Farmers' Perceptions, Production and Productivity Constraints, Preferences, and Breeding Priorities of Sweetpotato in Rwanda

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Abstract. The role of farmers and their production constraints and preferences are important for sweetpotato breeding and adoption of cultivars and agronomic production packages. The objective of this study was to assess farmers' perception, production constraints, preferences, and breeding priorities of sweetpotato in selected agro-ecologies of Rwanda. A total of 495 farmers were surveyed in 2013 in eight representative districts: Bugesera and Kayanza in the Eastern Province, Gakenke and Rulindo in the Northern Province, and Gisagara, Huye, and Muhanga in the Southern Province. Data were collected through a participatory rural appraisal (PRA) methodology using a semi-structured questionnaire and focus group discussions. Pairwise comparison of 16 food crops allocated sweetpotato as one of the five important food crops for food security and income generation. Drought stress, unavailability of improved cultivars and planting material, and pest and disease damage were perceived to be the five main constraints limiting sweetpotato production, contributing to 17.3%, 15.0%, 12.9%, 11.7%, and 11.5%, respectively. The most important sweetpotato cultivar traits had high yield, early maturity, drought tolerance, disease and pest tolerance, and good culinary taste at 22.5%, 18.5%, 15.4%, 12.7%, and 10.1%, respectively. The characteristics of good storage roots identified by farmers included high dry matter content, good culinary taste, good shape, root size, and sweetness representing 27.4%, 18.8%, 16.1%, 11.6%, and 9.4%, respectively. Each agro-ecological zone has its own specific sweetpotato production constraints and farmers' preferences, necessitating targeted breeding of different sweetpotato cultivars for each agro-ecological zone for enhanced productivity and successful adoption of cultivars.

Globally the demand for quantity and quality food is fast increasing as a result of population growth, limited water and land, and overexploitation of available resources (Godfray et al., 2010; Tilman et al., 2001). Moreover, global climate change aggravates the biotic and abiotic stresses on food crops (Tester and Langridge, 2010). These environmental changes will negatively affect crop production and food security. Therefore, novel mitigation strategies are required to boost crop productivity and ensure food security. Improved and resilient crop cultivars and their production technologies are

among these strategies (Brown and Funk, 2008).

Participatory plant breeding is usually conducted to ensure adoption of newly developed crop cultivars and their production packages by smallholder farmers of marginal agro-ecological and socioeconomic groups (Ceccarelli et al., 2007). In the past, plant breeding focused on developing high-yielding and improved crop cultivars in favorable environments and under controlled experimental situations (Bänziger and Cooper, 2001). As such, conventional plant breeding did not consider farmers' preferences and attributes, locally available germplasm, and the real conditions of small-scale farmers in pursuit of developing crop cultivars for broad adaptation (Ceccarelli et al., 2000; Witcombe et al., 1996). These failures to engage with the realities faced by local farmers have been identified as the primary causes for the consistently low adoption of newly developed "improved" crop cultivars and their production packages released by government and NGO scientists (Adesina and Baidu-Forson, 1995).

There are varied preferences and needs by end users for crop cultivars. For instance, for industrial starch production, sweetpotato cultivars are required to have high dry matter content, whereas cultivars for human consumption should have other traits such as attractive skin and flesh color, good cooking quality, and high β -carotene, among others. Sweetpotato cultivars intended for animal feed should have high protein content (Lebot, 2009). Therefore, sweetpotato breeding should involve the needs of stakeholders in the developing of new cultivars and new agricultural technologies to meet their diverse requirements (Atlin et al., 2001; Rees et al., 2003).

Agricultural technologies developed through participatory research have a greater chance of adoption and diffusion by farmers because they are developed in response to local constraints and meet end users' needs and preferences (Ashby and Lilja, 2004). Various research approaches have been reported in participatory breeding of new crop cultivars, including consultative approaches, collaborative approaches, collegial approaches, and farmer experimentation (Ashby and Lilja, 2004). Advantages of farmer participatory research include: 1) codefinition of breeding objectives; 2) participatory evaluation of germplasm; 3) identification of breeding priorities; and 4) participatory selection of promising progenies (Ceccarelli and Grando, 2009). In one case, the incorporation of participatory approaches into conventional breeding programs reduced the time taken for cultivar development from 9 to 6 years (Lilja and Aw-Hasaan, 2003).

In sweetpotato breeding, farmers' knowledge and experience during preliminary on-farm and on-station evaluations may enable quick identification of promising genotypes (Abidin et al., 2005). Song (1998) reported that the end users' participation in the improvement of seed systems led to the efficient use of national genetic resources and promoted their production. In selection of high-yielding genotypes, Ceccarelli et al. (2009) observed that farmers have the same selection ability as breeders. Therefore, close collaboration between farmers and breeders is necessary to speed up the breeding process and to respond to appropriate needs of stakeholders.

Application of participatory research requires integrated skills (Ceccarelli et al., 2009). A careful choice of research goals, target environments, and selection of partners are critical steps of participatory research. It also demands a systematic understanding of different types of participatory research approaches to select the most appropriate tools (Ashby and Lilja, 2004) such as participatory rural appraisal, focus group discussions, participatory selection in segregating populations, and participatory cultivar testing and selection (Sperling et al., 2001).

Sweetpotato is an important food and feed crop in sub-Saharan Africa and ranks fourth after maize, bananas, and cassava (FAOSTAT, 2013). It yields considerably well in poor soils and tolerates extreme weather conditions unsuitable to other food crops such as maize and banana (Woolfe, 1992). Therefore, it has an important role in food security in many

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Results

Demographic description of the study areas

The most important variables and descriptions of farmers chosen for the study are presented in Table 1. The number of female respondents was higher than males. Females represented 58.4%, whereas males were at 41.6%. The total number of interviewed farmers during the survey was 168, whereas 327 farmers were available for group discussions.

In this survey, 67.3% of the farmers had finished primary school, 4.2% had completed post-primary school, 1.4% had attended secondary school, and 26.9% were illiterate (Table 1). Training in agricultural practices was limited with only 28.5% of the interviewed farmers having been trained in some agricultural practices by various organizations such as World Vision and Catholic Relief Services, the Food Agricultural

Organisation of the United Nations, and national public agricultural institutions such as the Institut des Sciences Agronomiques du Rwanda, the Rwanda Agricultural Development Authority, and the RAB. Most farmers' training had focused on use of agricultural inputs, soil conservation, and agronomic crop management.

Farmers' perception and sweetpotato production

Importance of sweetpotato. The results from a pairwise comparison of the 16 food crops grown by farmers (banana, bean, cassava, cocoyam, fruit, Irish potato, maize, groundnut, dry peas, rice, sorghum, soybean, sunflower, sweetpotato, vegetables, and yam) revealed that the positions of sweetpotato in terms of food security and income generation varied from one district to another (Tables 2 and 3). In Bugesera district, sweetpotato ranked fourth as a food security crop after banana, bean, and cassava and ranked fifth in

income generation. In Kayonza district, sweetpotato ranked fifth after bean, cassava, banana, and rice for food security and ranked 13th in income generation. In Gakenke district, sweetpotato ranked fourth as a food security crop after banana, bean, and cassava and third in income generation. In Rulindo district, it was the fourth food security crop and the fifth in income generation. In Gisagara district, sweetpotato was the third food security crop after banana and cassava and the fifth in income generation. In Huye district, it ranked third for food security after cassava and bean and the sixth in income generation. In Muhanga district, sweetpotato was the fourth after bean, cassava, and banana as a food security crop and the sixth in income generation. In all districts of the study, cassava, banana, and sweetpotato were among the first five food crops, whereas banana was the only crop ranked among the first five crops in income generation.

Table 1. Description of sampled farmers from three provinces and seven districts of Rwanda in 2013.

Variable	Eastern Province		Northern Province		Southern Province			Total	Percent	Variance	SD	SE	<i>t</i> test statistic	CI (95%)	Probability*
	Bugesera	Kayonza	Gakenke	Rulindo	Gisagara	Huye	Muhanga								
Gender															
Female	37	31	49	56	39	36	41	289	58.4	72.2	8.5	3.2	12.9	(33.43–49.15)	<0.001
Male	26	19	36	34	38	26	27	206	41.6	46	6.8	2.6	11.5	(23.16–35.70)	<0.001
Age (years)															
<25	13	6	7	12	10	0	0	47	9.5	28	5.3	2	3.4	(1.85–11.65)	0.015
26–40	27	11	25	27	19	21	34	164	33.1	52.6	7.3	2.7	8.5	(16.68–30.10)	<0.001
>40	23	33	53	51	48	41	34	284	57.4	119.7	10.9	4.1	9.8	(30.45–50.69)	<0.001
Education level															
Illiterate	3	22	32	12	10	21	34	133	26.8	131.8	11.5	4.3	4.4	(8.45–29.68)	0.005
Primary	56	2	50	78	67	28	26	333	67.3	434.7	20.9	7.9	6.1	(28.48–67.04)	<0.001
Postprimary	3	0	4	0	0	7	7	21	4.2	9.9	3.1	1.2	2.6	(0.13–5.94)	0.043
Secondary	0	0	0	0	0	7	0	7	1.4	6.8	2.6	1	1	(–1.42 to 3.39)	0.356
Family size															
<5	27	28	39	47	48	48	34	271	54.7	89.6	9.5	3.6	10.8	(29.90–47.40)	<0.001
6–10	36	22	46	43	29	14	34	224	45.2	130.1	11.4	4.3	7.4	(21.51–42.61)	<0.001
Belongs to association															
Yes	20	6	21	35	39	21	41	182	36.8	161.1	12.7	4.8	5.4	(14.25–37.72)	0.002
No	43	44	64	55	39	41	27	313	63.2	137.2	11.7	4.4	10.1	(33.90–55.56)	<0.001
Trained on agricultural practices															
Yes	10	0	78	20	10	7	17	141	28.5	690.7	26.3	9.9	2	(–4.171 to 44.44)	0.089
No	53	50	7	70	67	55	51	354	71.5	432.6	20.8	7.9	6.4	(31.34–69.81)	<0.001

*Probability values based on one-sample *t* test.

CI = confidence interval.

Table 2. Score (%) of main food crops in terms of food security following a pairwise comparison of farmers (N = 327) of three provinces and seven districts of Rwanda.

Crop	Province and district							Mean
	Eastern Province		Northern Province		Southern Province			
	Bugesera	Kayonza	Gakenke	Rulindo	Gisagara	Huye	Muhanga	
Bean	21.8	12.5	16.5	17.0	11.5	33.3	17.4	18.6
Cassava	16.4	11.7	15.6	18.4	12.7	26.7	16.1	16.7
Sweetpotato	11.7	9.2	15.2	17.0	12.2	20.0	12.7	14.1
Banana	13.7	10.8	17.4	15.3	13.8	0.0	13.2	12.0
Sorghum	10.9	8.3	3.3	13.3	8.3	13.3	8.8	9.5
Maize	10.9	5.8	2.1	5.5	11.4	6.7	10.1	7.5
Soybean	5.5	2.5	3.3	2.0	6.5	0.0	5.4	3.6
Cocoyam	0.0	5.8	10.3	3.1	1.5	0.0	3.1	3.4
Rice	0.0	10.0	0.0	0.0	8.7	0.0	4.1	3.3
Groundnuts	7.3	3.3	0.0	0.0	1.0	0.0	7.2	2.7
Dry peas	0.0	5.8	6.8	2.0	4.4	0.0	0.0	2.7
Irish potato	0.0	7.5	2.5	4.4	3.1	0.0	0.0	2.5
Yam	1.8	4.2	2.0	2.0	3.2	0.0	1.8	2.1
Vegetables	0.0	0.8	5.0	0.0	1.0	0.0	0.0	1.0
Sunflower	0.0	1.7	0.0	0.0	0.7	0.0	0.0	0.3
Fruits	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Constraints of sweetpotato production.

The main constraints of sweetpotato production and their relative importance as reported by farmers during group discussions are presented in Table 4. In Bugesera district, drought, a shortage of planting materials (vines), and diseases were the three top constraints reported by farmers. Shortage of improved cultivars, drought, and pests were the leading constraints of sweetpotato production in Kayonza district. In Gakenke district, drought, diseases, and pests were considered the main three sweetpotato production constraints. In Rulindo district, drought, diseases, and shortage of vines were regarded as the most important constraints of sweetpotato production. In Gisagara district, farmers reported that drought, pests, and shortage of improved cultivars were the main production constraints. In Huye district, pests, drought, and shortage of vines were identified as the most important constraints of sweetpotato production. In Muhanga district, farmers prioritized drought, pests, and shortage of vines as the three main constraints of sweetpotato production. Overall, in the surveyed districts, drought stress, shortage of improved cultivars and planting material, and pest and disease damages were the five main constraints of sweetpotato production reported by farmers. These constraints represented at 17.3%, 15.0%, 12.9%, 11.7%, and 11.5%, respectively.

Farmers' preferences for sweetpotato cultivars and storage root traits. Various characteristics of a good sweetpotato cultivar and a good storage root were identified by respondent farmers (Table 5). The most farmer-preferred traits of a sweetpotato cultivar were high yield, early maturity, drought resistance, disease and pest resistance, good culinary taste, big storage roots, broad adaptability, good appearance of the storage roots, and high vine yield (Table 5). These were reflected by the votes for high yield, early maturity, drought tolerance, disease and pest tolerance, and good culinary taste being 22.5%, 18.3%, 15.1%, 12.3%, and 10.1%, respectively.

Farmers reported various characteristics of good storage roots such as skin color (white, cream, yellow, orange, brown, pink, red, or purple), high dry matter content, low fiber content, good taste, big size, varied shapes (round elliptic, elliptic, ovate, ob-ovate, oblong, long oblong, long elliptic, or long irregular), and sweetness (Table 5). However, preferences varied between farmers. The main five characteristics of good storage roots identified by farmers were high dry matter content, good culinary taste, good shape, storage root size, and storage root flesh color with votes of 24.2%, 18.4%, 14.6%, 12.9%, and 9.5%, respectively. Farmers grow cultivars with various flesh colors (white, cream, orange,

yellow). The value of orange-fleshed sweetpotato is known by farmers but cultivars with white flesh color dominate other cultivars.

Sweetpotato farming practices. Farmers grew sweetpotato on ridges (48.1%), flat ground (37.5%), or mounds (14.4%). Approximately 40.5% of farmers grew sweetpotato in an intercropping system with another crop. Sweetpotato is mainly intercropped with cassava, bean, and maize. Farmers prepare cuttings for large-scale planting from their own fields or collect vines from fields of neighbors. Production inputs such as fertilizers and pesticides are not commonly used by most of interviewed farmers for sweetpotato cultivation in Rwanda.

Seasonal calendar of sweetpotato production and market. The price of sweetpotato varied among districts and over months (Table 6). The price of 1 kg of sweetpotato reported by farmers ranged from 40 to 160 Rwandese francs (Rwf) (\$1 U.S. = 680 Rwf) at Bugesera, 50 to 180 at Kayonza, 60 to 170 at Gakenke, 70 to 180 at Rulindo, 70 to 200 at Gisagara, 70 to 200 at Huye, and 70 to 200 at Muhanga. High market prices were reported in November, December, and January when there was a slack, whereas low prices were noted in the months of September, October, March, and April during a glut.

Farmers indicated that the availability of sweetpotato is usually limited during the months of November, December, January,

Table 3. Score (%) of main food crops in terms of income generation after a pairwise comparison of farmers (N = 327) of three provinces and seven districts of Rwanda.

Crop	Province and district							Mean
	Eastern Province		Northern Province		Southern Province			
	Bugesera	Kayonza	Gakenke	Rulindo	Gisagara	Huye	Muhanga	
Banana	11.4	9.3	30.3	24.3	18.3	33.3	17.4	20.6
Cassava	22.7	7.6	27.7	12.6	16.6	20.7	16.0	17.7
Bean	29.6	12.7	2.0	13.7	10.7	0.0	15.7	12.1
Sorghum	18.2	6.8	2.0	3.3	4.8	20.0	15.1	10.0
Sweetpotato	6.8	2.5	15.7	10.2	6.5	6.7	9.8	8.3
Maize	2.3	4.2	6.1	10.3	13.2	6.7	5.3	6.9
Rice	0.0	11.9	0.0	0.0	14.7	6.0	6.5	5.6
Fruits	0.0	10.2	7.3	3.2	2.2	0.0	0.0	3.3
Groundnuts	4.6	11.0	0.0	1.5	1.5	0.0	4.5	3.3
Vegetables	0.0	5.9	4.0	5.9	3.0	0.0	3.2	3.2
Dry peas	0.0	5.9	5.0	8.9	1.2	0.0	0.0	3.0
Irish potato	0.0	5.9	0.0	0.0	3.5	6.7	0.0	2.3
Soybean	2.3	3.4	0.0	4.1	2.0	0.0	1.1	1.8
Cocoyam	0.0	1.7	0.0	1.7	1.7	0.0	5.4	1.5
Yam	2.3	0.9	0.0	0.2	0.0	0.0	0.0	0.5
Sunflower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Constraints of sweetpotato production and their relative importance (%) of three provinces and seven districts of Rwanda.

Constraint	Province and district							Mean
	Eastern Province		Northern Province		Southern Province			
	Bugesera	Kayonza	Gakenke	Rulindo	Gisagara	Huye	Muhanga	
Shortage of improved cultivar	11.0	19.8	10.1	6.0	14.6	10.0	10.1	11.7
Shortage of fertilizer	6.6	4.8	3.2	10.1	5.1	2.2	6.2	5.5
Shortage of land	3.0	11.5	10.8	3.0	12.1	9.8	13.3	9.1
Drought	15.7	19.1	17.2	15.7	16.3	17.2	20.1	17.3
Diseases	13.9	11.5	15.0	14.9	12.5	12.0	10.8	12.9
Pests	12.4	16.3	15.1	12.4	15.6	18.1	15.3	15.0
Heavy rain	0.0	0.0	5.0	4.0	2.1	2.0	0.0	1.9
Climate change	4.5	0.0	6.0	5.5	4.5	9.1	3.0	4.7
Training	9.0	2.0	5.3	8.5	5.4	5.3	2.0	5.4
Shortage of planting material	14.8	8.1	9.2	14.8	7.4	11.2	15.3	11.5
Low market demand	9.2	7.0	3.1	5.2	4.4	3.1	4.0	5.1

and February. These periods correspond with the highest market prices for sweetpotato (Tables 6 and 7). Overproduction and a market glut of the crop occur from April to August (Table 7). Other food crops produced during the months of sweetpotato overproduction included bean, rice, sweetpotato, maize, Irish potato, cocoyam, pumpkin, banana, and sorghum.

Gender and sweetpotato production. Activities of sweetpotato production are carried out by male and female farmers. However, female farmers contributed more than males in the overall sweetpotato production in Rwanda (Table 8). Farmers reported that the management of income derived from the sale of production depends on the market size. In case of big markets, for example, during the sale of bulk quantity of sweetpotato such as to a school or factory, income

is managed by males in 100% of cases. However, in cases of small markets, for example, selling few baskets of sweetpotato in a local market, the sales are managed by females in 70% of cases.

Discussion

Use of sweetpotato for food security and income generation. Food insecurity is a major problem in many nations as a result of biotic and abiotic constraints. According to Tshuma (2012), food security is achieved at various levels such as individual, family, national, regional, and global levels. Food security encompasses physical and economic access to sufficient quality and quantity food for an active and healthy life. Sweetpotato has been reported to be an important crop in the food security and economy of poor households in

the marginal agro-ecological zones (Bashaasha et al., 1995; Githunguri et al., 2006). Bashaasha et al. (1995) observed that farmers' sweetpotato plots contain many cultivars, which have various attributes such as maturity periods. Variation in maturity periods contributes to the continuous supply of food over the year. In Rwanda, the contribution of sweetpotato to family food security and income generation varied from one district to another (Tables 2 and 3). However, in all the study areas, sweetpotato was ranked among the top five major food crops.

Constraints to sweetpotato production. In the assessment of priorities for sweetpotato research in developing countries, Fuglie (2007) found common production constraints in almost all the major sweetpotato-producing areas. Some constraints were specific to certain regions. Viral diseases, shortage of post-harvest

Table 5. Preferred characteristics of a good cultivar and storage root of sweetpotato and their relative score (%) by growers in Bugesera, Kayonza Gakenke, Rulindo Gisagara, Huye, and Muhanga districts of Rwanda.

Cultivar	Eastern Province		Northern Province		Southern Province			Score (%)
	Bugesera	Kayonza	Gakenke	Rulindo	Gisagara	Huye	Muhanga	
Cultivar preferences								
High yield	19.8	24.8	25.3	19.4	23.3	22.6	22.3	22.5
Earlier maturity	17.7	16.7	17.5	18.7	21.2	17.2	19.4	18.3
Drought resistance	16.0	15.1	16.8	13.0	13.6	15.5	15.6	15.1
Disease and pest tolerance	13.2	13.0	12.4	11.2	11.1	12.0	13.1	12.3
Good culinary taste	9.3	12.5	12.0	10.3	9.2	9.3	8.2	10.1
Big storage root	9.2	11.2	1.6	10.2	9.7	8.9	9.9	8.7
Broad adaptation	3.8	1.8	4.5	4.8	3.8	4.1	3.8	3.8
Good appearance of storage root	3.1	3.1	1.8	4.1	2.5	3.5	3.1	3.0
High vine yield	3.2	1.2	4.1	4.2	3.1	3.6	2.7	3.2
All other traits	4.7	0.6	4.1	4.1	2.6	3.4	2.0	3.1
Storage root preferences								Votes (%)
High dry matter content	24.3	22.8	29.3	23.4	21.3	28.6	19.8	24.2
Good culinary taste	17.4	18.7	17.5	22.7	20.2	14.3	17.7	18.4
Good shape	16.6	15.1	14.7	13.0	13.6	13.5	16.0	14.6
Storage root size	12.1	13.0	12.4	11.2	16.1	11.9	13.2	12.9
Storage root fresh color	9.9	11.2	2.6	12.2	11.7	9.9	9.2	9.5
Sweetness	8.2	12.5	9.2	3.0	7.2	8.2	9.3	8.2
No sweet	3.8	1.8	4.4	2.0	3.8	2.1	3.8	3.1
Less fibers	3.1	3.1	4.6	4.8	3.5	4.5	3.1	3.8
Skin color	3.7	0.2	3.3	6.2	2.1	3.4	3.2	3.2
Others	1.0	1.6	2.0	1.5	0.6	3.6	4.7	2.1

Table 6. Market price variation of sweetpotato (Rwf/kg) in Bugesera, Kayonza Gakenke, Rulindo Gisagara, Huye, and Muhanga districts of Rwanda in 2013.

District	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
Bugesera	160	130	80	80	110	125	125	120	40	110	160	160
Kayonza	180	130	90	90	110	130	130	120	50	110	180	180
Gakenke	170	140	100	100	100	100	100	90	60	120	170	170
Rulindo	170	150	130	120	120	120	120	100	70	140	180	180
Gisagara	200	160	120	120	120	120	120	100	70	140	170	170
Huye	200	170	100	100	120	140	140	130	70	120	200	200
Muhanga	180	140	120	110	110	110	110	100	70	150	200	200
Average	180	145.7	105.7	102.9	112.9	120.7	120.7	108.6	90	127.1	180	180

Table 7. Availability and seasonal calendar of sweetpotato production in Rwanda.

Period	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
Limited supply	x	x									x	X
Overproduction				x	x	x	x	x				
Planting	x	x	x	x		x	x				x	X
Harvesting			x	x	x	x	x	x	x	x		

X = month of the period.

Table 8. Sweetpotato production activities and role of gender of three provinces and seven districts of Rwanda.

Activity	Eastern Province		Northern Province		Southern Province	
	Male	Female	Male	Female	Male	Female
Land preparation	42.4	57.7	45.9	54.2	53.7	46.3
Fertilization	44.0	56.1	45.6	54.4	34.2	65.8
Preparation of planting material	5.1	95.0	27.3	72.8	23.0	77.0
Planting	0.0	100.0	10.3	89.7	15.1	84.9
Weeding	22.9	77.1	27.0	73.1	25.0	75.0
Harvesting	19.8	80.2	13.4	86.6	17.8	82.2
Sorting	5.5	94.6	10.9	89.2	9.8	90.2
Cleaning	7.5	92.5	4.1	95.9	5.6	94.4
Selling	16.9	83.2	17.9	82.1	16.8	83.2
Percentage (%)	18.2	81.8	22.5	77.6	22.3	77.7

processing technologies, lack of clean planting materials, and improved cultivars with high and stable yield potential were the main constraints of sweetpotato production in almost all the major sweetpotato-producing regions. Sweetpotato weevils and butterflies were the main pests of sweetpotato, whereas drought stress was the most important abiotic stress in Uganda (Bashaasha et al., 1995; Muyinza et al., 2007). Kapinga and Carey (2003) reported that viral and *Alternaria* diseases, drought, shortage of planting materials, and low soil fertility were the main production constraints of sweetpotato in Rwanda. Unlike previous findings, the present study found types and intensity of sweetpotato production constraints differed across districts (Table 4). Drought stress, shortage of improved cultivars and planting material, and pest and disease damage were the five main constraints of sweetpotato production reported by farmers in Rwanda.

Attributes of good sweetpotato cultivars and storage roots. The selection of cultivars to be grown by farmers is tightly linked to farmers' preferences and cultivar characteristics. Different storage root characteristics such as storage root formation, root shape, surface defects, latex production, skin and fresh color, dry matter content, sugar content and culinary taste are positive attributes for farmers' choices of cultivars in Uganda (Gibson et al., 2008). High dry matter content, good shape, and culinary taste were the main characteristics of good storage roots in the present study. It was also observed that a good cultivar must have high yields, early maturity, and drought tolerance (Table 5). In another study, Laurie and Magoro (2008) in South Africa found that the most important traits used by farmers to select good sweetpotato cultivars were a sweet taste, dry texture, and good yield. Githunguri et al. (2006) observed that yield is the most important selection criterion of a good cultivar of sweetpotato in Kenya. Low fiber and high dry matter content and taste were the main characteristics influencing the choice of good storage root by Kenyan women farmers (Githunguri et al., 2006). In a participatory cultivar selection, characteristics such as high yield, early maturity, and large storage root were the main attributes of a good cultivar (Gibson et al., 2008). High dry matter content

is the main characteristic for sweetpotato processors and consumers, whereas skin color and root shape are also important traits of preference for sweetpotato cultivars (Rees et al., 2003). These findings reveal that farmers' and end users' preferences are diverse. Therefore, there is a need for clear communication between breeders and stakeholders for the successful improvement of the crop with high levels of farmer adoption of new cultivars.

A high level of vitamin A deficiency (VAD) prevails in Rwanda, especially among women. In the country, 7% of mothers showed some form of night blindness during their last pregnancy. A 5% VAD in a population is reported to be severe (Shaikh and Mahy, 2003). To tackle VAD, the government of Rwanda adopted a schedule of vitamin A supplements in the form of capsules to all children aged from 6 to 59 months. Also, a single dose of vitamin A supplement is being given to mothers 2 months after delivery. However, this practice is expensive and depends on positive perception by the population toward vitamin A supplementation. Contrastingly, Van Jaarsveld et al. (2005) found that daily consumption of 125 g of orange-fleshed sweetpotato improved the vitamin A needs of children in South Africa. This suggests that sweetpotato could play a significant role in circumventing VAD in developing countries as a cheap, alternative, and long-term food-based strategy. By virtue of its wide-area production and daily consumption by a large group of the population, promotion of the orange-fleshed sweetpotato cultivars could have a substantial effect to combat VAD in Rwanda. Therefore, sweetpotato breeding programs in the country should consider β -carotene content as one of the important traits to develop high-yielding and vitamin A-enriched cultivars.

Agronomic management of sweetpotato. In Uganda, sweetpotato is cultivated on small plots, mainly in upland areas, during the rainy season and wetland during the dry season for vine maintenance (Bashaasha et al., 1995). However, in Rwanda, the wetlands are dedicated to cereal crop production, mainly rice and maize, with none of these lands used for sweetpotato production.

Sweetpotato is grown on ridges, mounds, or flat ground in Rwanda. The size of ridges and mounds varies and the number of vines per mound and ridge depends on vine sizes.

Bashaasha et al. (1995) reported that in highland areas, ridges are used to control soil erosion. In Rwanda, however, the effects of ridging, mounds, or flat ground on yield of sweetpotato are not well documented. Therefore, a detailed study is needed to develop recommendations for the proper method of planting and land preparation for all soil conditions and geographical aspects and gradients of lands.

This study showed that a high proportion (59.5%) of sweetpotato is grown under monoculture, but that it is sometimes intercropped with other crops, mainly cassava, beans, and maize. The same observation was reported by Bashaasha et al. (1995). Intercropping is the practice of growing two or more crops together in one field (Khan et al., 2012). The main objective of intercropping is to maximize the land use, to control pests and diseases, to improve ecological protection, and to maximize crop output from available land (Malézieux et al., 2009). Intercropping systems may have negative or positive effects on crop yield. Interspecific competition for light and nutrients has been reported in various intercropping systems (Baumann et al., 2002; Hauggaard-Nielsen et al., 2001). The comparison of monoculture and intercropping of cereals and legumes revealed that intercropping is more profitable than monoculture (Zhang et al., 2007). A field experiment to assess the productivity of three sweetpotato cultivars intercropped with three okra cultivars revealed that the intercropping generally increased the height of okra plants height and the number of pods per okra plant. It was also observed that both pod and storage root yields were unaffected by intercropping (Njoku et al., 2007). Ndamage (1984) reported that the most beneficial effects were achieved with intercropping systems of sweetpotato and soybean; sweetpotato and bean; sweetpotato, bean, and maize; and sweetpotato, soybean, and maize. In intercropping system, sweetpotato cultivars with few branches were preferred, whereas in a monoculture system, cultivars with spreading vines were preferable because of their ability to suppress the growth of weeds (Wilson et al., 1989). These attributes of sweetpotato in intercropping systems are profitable and sustainable for food security of small-scale farmers.

Farmers use planting materials from their own fields or neighbors. This system may favor pest and disease epidemics. For example, the exchange of planting materials among farmers was reported to be the main cause of persistence and severity of sweetpotato viral diseases in east and central Africa (Aritua et al., 2007). In sweetpotato production, farmers rarely used purchased inputs and this had a negative effect on yields. Therefore, the combination of breeding and improvement of seed production systems and agricultural practices of sweetpotato are needed to enhance productivity.

Seasonal calendar of sweetpotato production. The price of sweetpotato varies through districts and months. In all surveyed districts, the high price was reported in November, December, and January, whereas low prices were reported in

September, October, March, and April (Table 5). Patterns of food prices are indicators of food availability (Godfray et al., 2010). In Rwanda, sweetpotato is planted and harvested throughout the year and the peak harvesting month is September. This peak period corresponds with the low price of sweetpotato on the market. During this period, many sweetpotato fields are cleared to plant other crops. Therefore, large quantities of sweetpotato are marketed at the same time, leading to low demand and poor prices.

Unavailability of sweetpotato was reported in November, December, and January (Table 6). This period is marked by food insecurity in many rural families. The main cause of this food shortage is that farmers do not grow crops during the dry spell of May to August. Therefore, during November to January, limited crop harvests are available. Moreover, stocks of food crops harvested during September to January, and January to June, have been depleted or finished by then. The period of overproduction of sweetpotato was reported from April to August (Table 6). This period corresponds to a high level of food availability from several major crops for many rural families.

Gender and sweetpotato production. The present study showed that female farmers made greater contributions to sweetpotato production than male farmers (Table 8). This agreed with findings of Horenstein and Mundial (1989) who reported that sweetpotato is grown by rural households for food and cash, and women play a major role in its cultivation. Women have an important role to ensure household food security. Agriculture is the main activity of smallholders and women farmers who constitute the largest proportion of the smallholder farming system. According to FAO (2000), 96% of rural women work in field and provide three-fourths of farm labor. As a rule of thumb in rural areas, women tend to focus on food crops and men on cash crops. This ties in with the finding that crop production by women contributed more to household food security than the income from cash crops usually managed by men (Quisumbing et al., 1995). Therefore, to improve food security and to satisfy the food needs of the current growing population, it is necessary to acknowledge the importance of women in food crop production systems and the need to involve women in development of new crop cultivars and agricultural technologies (Carney, 1999).

Women participate in the market of agricultural products as suppliers and buyers. They sell different food and cash crops from their farms. However, their responsibility of managing income from agricultural products is limited (Horenstein and Mundial, 1989). This study concurred with previous findings, showing that when there is a good market for sweetpotato, income from sales are managed by men, a social dynamic that may demotivate women from sweetpotato production for the cash economy.

Conclusion

Sweetpotato is among the main food crops of many rural poor households. In

Rwanda its contribution in family food security and income generation varies from one district to another. To ensure food security for Rwanda's growing population, strategic sweetpotato production is imperative, gearing toward food security and income generation. Farmers identified the major production constraints of sweetpotato to include drought stress, shortage of improved cultivars, diseases and pests, and a shortage of planting materials. Quality traits such as high dry matter content of storage roots and early maturity were important attributes for storage root and sweetpotato cultivars, respectively. Therefore, to sustain sweetpotato production, there is a need to breed and release drought-tolerant cultivars with high dry matter and β -carotene content. Furthermore, sweetpotato breeding programs need to consider all of the documented farmers' preferred traits such as disease and pest resistance, high yield, and early maturity.

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