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Abstract- There is continued demand for new varieties to satisfy the needs of farmers in Uganda for different production regions or agro ecological zones. Despite release of several improved high yielding varieties by National Agriculture Research Organization, farmers in South Western Agro-Ecological Zone have continued to rely on landraces whose production adversely is affected by both biotic and abiotic stresses. Besides, most landraces grown are white fleshed with traces of Beta-carotene. Mbarara Zonal Agriculture Research and Development Institute identified eleven sweet potato varieties, some of which orange-fleshed rich in beta carotene, to evaluate the in the zone and subsequent promotion. All the improved varieties evaluated were high yielding (11-20 t/ha) and their palatability and sensory tastes were not different from the farmer preferred local check Nderera. Promotion of these vitamin rich sweet potato varieties in the zone would increase sweet potato production, household income and improve nutrition in the zone.

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I. Introduction

Worldwide, Sweet potato (*Ipomoea batatas*), ranks third most important tuber crop after potato (*Solanum tuberosum L.*) and cassava (*Manihot esculenta Crantz*) (FAO, 1998). In Africa, the crop is largely grown in East Africa where it is a staple for rural communities. It forms a major part of the diet for the people of Uganda, Rwanda, Burundi and eastern Congo (Kapinga *et al.,* 2003; Rees *et al.,* 2003), and is also grown as a major income generator for the smallholder peasant farmers in these countries (Andrade *et al.*, 2009). By 2009, Uganda was reported to be the third largest producer of sweet potato with annual production of 2.7 million metric tonnes, representing almost 3% of the total world production (FAOSTAT, 2009). In Uganda, sweet potato is the third most important source of carbohydrates after banana and cassava (Yanggen and Nagujja, 2006) and is grown mainly by small scale subsistence farmers on plots that rarely exceed 0.5 ha (Kapinga *et al.,* 2003). The crop is cultivated in almost all districts of Uganda and ranking as second most important root crop after cassava.

Sweet potato provides household food security because it stores well in the soil as a famine reserve crop. The crop can be harvested in 3-6 months but can remain in the ground for "piece meal" harvesting, a common sweet potato "storage" practice in the tropics. The low level of agricultural input requirement, high productivity per unit area, good nutritional value, and increasing demand for food make sweet potato an ideal starch staple for food security in subsistence economies of Uganda (Mukasa *et al.,* 2003). Sweet potato is used for human consumption, livestock feed, and in industrial processes to make alcohol and starch, and other products such as noodles, candy, desserts, and flour.

Although the majority of sweet potato varieties are high in carbohydrates, orange-fleshed varieties also provide vitamins A and C. In addition, the green leaves of the crop can be consumed by both humans and animals providing additional protein, vitamins and minerals. In Uganda, the annual per capita sweet potato consumption is 82.5 kg ranking among countries with the highest per capita consumption in Africa (Yanggen and Nagujja, 2006). Due to the vital role of Sweet potato in the nutrition, food security and economy of the people of Uganda (Bashaasha et al., 1995), the National Agricultural Research Organization (NARO), has given high priority to research on the crop. The National Sweet potato Program of NARO has released nineteen sweet potato cultivars between 1995 and 2010 (Table 1). These developed and released varieties are superior to landraces in terms of yielding potential as well as Vitamin A content.

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Table 1 : Sweet potato varieties released in Uganda between 1995-2010

S. No	Variety	Year of Release	References
1.	Ejumula	2004	Mwanga et al. (2007)
2.	Bwanjule	1995	Mwanga et al. (2001)
3.	Dimbuka-Bukulula	2007	Mwanga et al. (2009)
4.	NASPOT 1	1999	Mwanga et al. (2003)
5.	NASPOT 2	1999	Mwanga et al. (2003)
6.	NASPOT 3	1999	Mwanga et al. (2003)
7.	NASPOT 4	1999	Mwanga et al. (2003)
8.	NASPOT 5	1999	Mwanga et al. (2003)
9.	NASPOT 6	1999	Mwanga et al. (2003)
10.	NASPOT 7	2007	Mwanga et al. (2009)
11.	NASPOT 8	2007	Mwanga et al. (2009)
12.	NASPOT 9	2007	Mwanga et al. (2009)
13.	NASPOT 10	2007	Mwanga et al. (2009)
14.	NASPOT 11	2010	Mwanga et al. (2011)
15.	New Kawogo	1995	Mwanga et al. (2001)
16.	Sowola	1995	Mwanga et al. (2001)
17.	SPK004 (Kakamega)	2004	Mwanga et al. (2007)
18.	Tanzania	1995	Mwanga et al. (2001)
19.	Wagabolige,	1995	Mwanga et al. (2001)

There is however, continued demand for superior varieties with farmer preferred sensory attributes and specific adaptation to production regions. Despite the several biofortified sweet potato varieties released by the National sweet potato breeding program, farmers in SWAEZ have continued to rely on landraces due to limited exposure of these materials to farmers for selection. Sweet potato productivity has remained low in this region. This necessitated us to carry out participatory sweet potato varieties selection so as to increase adoption of bio-fortified sweet potato varieties in the zone. The objective of this study was to evaluate agronomic performance of selected biofortified sweet potato varieties as well as their sensory acceptability to local communities in south western Agro-ecological zone.

II. Materials and Methods

a) Site

The experiment was conducted at Mbarara at Mbarara Zonal Agricultural Research and Development Institute (MBAZARDI) of National Agricultural Research Oragnization (NARO) in the South Western Agro-Ecological Zones of Uganda. The experimental site is located at 0o36' S and 30o42' E and 1443 meters above sea level. A panel of stakeholders involved in sweet potato value chain was constituted for sensory evaluation of varieties included in the study.

b) Materials and experimental design

Eleven biofortified sweet potato varieties (NASPOT1, NASPOT 5, NASPOT 8, Jewel, NASPOT 7, Ejumula, Tanzania, NASPOT 9, SPK004 (Kakamega), Naspot 10 and NKA108L) were evaluated in the study. The biofortified sweet potato varieties were obtained from the sweet potato programme at National Crop Resources Research Institute (NACRRI) at Namulonge in Uganda. For comparison purposes, one local sweet potato variety (Nderera) was included in the study, making a total of twelve sweet potato varieties. The experiment was laid in Randomised compete block design (RCBD) at a plant spacing of 1m x 1m in 4m x 4m plots in three replications. Each plot in each replication consisted of 16 mounds and three vines were planted per mound. Weeding was regulary done with a hand hoe. the experiment was repeated for three growing seasons.

c) Data collection and analysis

The agronomic performance data were collected on; Plant growthVigour on scale of 1-5 (1=Vigour very poor; 2= vigour poor; 3=Vigour neither poor nor good; 4; Vigour good; 5= Vigour very good), Total root tuber Yield (t/ha), Marketable root tuber yield (t/ha) and incidence of Sweet potato virus disease (SPVD) (percentage incidence). For acceptability and sensory evaluations for the varieties, farmers and other stakeholders including researchers, traders and consumers (participatory evaluation) were involved to determine if the varitieties were acceptable to farmers and other end users using criteria comprising of key attributes that end users consider very important in adaption and adoption sweet potato varieties. Palatability and sensory evaluation (for taste, texture and flavour) of the varieties was done at harvest. Sensory evaluation was done basing on 1-5 hedonic scale (1=dislike; 2=neithe like nor dislike; 3=Like moderately; 4=Like very much; 5=Llike extremely). All data were entered into MS excel and analysed using the GENSTAT. Sensory evaluation data were analyzed using logistic regression.

III. Results

The growth vigour performance of the varieties showed significant variation among varieties and seasons. Plant vigour was generally low ranging between 0.8 in NASPOT 5 and NASPOT 10 for season 2010A and 4.1 in NASPOT 1 for season 2010B. Across the three seasons grown, NASPOT 5 had the least (1.4) mean vigour while the local check Nderera had the highest (3.1) mean vigour. Among the biofortified varieties, Jewel showed the highest vigour (2.5) followed by NASPOT 1 (2.4), across the three growing seasons (Table 2).

Table 2 : Evaluation of plant growth vigour of 12 sweet potato varieties (scale of 1-5)

Variety	2010A	2010B	2011A	Average
NASPOT5	0.8	1.9	1.5	1.4
NASPOT8	0.9	2.9	1.9	1.9
Jewel	1.1	3.9	2.5	2.5
NASPOT9	0.8	3.6	1.6	2.0
Tanzania	1.1	2.8	1.8	1.9
NASPOT1	1.2	4.1	1.9	2.4
Kakamega	0.9	2.4	1.5	1.6
Ejumula	1.1	2.9	1.6	1.9
NASPOT10	0.8	3.3	1.3	1.8
NKA 108L	0.9	3.4	2.4	2.3
NASPOT7	1.1	2.9	1.8	1.9
Nderera	-	3.7	2.4	3.1
Mean	*1.0*	*3.0*	*1.8*	*2.0*
LSD (P≤0.05)	*0.3*	*1.2*	*0.8*	*0.2*

Viral disease incidence varied among the seasons and varieties. Season 2011A had the highest virus incidence with mean viral disease incidence of 5.1% while season 2010A had least disease incidence (1.9%). Among the varieties and across the three growing seasons, Tanzania had the highest mean viral incidence (8.3%) while Nderera (local variety) and NKA 108L had least (1.5%) mean viral incidence (Table 3). Generally, viral incidence was very low among the varieties across the three growing seasons.

Table 3 : Assessment of viral disease incidence (percent incidence) on 12 sweet potato varieties evaluated in SWAEZ in 2010 2011

Variety	2010A	2010B	2011A	Average
NASPOT 8	2.8	5.1	4.6	4.2
Jewel	1.0	3.2	3.9	2.7
NASPOT 9	0.0	4.2	5.6	3.3
Tanzania	6.9	7.9	10.0	8.3
NASPOT 1	0.0	5.0	4.4	3.1
Kakamega	3.5	6.0	3.9	4.5
Ejumula	5.3	6.9	4.4	5.5
NASPOT 10	0.0	3.2	7.8	3.7
NASPOT 5	1.4	5.6	8.9	5.3
NKA 108L	0.0	2.3	2.2	1.5
NASPOT 7	0.0	6.5	4.4	3.6
Nderera	-	2.3	0.6	1.5
Average	*1.9*	*4.9*	*5.1*	*3.9*
LSD (P≤0.05)	*7.4*	*10.5*	*6.3*	*8.1*

The highest mean total root tuber yield across all the varieties was recorded in Season 2010B (21.7 t/ha) and was least in season 2010A (13.6 t/ha). Across the three growing seasons, the results showed that the highest tuber yield (22.6 t/ha) was recorded by variety Ejumula and was least (11.5 t/ha) in NASPOT 5 (Table 4).

Table 4 : Total root tuber yield (t/ha) of 12 sweet potato varieties at MBAZARDI during 2010 and 2011

Variety	2010A	2010B	2011A	Average
NASPOT 5	13.9	8.6	13.9	12.1
NASPOT 8	12.9	24.4	18.3	18.5
Jewel	3.8	23.3	14.2	13.8
NASPOT 9	14.6	22.2	18.3	18.4
Tanzania	7.7	16.1	10.4	11.4
NASPOT 1	15.6	30.6	9.4	18.5
Kakamega	8.3	14.7	11.6	11.5
Ejumula	25.2	24.7	17.8	22.6
NASPOT 10	16.3	24.7	13.9	18.3
NKA 108L	16.7	15.8	10.9	14.5
NASPOT 7	15	25.6	20.4	20.3
Nderera	-	29.4	13.1	21.3
Average	*13.6*	*21.7*	*14.4*	*16.8*
LSD (P≤0.05)	*6.8*	*9.1*	*8.6*	*8.5*
CV %	*16.5*	*28.4*	*37.1*	*27.3*

Although Ejumula recorded the highest total tuber yield (22.6 t/ha) across the seasons, its marketable tuber yield was low (10.1 t/ha) (Table 5). The highest marketable tuber yield was recorded in Nderera (14.8 t/ha) followed by NASPOT 7 (13.1 t/ha) and NASPOT 8 (12.9 t/ha). The least marketable yield was still recorded in Tanzania with 4.6 t/ha (Table 5).

Table 5 : Marketable root tuber yield (t/ha) of 12 sweet potato varieties at MBAZARDI during 2010 and 2011

Variety	2010A	2010B	2011A	Average
NASPOT 5	8.3	5.6	1.7	5.2
NASPOT 8	6.3	19.2	13.3	12.9
Jewel	1.8	19.7	10.3	10.6
NASPOT 9	8.1	11.1	10.3	9.8
Tanzania	2.5	7.8	3.6	4.6
NASPOT 1	7.5	22.2	5.3	11.7
Kakamega	4.4	8.6	8.2	7.1
Ejumula	13.1	10.3	6.9	10.1
NASPOT 10	9	11.4	8.3	9.6
NKA 108L	12.7	12.5	8.3	11.2
NASPOT 7	4.6	18.9	15.9	13.1
Nderera	-	21.4	8.1	14.8
Average	*7.1*	*14.1*	*8.4*	*10.1*
LSD (P≤0.05)	*3.9*	*11.8*	*7.4*	*7.7*

Generally, all 12 varieties evaluated scored highly in most palatability and sensory attributes. The control variety Nderera had the highest preferences among the farmers with average score of 4.1 followed by Tanzania (3.6). Other than NKA 108L which had a

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score of less than 3 (Table 6), the rest had preferred traits including size, shape and texture.

Table 6 : Sensory comparison of 12 sweet potato varieties using matrix scores (1-5) in Masha and Birere sub-counties in Insigiro district during 2011B season

Variety	*Flesh colour*	*Matrix score before pealing*			*Matrix score after pealing*				*Matrix score after cooking*				
		CO	*SI*	*SH*	*CO*	*TA*	*FL*	*TX*	*CO*	*TA*	*FL*	*TX*	*Average*
NASPOT 8	*Orange*	*3.6*	*3.8*	*3.7*	*2.9*	*3.3*	*2.7*	*3.7*	*3.1*	*3.3*	*3.1*	*3.2*	*3.2*
Jewel	*Cream*	*3.4*	*3.4*	*3.6*	*3.5*	*3.6*	*4.3*	*3.7*	*3.1*	*3.2*	*3.1*	*3.2*	*3.2*
NASPOT 9	*Orange*	*3.2*	*3.3*	*3.0*	*3.3*	*2.7*	*4.0*	*2.3*	*3.9*	*3.1*	*2.8*	*3.2*	*3.3*
Kakamega	*Orange*	*3.4*	*3.0*	*3.2*	*3.3*	*3.1*	*2.7*	*1.3*	*3.2*	*3.3*	*2.6*	*2.8*	*3.0*
NASPOT 10	*Orange*	*3.4*	*3.8*	*3.5*	*3.2*	*2.7*	*3.0*	*3.7*	*3.6*	*3.2*	*3.4*	*3.4*	*3.4*
NASPOT 5	*Orange*	*3.5*	*3.2*	*3.4*	*3.6*	*3.7*	*3.7*	*2.7*	*3.0*	*2.8*	*2.6*	*3.5*	*3.0*
NKA 108L	*Orange*	*5.0*	*4.2*	*4.1*	*3.3*	*3.0*	*4.3*	*2.7*	*3.4*	*1.9*	*2.2*	*3.5*	*2.8*
Ejumula	*Orange*	*3.0*	*3.5*	*3.6*	*3.2*	*3.0*	*3.3*	*3.0*	*3.3*	*3.3*	*3.0*	*2.7*	*3.1*
Tanzania	*White*	*3.7*	*3.2*	*3.1*	*3.4*	*3.7*	*3.3*	*4.3*	*3.6*	*3.9*	*3.4*	*3.4*	*3.6*
NASPOT 1	*Orange*	*3.3*	*2.9*	*3.2*	*3.1*	*3.3*	*3.3*	*3.3*	*3.3*	*3.4*	*3.4*	*2.6*	*3.2*
NASPOT 7	*Orange*	*3.7*	*4.0*	*3.6*	*3.5*	*3.2*	*4.0*	*2.7*	*3.6*	*3.5*	*3.4*	*3.5*	*3.5*
Nderera	*White*	*4.2*	*3.9*	*4.2*	*4.0*	*3.7*	*2.7*	*3.5*	*4.1*	*4.3*	*3.9*	*3.9*	*4.1*
LSD (P≤0.05)	-	*0.6*	*0.5*	*0.5*	*0.6*	*NS*	*NS*	*NS*	*0.8*	*0.9*	*1.0*	*0.9*	-
CV (%)	-	*30.4*	*26.5*	*28.8*	*35.1*	*37.4*	*37.3*	*41.4*	*32.4*	*36.0*	*39.7*	*37.0*	-

CO=colour, SH=shape, SI=size, TA=taste, FL=flavour, TX=texture

IV. Discussion

Generally, all the varieties had low growth vigour during the three growing seasons. During the three growing seasons, there was prolonged drought spell. This could have resulted in the general low vigour among the varieties. The low vigour can also be attributed to genetic makeup of the biofortified varieties since the local variety had higher vigour than all of them. On the other hand, all varieties expressed high viral disease tolerance. Though the viruses have not been reported as major production constraint in the South Western agro-ecological zone, its management is paramount for expression of varieties' yield potential. However, all varieties were severely infested with weevils (data not shown) reducing the marketable yield. Weevils have been reported as the major constraint to sweet potato production with no resistant varieties available all over the world to date (Mwanga et al., 2009).

The biofortified sweet potato varieties evaluated recorded high yields and were preferred by farmers and other stakeholders. Their inclusion in the current germplasm grown in the region enriches the region's diversity of sweet potatoes from which selection can take place. Although Nderera, the local variety reported to have high dry matter preferred by farmers its acceptability level was not significantly different from that of biofortified orange fleshed varieties. Farmers should therefore be encouraged to grow orange flesh sweet potato and its consumption promoted since it is enriched with Pro-Vitamin A (beta carotene). It has been reported that some orange fleshed sweet potatoes have high beta-carotene content of up to 27,698 μg of retinol equivalents (RE) per 100 g fresh weight (Mwanga et al., 2007). South Western Agro-ecological zone is dominated by banana growing which is mainly carbohydrates and therefore increased consumption of orange fleshed sweet potato varieties rich in pro-Vitamin A and C would supplement the diet and reduce Vitamin A deficiencies common in the zone. Vitamin A deficiency (VAD) continues to be a public health concern in developing countries among children and women of childbearing age and is estimated to account for >600,000 deaths each year globally among children <5 y of age (Black, 2008; WHO, 2009).

The yield of the biofortified varieties was generally lower compared to earlier reports during their release (Mwanga *et al.,* 2001; 2003; 2007; 2009). This is attributed to differences in the agro-ecological conditions since these were different from the site where they were evaluated during their release. Moreover, they were affected by weevils, viral diseases and prolonged drought. Mwanga *et al* (2009) reported that sweet potato varieties NASPOT 7, NASPOT 8, NASPOT 9 and NASPOT 10 had significantly different yields at different sites and different years using five sites in Uganda. This is an indication that the yield stability of these varieties is low. In the definition of Shukla (1972), a stable variety is a variety in which yield varies relatively little around the average yield for that variety, after correction for the average differences that will always exist between environments. All the varieties were sensitive to seasonal conditions. This observation is in agreement with previous studies (Carpena *et al.* 1982, Janssens 1984, Bacusmo *et al.* 1988). Seasonal yield variations were highest in NASPOT 5. Manrique and Hermann (2002) reported that none of cultivars used in their study had satisfactory stability for total root yield and suggested the need for further study to elucidate the nature of sweet potato root-yield performance in response to varying agro-ecological conditions. Nevertheless, the varieties evaluated in this study had higher yields compared to the national average of 4 t/ha (International potato centre, 1999) and comparable yields to previously reported (Mwanga *et al.,* 2001; 2003; 2007; 2009). Although, the local variety yielded better than most biofortified varieties, it had one of the highest yield losses due to weevils implying that biofortified varieties were still more beneficial to farmers.

Contrary to the previous belief that orange-flesh sweet potatoes are not preferred by farmers due to; their very softness, low dry matter (Mwanga *et al.,* 2001), flat taste or no taste, very small size and bad flavour, there was no evidence to this during the study. Both white and cream skin flesh coloured varieties such as Nderera, Jewel and Tanzania and orange flesh varieties such as NASPOT 10, NASPOT 7 and NASPOT 1 were preferred. The only less preferred variety was NKA 108L, the rest were not significantly different in their preference attributes from the local variety. Since orange-flesh sweet potato varieties are rich in B-carotene, the precursor for Vitamin A, they can be promoted to areas were Vitamin A deficiency symptoms are prevalent. Previous studies have shown that *Beta-carotene* rich orange potatoes increased vitamin A intake among children and women of Uganda, and was associated with improved vitamin A status among children (Hotz *et al.,* 2012).

V. Conclusion and Recommendations

Given the fact most local white flesh sweet potato varieties are vitamin A defficient, the biofortified vitamin A rich sweet potato varieties are more beneficial to rural consumers whose intake of vitamin A is limited. NASPOT 1, NASPOT 7, NASPOT 8, NASPOT 9 and NASPOT 10 were all well accepted by farmers and are also high yielding. They also showed high level of virus disease tolerance. They are therefore, recommended for promotion in the South Western Agro-Ecological Zones (SWAEZ) to reduce vitamin A deficiency. A research study to determine IPM technologies for controlling weevils should be developed improve the production of these biofortified varieties

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