Uganda and (2) mechanized sweetpotato production in South Africa. Each of these systems is described in this section, highlighting how they differ with smallholder production systems.

Kenyan Example

A study conducted in Western Kenya in the mid-1990s (Low, 1995) in 4 distinct agro-ecologies where sweetpotato is grown, pinpointed distinct characteristics found on farms where sweetpotato was principally grown for home consumption versus grown for cash.

These characteristics are presented in Table 16.6.

Commercially-oriented growers in Nyanza Province cultivate fewer varieties, tend to plant in pure stands, engage in progressive (harvesting one section completely at a time) or one-time harvesting of the entire field, rely heavily on oxen to plough and harvest, and employ significant amounts of hired labor. These farmers rented additional land to expand their sweetpotato production. The components of total cost for producing one acre of sweetpotato are shown in Table 16.7. At the time, average yields were 10.3 t/ha. Due to sweetpotato's bulky nature, transport and marketing costs were the major cost components.

Table 16.6 Characteristics of farms growing sweetpotatoes principally for home consumption, compared to those growing sweetpotatoes mainly for cash

Characteristics of farms growing sweetpotatoes principally for home consumption	Characteristics of farms growing sweetpotatoes principally for cash
Diversity of varieties, with differing maturation periods	1–3 varieties, all meeting qualities demanded by market (e.g. red-skinned, white-fleshed)
Piecemeal harvesting as needed (in-ground storage)	Increase in demand for early-maturing varieties
Relay and intercropping dominates pure	Progressive or one-time harvesting (still reliant on in-ground storage)
Average plot size rarely exceeds 0.5 acre	Pure stands dominate relay planting and intercropping
Never rent land strictly for sweetpotato production	Plot sizes often exceed 0.5 acre; sometimes rented
Limited male labor involvement, except for land clearing	Increased male and female labor involvement (esp. number of household members involved)
Oxen used only occasionally on heavy soils for ploughing; never for harvesting	Increased oxen use for ploughing, harvesting, and transporting to market outlets
Dominance of soils of average fertility	Intensification of pest problems, due to inadequate rotation, decrease in use of proper cultivation practices
Preference for very large tubers	Preference for medium-size tubers (easy to pack)
Planting material purchased by farmers only in areas with one annual growing season for sweetpotato	

Source: Survey of 81 sweetpotato producers in Rongo, Ndhiwa, Kabondo, and Kendu Bay in Nyanza Province, Kenya (Low, 1995).

Table 16.7 Components of total cost for 1 acre of sweetpotato production for sale in Kabondo, Kenya

	Percent of total cost
1. Land Rental	12%
2. Land Clearing	4%
3. Ploughing with Oxen	11%
4. Mound Construction	7%
5. Planting	4%
6. Single Weeding	9%
7. Harvest with Oxen	12%
8. Packing into Bags	8%
9. Transport and Marketing	33%

South African Example

Sweetpotato is considered to be a vegetable in South Africa. Commercial sweetpotato production represents less than 2% of total vegetable production in that country. The majority produced is sold to the internal fresh market; 5% is exported to Europe and the U.K. (Niederwieser, 2004).

Average commercial yields are 40 t/ha in the highly mechanized commercial sector compared to 5–10 t/ha in the rainfed smallholder sector. Clean planting material, excellent soil fertility management, and quality harvest management underlie the yield differences. The national research program, ARC-Roodeplaat, annually uses virus indexed nuclear plants of the major commercial varieties to establish mother plants and sells this clean primary material to specialized vine growers. If large roots are desired, planting densities of 33,000 plants per hectare are used; for medium sized roots (200–400 g), planting densities range from 40,000 to 45,000 plants per hectare.

Sweetpotato requires 450–600 mm water that is well distributed throughout the growing season. Key periods are at establishment (3–5 mm per day until cuttings have rooted) and 40–60 days after planting when storage roots form. Twenty-five to fifty mm per week of water is recommended during the active growing period of the crop, with water withheld 30 days prior to harvest to assure root quality. Niederwieser (2004) provides data on the amount of key nutrients sweetpotato removes from the soil, advocates soil testing for determining optimum fertilization regimes, and provides guidelines for fertilization for different yield goals. To obtain yields of 40 t/ha, farmers incorporate fertilizer prior to planting and then apply two top dressings (21 and 42 days after planting). In total, 137.3 kg of nitrogen, 80 kg of phosphorus and 106.7 kg of potassium are provided to the crop. With sweetpotato the potassium to nitrogen (K:N) ratio must be kept high to avoid excessive foliage in relation to root development. Most commercial South African farmers use herbicides to control weeds once due to their ease of application. Once the canopy is well established, further weed control is usually unnecessary (see Niederwieser, 2004 for more detailed information).

Pests and diseases and other constraints

A. Overview

Among the smallholder sector in SSA, there are five major constraints to improved productivity and incomes from sweetpotato.

1. The lack of access to virus- and pest-free "clean" planting material. Most of the local landraces and some of the introduced material are degenerated because of the sweetpotato virus disease. Yield gains of 30–60% can be obtained through use of healthy planting material (Clark and Hoy, 2006; Fuglie et al., 1999; Gibson et al., 2004; Karyeija et al., 1998). In addition, prolonged dry spells in many areas threaten the maintenance of planting material until the next growing season. Traditionally, most farmers in drought-prone areas maintain vines in valley bottoms with residual moisture, or leave roots in their fields to re-sprout when the rains return. The bottom line is that the area planted to sweetpotato is heavily constrained by limited availability of vines at the most appropriate planting times. Addressing drought through new vine conservation techniques, more drought-tolerant varieties, and small-scale dry season irrigation could radically increase sweetpotato production. In addition, insect pests facing their own food shortages during the dry season often concentrate with the first rains in vine multiplication plots with resultant high losses of planting material due to defoliators and early virus infection due to virus transmitters. Hence, locally developed and adapted pest management strategies are important to supply healthy pest and virus-free planting material to avoid early crop infestation. Moreover, as clonally propagated sweetpotato degenerates due to virus within 3–8 years, farmers must be able to periodically access clean material from primary multiplication sites typically reliant on tissue culture facilities with virus clean-up and testing capability.

The sweetpotato virus disease (SPVD) complex caused by mixed infection of *Sweetpotato feathery mottle virus* (SPFMV) and *Sweetpotato chlorotic stunt virus* (SPCSV) is, by far, the most destructive viral disease of sweetpotatoes in Africa (up to 50% in East Africa), and perhaps worldwide (Carey et al., 1999). In many cases, cultivation practices ensure that sweetpotato plants can be infected all year round. Farmer use of cuttings from their previous crop as planting material and the abundance of weed vegetation, which serves as a continually present reservoir of viruses and vectors, makes the control of the disease difficult (Karyeija et al., 1998).

Njeru et al. (2006) reported that although most farmers (73%) in Rwanda were able to identify sweetpotato virus disease (SPVD) as the most damaging disease (also confirmed by laboratory testing) the majority (65%) were not aware of what causes the disease and 53% used no control measures against it. Laboratory testing of over 300 fields in Rwanda by the same author (Njeru, personal communication in 2008) revealed that 83% of symptomatic plants and 31% of asymptomatic plants were virus infected, and with mixed infections common in symptomatic plants but not so in asymptomatic plants. Recent virus surveys in Uganda and Tanzania report varying levels of SPVD infection (Ndunguru et al., 2008; Ndunguru and Kapinga, 2008). Between 10–40% infection levels were found in Central Uganda where symptoms were recorded as being from mild to moderate. The majority of farmers practice control measures and improved varieties are widely grown. In Tanzania SPVD levels varied from 94% in the Northwest, where there was less knowledge about virus control and more local varieties grown, to 54% in the Eastern part of the lake zone (Mwanza). Limited virus testing using samples originating in this Eastern region reported less diversity of different viruses and that in particular, the mixture of viruses responsible for SPVD in Eastern Africa was not found in this particular area. In general there is a lack of current good and systematic virus survey data, particularly from Western and Southern Africa where little is known about virus incidences or the diversity of viruses present. A comprehensive virus survey has recently commenced in Rwanda, Burundi, Uganda and Congo in a CIP co-ordinated Belgian funded project (Kreuze, pers com.) Initial findings from this survey from Rwanda reinforce earlier work and indicate that 62% of farmers believe that the virus problem is increasing or at least not changing (38%). Farmers not practising any control measures amounted to 47%, 95% and 65% in Rwanda, Burundi and DR Congo, respectively.

2. Lack of improved varieties adapted to local environments. Genetic gains in terms of yield are expected to be about 20% compared to healthy local landraces (Grüneberg et al., 2004). Breeding is also the pathway for introducing quality traits (higher micronutrient content, dry matter content, sugar content, taste) that do not contribute towards improving yields but are essential for achieving other goals, such as consumer acceptance and improved diet quality.

3. Damage due to the sweetpotato weevils, particularly in drier production zones. Sweetpotato weevils are the most important pests of sweetpotato in Africa and worldwide, and production losses may often reach 60% to 100% (Stathers et al., 2003). The two species found in SSA are *Cylas puncticollis* and *Cylas brunneus*. Moderately damaged roots are unsuitable for human consumption. The search for sources of resistance to sweetpotato weevils in the crop's germplasm has not yielded reliable results and hence no conventional resistance breeding has been possible to date. Because of a lack of funding and entomological capacity, African national research programs have not been able to develop an Integrated Pest Management (IPM) program for sweetpotato to reduce major losses by sweetpotato weevils and other regional pests. That IPM can successfully work to control sweetpotato weevil was clearly demonstrated by CIP scientists and national collaborators in Cuba (Lagnaoui et al., 2000). In this collaborative IPM project the national mean damage by sweetpotato weevils was reduced from 45% to 6% on a production area of 45,000 ha within a period of 6 years. Besides using deep-rooting varieties, the major cultivation practices advocated for weevil control are: (1) crop rotation, (2) removal of infested vines, root residues, and volunteer plants, (3) use of uninfested vines (especially tips) as planting material, (4) avoiding cracks in the soil through hilling up of soil around the base of the plant, mulching, or through irrigation, (5) timing harvesting to avoid the dry season and (6) flooding for at least 48 hr after harvesting (Stathers et al., 2005). However, experience in Mozambique has indicated that smallholder farmers are only willing to adopt a significant number of cultural control practices *if* there is a market for their roots to justify their additional labor input (Low et al., 2007b).

Weevil resistance or control would bring true advantages, especially for sweetpotato production in drought-prone areas, as it would extend the possible period of in-ground storage in drier areas, reducing seasonality and improving food security. The International Potato Center is currently working with 4 countries in SSA to develop genetically modified *Bt* sweetpotato as the long-term strategy to combat this damaging pest (Ghislain, personal communication).

4. Insufficient knowledge and use of better agronomic practices. Adoption of better agronomic practices, such as site selection, planting techniques, spacing, weed control, soil fertility and water management, can substantially increase yields (more than 100%). Unfortunately, in the medium term smallholder access to fertilizers (both organic and inorganic) and irrigation is likely to remain limited. However, better management of local sources of nutrients and adoption of practices not requiring cash outlay could improve yields as much as 60% (Sevastiani et al., 2005; Niederwieser, 2004).

5. Lack of markets. Research in Mozambique and Kenya has demonstrated that farmers will substantially invest in labor-demanding technologies or technologies requiring purchased inputs to improve productivity and quality *only* when there is a market to absorb surplus root production (Low et al., 2007b; Kimathi et al., 2004). Like other roots and tubers, fresh sweetpotato roots are bulky, and hence relatively expensive to transport and good post-harvest care is essential to assure reasonable shelf life. In China and many other parts of Asia, roots are exploited as animal feed, starch, and a variety of processed products. The value-added use of sweetpotato in SSA is in its infancy. A discussion of sweetpotato marketing is provided in a section below.

B. Other Pests and Diseases

Sweetpotato is a rustic crop and while there are many diseases, which can affect sweetpotato, viruses and the sweetpotato weevil are the major ones causing economic levels of damage. Other pests and diseases of economic importance in SSA are described briefly in this section. Please refer to Skoglund and Smit (1994) for full details.

The rough sweetpotato weevil (*Bosyrus spp.*) also damages sweetpotato roots by gouging deep grooves in the surface. It is much less common and destructive than the sweetpotato weevil, but the cultural methods of control are the same.

At the beginning of the dry season in East Africa, the larvae of the sweetpotato butterfly can explode if left unchecked and cause complete defoliation. Severe outbreaks are sporadic and usually controlled with contact insecticides.

Farmers frequently complain of vertebrate pests. Near forested areas, monkeys and wild pigs can cause widespread losses and farmers have limited options for controlling them, especially in countries where firearm ownership is illegal. Domestic pigs adore sweetpotato roots and can be particularly troublesome in communities where it is common practice to allow them to roam free. Mole rats can dig through complete ridges or steal exposed roots. They can be highly destructive, at times destroying more than they eat. In certain areas, individuals knowledgeable in trapping mole rats are hired to deal with the problem. In Tanzania, a local shrub is used as a repellent. In Western Kenya, farmers try to burn cow dung mixed with pepper at the burrow entrance to smoke the mole rat out (Stathers et al., 2005).

Besides viruses, the other disease often encountered in humid environments, especially in the Central African Highlands, is the fungus *Alternaria*. The fungus survives in soil and plant debris and is spread by wind and splashing rain. It causes lesions on the foliage, especially in the base and middle sections and can lead to death of the vines. Some varieties are more resistant to *Alternaria* than others and breeding programs select for this resistance in areas with high incidence of the fungus. Use of clean planting materials and good sanitation practices are the best way to keep it under control.

C. *Addressing the Yield Gap*

The potential to significantly address the yield gap on farmer's fields in SSA is real. Experiments conducted in 12 East African environments with 15 improved genotypes using clean planting material yielded an average of 24.2 t/ha, compared to the average yield in the region of 5.6 t/ha (Grüneberg et al., 2004). The dissemination of clean planting material of improved varieties is capable of at least doubling current average yields under rainfed conditions from 6 to 12 t/ha. Combining such introductions with improved crop and soil fertility management practices could at least triple existing yields obtained by smallholder farmers to 18–20 t/ha. Irrigation supplied in a timely manner could also contribute to an additional 30% yield increase (Niederwieser, 2004).

Harvesting, Storage, Marketing and Profitability

A. *Harvesting and Storage*

In many parts of SSA there is a marked dry season and sweetpotato is only produced part of the year. Roots can be stored in the ground for an additional period but they are attacked by weevils when soil is dry and cracked. Farmers have developed in ground storage and piecemeal harvesting technology to maintain the supply of fresh sweetpotato for as long as possible (Hall et al., 1998). In Uganda this involves:

- Staggered planting, so that the crop will not all mature simultaneously
- Menu of varieties with different characteristics including maturation time to make fresh sweetpotato available over a longer period and provide roots with different post harvest characteristics e.g. yield, in ground storability and taste
- In ground storage of roots after maturity, for up to six months
- Piecemeal harvest of roots needed for immediate use

Piecemeal harvesting is an indigenous practice which may reduce weevil losses as more superficial and potentially damaged roots are harvested first (Smit, 1997). In the piecemeal system, women search the field for cracks in the mounds/ridges or exposed roots, which indicates to them that a mature root may be ready for harvesting. After removing such roots, the soil is hilled up again around the plant. When farmers are harvesting for longer periods of out-of-ground storage or sale, usually greater care is taken to avoid cutting the roots.

Damage to sweetpotato skin occurs very easily and abrasions are a major point of entry for disease pathogens. Farmers harvesting for home consumption often do not take care about avoiding damage, as immediate consumption is the intent. Roots are perishable, and unless cured or placed in stores, will likely not be marketable 1–2 weeks after harvest. Market traders in Nairobi and Kampala reported selling consignments within 3 to 4 days after arrival before rotting occurs (Omosa, 1997).

The possible duration of in-ground storage varies widely by variety with deep rooting varieties typically storing longer. Variability in maturity periods and in-ground storage capability and flexibility in planting times leads to a marked seasonality of supply with substantial price variability and deterioration in quality as the dry season progresses. Seasonality of supply creates a barrier to increasing per capita consumption and income earning possibilities both for fresh sales and for processing. There are some places, such as Rwanda, where production occurs in wetlands outside the rainy season and seasonality of supply is less marked.

If farmers could store fresh roots they could benefit from higher prices at the end of the harvest season. In practice there is little use of pits, clamps (mounds of sweetpotato sealed with earth to maintain humidity and keep out pests) or other types of stores in SSA; Malawi and Northern Nigeria are exceptions (Hall and Devereau, 2000; Tewe et al., 2003). Research by the Natural Resources Institute (NRI) on low cost storage using pits and clamps with thatched roofs showed that storage up to 4 months is possible. Stored roots are fit for home consumption but sell with a price penalty or may not be marketable because they lack the "just from the garden look" which consumers expect in fresh products (Hall and Devereau, 2000). Low cost storage was validated by the NRI in Tanzania (Rees et al., 2003). Adoption of stores for commercial use depends upon the expected price difference between the time of harvest and the moment of sale and this is variable across and within countries. A much higher price out of season was encouraging adoption of storage in Tanzania in 2004 (RIU, 2007). A cost benefit analysis of stores for home consumption in Uganda showed much higher rates of return than for any other sweetpotato enterprise (Wheatley and Loechl, 2008).

Sweetpotato roots respire during storage, but curing can reduce this. Curing sweetpotato roots at about 29 °C with high humidity for four-seven days prior to storing at 12–14 °C is used commercially in the US to heal wounds, protect against disease, reduce shrinkage and extend storage (Kemble, 2004). High ambient temperatures may mean that this type of curing is not applicable in SSA (Hall and Devereau, 2000). NRI has tested pre-harvest curing by removing sweetpotato foliage 14 days before harvesting, which reduced post harvest losses by up to 40%

(RIU, 2007). Breeding is possible to improve storability as shelf life is a varietal characteristic but it appears that cultivars that lose weight rapidly rot more (Rees et al., 1998).

B. Marketing and Profitability

Uncured sweetpotato roots are bulky and perishable. This limits the distance over which sweetpotato can be economically transported (Hall et al., 1998). Farmers in less favored locations often report that marketing sweetpotato is difficult; either markets are too distant using local transport or farmers are forced to be price takers of a sole trader serving the area. The risks of oversupply are also greater in rural locations distant from significant urban populations, as reported in Rwanda and elsewhere so that when harvests are heavy no market exists for extra production.

Production areas capable of generating surpluses tend to be relatively localized but dispersed, which leads to a lack of market integration and limits market size. Moreover, production is highly seasonal in most countries leading to marked variation in the quantity, and quality, of roots in markets and associated price swings. There is little commercial processing into chips or flour, which could be stored for year round consumption for use in stiff staple porridges, bread and cakes, or processing into fermented and dried products like *fufu* (stiff porridge). Sweetpotato consumption tends to decline as incomes rise, a change often linked with urbanization, partly because it is perceived as a "poor man's food" but also driven by the change in relative prices of root crops compared to grains in urban areas due to transport cost differentials.

The example from Kabondo in Nyanza Province Kenya cited earlier demonstrates how profitability of commercial sweetpotato production is extremely sensitive to seasonal price fluctuations and yields (Low, 1995). A farmer renting land at 800 Ksh per acre, for example, had to produce 35 bags per acre (10,300 kg/ha) in 1995 to break even, if a bag of sweetpotatoes was selling for 200 Ksh. The breakeven point would drop to around 20 bags per acre when the price of sweetpotatoes rose to 300 Ksh per bag. For perspective, average prices in the major market (1995) were 300 Ksh/bag from January through April, 250 per bag during May through September, and 400 Ksh per bag from October through December. Regardless of the final price per bag, farmers on average spent 75 Ksh per bag in transport and marketing fees. Staggering planting periods and maintaining high yields were the strategies used for dealing with these price fluctuations given the lack of knowledge and unknown profitability of post-harvest fresh root storage techniques.

Discontinuous supply from relatively specialized production zones, high transaction costs and the bulky and perishable nature of the root leads to relatively high marketing costs increasing prices to urban consumers. In Kenya and Tanzania, the commercial value of sweetpotato is highest during the month of Ramadan as sweetpotato is often used to break the fasting period. In Nigeria, profits from sweetpotato can vary considerably by zone due to differences in access to markets and availability, use, and cost of inputs such as fertilizer and hired labor. One study conducted in 1995 found profit margins per hectare of 44, 57, and 105 USD in Southwest, Central, and Southeastern Nigeria, respectively (Tewe et al., 2003).

The high transport costs and tax structure of urban markets in East Africa have resulted in sweetpotato being jammed into large extended bags, often weighing over 200 kg, by traders/transporters hauling large amounts of sweetpotato to urban markets. Two to four persons are often required to load these large bags on trucks, and upon arrival, the sweetpotato is often bruised or damaged during unloading. This common practice lowers the quality of the roots and shortens shelf life.

The dispersed and seasonal nature of sweetpotato production, high costs of marketing (lack of processing opportunities), competition with other staples, the periodicity in the diet and limited consumption in towns lead to low volume or "thin" urban markets in those SSA countries where it is a secondary staple. This limits the adoption of productivity enhancing technology as additional supply leads to sharp price falls. This expectation may choke off production increases or technology adoption. These varied market problems means that there is no single critical entry point into sweetpotato value chains that would release a transformation of production and consumption. Any such transformation would have to take place across the value chain.

The promotion of orange-fleshed sweetpotato (OFSP) or diversified use into processed products or animal feed could potentially drive such a transformation of the value chain. Both strategies rely on the development and marketing of a new product. An alternative or complementary strategy would be to extend the supply period through the year, either through storage or extension of the production period.

A market transformation strategy based on the introduction and promotion of OFSP will need to be adapted to the very different market contexts for sweetpotatoes across Africa. In both West and East Africa, OFSP will have to break into markets with strong existing preferences, in these cases, for high dry matter, white or yellow-fleshed varieties. In the Southern African context, the challenge is to build market demand where sweetpotato is consumed seasonally as a secondary staple and there are no strong preferences at present, as is the case in Mozambique. This is also true in many countries emerging from conflict. Experience from pilot projects in Mozambique suggests that the second context will be less problematic for market penetration of OFSP (Low et al., 2007b).

Uses of Sweetpotato

A. Roots

Boiled and steamed roots often serve as a breakfast food or snack. In rural areas, traditional dishes often mix sweetpotato with cowpeas, coconut milk, and dark green leaves. Farmers in areas with marked dry seasons in Uganda and Tanzania sundry sweetpotato to extend the period when it may be consumed. In Uganda, roots are sliced (*amokeke*) or crushed (*inginyo*) before drying (Hall et al., 1998). *Amokeke* is reconstituted whole as a breakfast food and *inginyo* used for flour to produce *atapa*, a starchy staple. In Tanzania, roots are sliced fresh (*vichembe*) or after boiling (*matoborwa*) before drying. These products can be stored for six months in Uganda and perhaps longer in Tanzania. Attack by insects limits storage period. Artesanally dried products are mostly used for home consumption with limited commercialization, probably because they are not competitive with dried cassava chips. Since 4–5 kg of fresh roots are required to produce 1 kg of dried chips, farmers often prefer to sell in the fresh root market as the equivalent price can not be gained in the dried chip market. Slicing and drying by hand is labor intensive for processing large quantities when fresh storage would be preferable but is an option for dealing with small quantities at a time.

In Nigeria, principal sweetpotato utilization varies considerably by agro-ecology. In humid zones, sweetpotato is mixed cropped with maize and consumed as a snack, as sweetpotato flour mixed into other main dishes, and sweetpotato leaves are used for livestock feed, especially rabbits. In the sub-humid zones, sweetpotato is mixed cropped with millet and used for stiff porridge (*foofoo*), as a vegetable and in snacks. In the semi-arid north, sweetpotato is single cropped in the lowlands and is boiled for food, used to sweeten other dishes and a local fermented drink (*kanuzaki*). Dried forage is used for livestock feed in the north (Tewe et al., 2003).

Solid consumption data in urban areas for sweetpotato is rare. One study from Rwanda found that consumption of sweetpotatoes is substantially lower in urban than in rural areas and fell with increasing income confirming that its status as an inferior good in Rwandan urban areas (DeWalt, 2007). Existing evidence does indicate that its use as a breakfast and snack foods in urban settings is increasing, especially in countries facing rising cereal prices. In Zimbabwe, significant production of sweetpotato occurs in the peri-urban area surrounding the capital city of Harare. In that country, per capita sweetpotato consumption levels are higher in cities than in rural settings (Rukumi and Mutungamior, 2002). In West Africa, sweetpotato snacks are often fried and sold along the roadsides.

Some consumers report not liking to eat much sweetpotato as it can cause flatulence (due to undigested and dietary fiber). The degree to which cooking controls the flatulence varies by cultivar (Tsou and Yang, 1984) and improved techniques are needed to evaluate this negative varietal characteristic.

Regional networks such as PRAPACE for Eastern and Central Africa and SARRNET for Southern Africa have backstopped national program scientists and other stakeholders in developing a range of recipes in which sweetpotato is a primary ingredient. Uganda and Mozambique have recipe books published in English and Portuguese, respectively (Owori et al., 2007, INIA and SARRNET, 2002). Pilot efforts to link farmers to markets in Kenya (roots and flour), Uganda (roots and dried chips), and Mozambique (roots, juice, and bread) have shown that farmers respond to profitable income-earning opportunities, demonstrated by the significant expansion of sweetpotato production for market. Rural bakers substituting 38% of wheat flour (by weight) in bread buns ("*golden bread*") with boiled and mashed

OFSP from fresh roots produced economically viable products with at least 15 μg/g product of *trans*-β-carotene and hence, considered to be good sources of vitamin A (Low and van Jaarsveld, 2008). Further work is needed to improve product quality and market chain efficiencies.

Some SSA countries exhibit some of the highest urbanization rates in the world. By 2020 nearly half (46.2%) of the SSA population will be urban (UN-Habitat, 2001). Poorer rural households migrating to urban centers will carry their diverse food preferences with them and will also need good, inexpensive sources of quality food. Investments in improved infrastructure and value chain efficiency enable the expansion of sweetpotato as an urban foodstuff.

B. Foliage

Sweetpotato leaves are also consumed in many countries in SSA, with the notable exceptions of Kenya and Uganda where they are principally considered to be livestock feed. The leaves also contain significant amounts of beta-carotene, but their bioavailability is unknown and likely to be lower than the OFSP roots. In parts of Tanzania where fresh leaves are consumed, there is a strong preference for varieties with narrow leaves and deep lobes. In other parts, dried sweetpotato leaves are preferred. The traditional drying technique involves leaving fresh leaves to wither in the sun, then parboiling them for 20–30 min, removing the excess water, and subsequently sun-drying them (Kapinga et al., 1995).

Enhanced demand for sweetpotato roots could generate a secondary market for vines with income earning opportunities. The use of sweetpotato as a feed source in sub-Saharan Africa has been limited thus far and its use principally consists of vines being fed to dairy cattle and goats as supplements in highland environments. Vines from so-called dual purpose (for vines and roots) or forage varieties (vines only) are valuable as feed because of their good palatability and higher yields and crude protein content compared to alternatives such as Napier grass (Table 16.8).

In a country such as Rwanda where sweetpotato is the second largest staple crop (after banana), large quantities of sweetpotato roots are consumed and this

Table 16.8 Comparison between fresh yield, dry matter yield, and protein yield of Napier grass and sweetpotato vines

	Napier		Sweetpotato vines		
	Flat land	Rocky soil	Uganda	Kenya	Rwanda
Fresh yield (ton/ha/yr)	35	17.5	70	90	70
Dry matter content (%)	14	15	13	13	13
Dry matter yield (ton/ha/yr)	4.9	2.6	9.1	11.70	9.10
Protein yield (ton/ha/yr)	0.44	0.24	1.82	2.34	1.82

Lykuyu et al. (2007) and Peters (2008).

consumption pattern generates a large amount of sweetpotato vines that are used as feed for dairy cows. Sweetpotato vines sold in Rwandese markets are used either as planting material or feed for dairy cattle. The introduction of a zero grazing policy for cattle has led to an increase in feed prices in Rwanda. Prior to the zero grazing policy, each bundle of sweetpotato vines (15–20 kg) cost 200 Rwandese Francs (RWF), but now cost 250–300 RWF (Peters, 2008).

Because of abundant supply, Rwandan farmers have cheaper access to sweetpotato vines for feed (Table 16.9), and subsequently seem to be more familiar with the benefits of sweetpotato vines for milk production than farmers in Kenya where sweetpotato roots are consumed as a secondary staple.

Research conducted by CIP in China and Vietnam and a feasibility study in Uganda indicates that sweetpotato could also be a significant, cost-effective ingredient in pig feed in SSA (Peters, 1998; Peters, 1999; Peters et al., 2002). Until now, no major efforts have exploited this opportunity to improve low rates of weight gain among smallholder-raised pigs in SSA where around 17.6 million pigs are produced annually in the 17 major sweetpotato producing countries (FAOSTAT, 2006). The use of sweetpotato silage (fermented roots and vines) is unknown except on an experimental basis in SSA.

In conclusion, sweetpotato as a robust relatively quick maturing crop which requires few inputs is playing a significant role in securing food security in SSA. Sweetpotato is almost exclusively grown by smallholders often on small patches of land for household consumption. Its importance has steadily grown over the past decade because of increasing pressure on land, political instability and the opening of markets. The growing availability of pro-vitamin A rich orange-fleshed varieties presents an opportunity to meaningfully tackle vitamin A deficiency among vulnerable groups, especially in rural areas, and also to stimulate increased demand for sweetpotato in urban areas. A lack of year round supply is one of the constraints on further growth and this could be addressed through improved planting material supply, better management of weevils which limit storage in the ground, improvements in storage and exploiting agroecological niches where off season production is possible. In many places however, sweetpotato has been neglected in agricultural development policy and one of the principal challenges is to strengthen the evidence base to give it more visibility. The true potential of sweetpotato is of yet unleashed on the continent.

Table 16.9 The prices of sweetpotato vines for feed in Rwanda and Kenya (June 2008)

	Rwanda			Kenya	
	RWF/kg	USD/kg		Ksh/kg	USD/kg
Before zero grazing	11	0.021	When maize is available*	5	0.08
			Wet season	10	0.16
Currently	16	0.029	Dry season	20	0.32

* During maize harvest season, maize stalks are widely available and cheap, thus offering serious competition with SP vines.

Source: Peters, 2008. 545 RWF for $1 USD and 64 Ksh for $1 USD.

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