COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

SAVANNA AGRICULTURAL RESEARCH INSTITUTE

SWEETPOTATO IMPROVEMENT PROGRAMME

Proposal for the Release of:

A high dry matter orange-fleshed, an anthocyanin-rich purple-fleshed and a consumer-preferred white-fleshed sweetpotato genotypes

Presented to

THE NATIONAL VARIETY RELEASE AND REGISTRATION COMMITTEE

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EXECUTIVE SUMMARY

In spite of sweetpotato's potential in fighting malnutrition and food insecurity as well as its therapeutic effects on the aforementioned conditions, there is the need to develop sweetpotato varieties with high Pro Vit-A precursor and high anthocyanin content for northern Ghana. Although to some OFSP varieties are being cultivated by farmers, they are low in dry matter content and high susceptibility to weevil infestation. The objective was to evaluate the agronomic performance, and propose for release, sweetpotato genotypes adapted to the Guinea and Sudan Savannah agroecological zones of Ghana. Eight (8) sweetpotato gemplasm materials (Nanugungungu, Kuffuor, TU-1-12, TU-Orange, Obari, Voggu-O and TU-Purple) collected from the northern Ghana, of which three (3) genotypes were introduced from the Tuskegee University in the United States were evaluated, at multilocations and at on-farm, along with farmers' preferred varieties as checks. We used the mother-baby design through participatory approach. These sweetpotato germplasm materials were evaluated and compared to a local cultivar and an improved variety (Apomuden) as checks. The genotypes were tested over two years (2014-2015), in both on-station and on-farm trials. On-station trials were conducted at Nyankpala, Manga-Bawku, Navrongo, Damongo and Babile, while the on-farm baby trials were tested at Demabi, Sumbrungu, Navrongo, Garu, Bawku, Jirapa and Yagtouri for the 2014 season. For the 2015 season, on-farm testing were carried out at Tali, Golinga, Nyohindanyili, Zugu-yipala, Balungu, Nwan, Zinborg, Tindonmolgo, Bus-natinga, Naawie and Buli. After the on-farm evaluation for two seasons (2014-2015) three ogenotypes have been proposed for release based on the their tuberous root yield performance, beta carotene and anthocyanin content, high dry matter content, adaptability to northern Ghana as well as consumer preference.

Variety names

The proposed names of the genotypes

Genotype	***Propoed name***	***Meaning***	***Language***
Nanungungungu	"SARI-Nan"	Named after H.E. Nane Annan	English
TU-Purple	"SARI-Diedi"	Collect and eat	Dagbanli
Obari	"SARI-Nyumingre"	Proper yam	Nankana

Ecological adaptation

The above genotypes proposed for release were evaluated in the Northern, Upper East and West Regions. The three regions fall within the Guinea and Sudan Savannah Ecologies of northern Ghana. The results showed the three genotypes performed well and have the potential to increase yield with improved management practice.

Characteristics of the proposed varieties

Nanugungungu

Predominantly green vine colour with yellow-green young leaves and green leaf vein (abaxial view). It has a high (75-90%) ground cover after 40-60 DAP. The petiole colour is also green.
The tuberous root is long oblong in shape with brownish orange skin colour and intermediate orange flesh colour. Root suface defect is absent.

TU-Purple

Has a predominantly green vine with few purple spots and greyish green vine apex. It has ground cover of above 90% after 40-60 DAP. The leaves are green and slightly lobed in shape, with triangular central leaf lobe. The young leaves are greyish-green due to the dense pubescene. The petiole colour is green with purple colaration both ends. The tuberous roots are obovate (regular root shape) in shape with purple-red skin colour and strongly pigmented with anthocyanins flesh colour. Root surface defects is absent.

Obari

It has a predominantly green vines colour with purple veins at the apex. The vines are thin with purple nodes and mostly spreading. It has a high (75-90%) ground cover after 40-60 DAP. Its leaves are triangular in shape, green with purple veins on the upper surface. Petiole is green with purple colour at both ends. Its tuberous roots are oblong in shape has white skin and flesh colour. The tuberous roots exhibit shallow horizontal constrictions on the root surface.

INTRODUCTION

Vitamin A deficiency (VAD) is one of the micronutrient deficiency diseases of public health importance in Ghana. Poor vision and reduced cellular integrity are among the symptoms of VAD and several programmes have addressed these challenges with key interventions such as vitamin A supplementation (VAS) for children under five years and the production and consumption of crops that are high in carotene which is then converted to vitamin A in the body. In a recent study spearheaded by the University of Ghana (Ghana Micronutrient Survey 2017) the prevalence of VAD was 20% in children with a higher prevalence of 31% in Ghana's northern belt. Food based approaches have proved to be more sustainable interventions and Agricultural Research in Ghana and the International Sweep Potato Centre (CIP) have developed and promoted Orange Fleshed Sweet Potato (OFSP) varieties to address vitamin A deficiency.

Sweetpotato (*Ipomoea batatas* L.) produces the highest root dry matter for animal, human consumption, and industrial purposes and contains high amount of calories at 152 MJ ha^{-1} day^{-1} compared to 121, 135, 151 and 159 MJ $ha^{-1}day^{-1}$ calories, for cassava, wheat, rice and corn, respectively (FAOSTAT, 2015). With a relatively shorter maturity duration, the crop has a comparative advantage over other root crops in terms of cultivation in the Guinea Savannah ecology of Northern Ghana. This thus makes it a food security crop of choice and a better tool for biofortification. Though commonly white-fleshed sweet potato varieties are predominantly cultivated, high genetic diversity has been observed among the sweetpotato germplasm for fleshed colour, resulting in distinctive flesh colours mostly white, cream, deep yellow, orange and purple. The orange-fleshed sweetpotato (OFSP) and purple-fleshed sweetpotato (PFSP) cultivars contained high amounts of carotenoids and anthocyanins, respectively. The white-fleshed sweetpotato (WFSP) cultivar contains no carotenoids and anthocyanins, but are a great feedstock to the white starch industry and preferred by most Ghanaian consumers because of its dry texture after cooking.

Purple-fleshed sweetpotato (PFSP) contains high amount of stable and bioavailable anthocyanins in the storage root than ordinary orange-fleshed sweet potato and a number of varieties with different anthocyanin contents and profiles were bred and grown for their potential health benefits such as antioxidative, antineoplastic, as well as anticancer properties (Goda *et al.,* 1997; Odake *et al.,* 1992; Terahara and Konczak, 2004; Teranara *et al,* 1999). Wang and Stoner (2008) in a study confirmed that PFSP reduce risk and progress of colon cancer. Purples-fleshed sweet potato have been reported to significantly inhibit the growth of the human colon cancer cells by arresting cell cycle phase at G1 (Lim *et al.*, 2013). The chemical structures of the major anthocyanins in the purple-fleshed sweet potato are monoacylated and diacylated forms of cyanidin and peonidin (Goda *et al.* 1997; Terahara *et al*. 1999). These Anthocyanin pigments have high stability against heat and ultraviolet irradiation owing to their acylated forms, which is an advantage when they are used in food additives as natural colorantsThis justifies the introduction of PFSP in the diet of Ghanaians.

Purple-fleshed sweetpotato has shown excellent colouring properties in numerous acidic to neutral foods as a popular natural colourant and functional ingredient in the bakery, confectionery, juices, beverages, and dairy food industries (Suda *et al.*, 2003). It is also used as natural food colorant, and the deep purple paste and flour are used for the preparation of noodles, bread, jams, chips, confectionery, juices and alcoholic beverages. OFSP contains β-carotene which is a precursor of vitamin A and its intake will improve on the vitamin A status of consumers.

As the nutritional status of populations largely depends on what they eat, the unacceptably high occurrence of vitamin A deficiency (VAD), as prevailing in Ghana, could be attributed to over-dependency on white-coloured foods. World Health Organization (2015) classified vitamin A deficiency as a public health problem affecting about 48% of children aged 6-59 months in Sub-Saharan Africa. In Ghana, it is a leading cause of preventable childhood blindness and increase the risk of death from common childhood illnesses such as diarrhea (UNICEF, 2016).

Strategies used to bring vitamin A deficiency under control include dietary diversification, food fortification, and vitamin A supplementation. Dietary diversification is the way to go and this includes the production and utilization of β-carotene-rich crops, such as OFSP. Apomuden is so far the only officially released OFSP variety available to producers and no PFSP is available. Furthermore, producers of white and yellow-fleshed varieties traditionally demanded by local commercial markets, currently rely on so-called farmers' varieties, which have not been officially released. With the growing awareness of the nutritional value of OFSP, the health benefits of PFSP and the potential for a high starch variety in-line with Government policy of one district one factory, there is the need to meet these demands by releasing OFSP, PFSP and WFSP varieties in the guinea and sudan savanna agroecological zones of Ghana.

In spite of sweetpotato's potential in fighting malnutrition and food insecurity, as well as its therapeutic effects on the aforementioned conditions, few coloured fleshed varieties have been released and adopted by farmers. However, few OFSP varieties have been released in Ghana since 2005. One major challenge with OFSP varieties is their low dry matter content which limits their utilization in most food preparations since they tend to be soggy when fried. High dry matter content is an indication of sweetpotato quality and shows correlation with other nutritive characteristics (Rodriguez-Amaya, 2001). Development of a high dry matter orange fleshed sweet potato variety will help curb this challenge.

Though several other coloured sweetpotato varieties have been released in Ghana; Sauti (yellow-fleshed), Faara (cream-fleshed), Santom Pona (light yellow-fleshed), Okumkon (white-fleshed), Dadanyue (white-fleshed), Ligri (white-fleshed), Bohye (light orange) and Patron (light orange) very few are adapted to the Guinea savanna ecology. All these with the exception of Apomuden and Ligri had limited adaptation to the Guinea and Sudan Savannah agroecological zones of Ghana. It is therefore necessary to develop and release new biofortified sweetpotato genotypes adapted to the Guinea and Sudan Savannah agroecological zones of Ghana for enhanced nutrition and food security.

SPECIFIC OBJECTIVES

- To assess performance (yield parameters, pest and disease tolerance) of the sweetpotato genotypes under study.
- To assess the nutritional composition and consumer acceptability of the sweetpotato genotypes under investigation
- To make informed varietal recommendations based on all traits

MATERIALS AND METHODS

In collaboration with Scientists at CIP, UDS and Tuskegee University, six sweetpotato genotypes ("Kuffuor", "Nanugungungu", "Obari", TU-1-12, TU-Orange and TU-Purple) were evaluated and compared to a local cultivar and a released check, Apomuden. The genotypes are listed in the Table 1. The genotypes were tested over two years (2014-2015), in both on-station and on-farm trials. On-station trials were conducted at Nyankpala, Manga-Bawku, Navrongo, Damongo and Babile, and on-farm trials using a mother-baby design were conducted in nine communities. The on-station trials were established in a randomized complete block design with three replications. Each plot measured 4 x 5m at each site.

The on-farm trials were conducted at nine communities in Northern, Upper East and Upper West regions of Ghana. In the 2014 rainy season, the on-farm locations were Voggu-Kushibu and Dimabi in Northern region; Sumbrungu, Navrongo, Binduri, Garu and Bawku in Upper East and

Jirapa and Yagtouri in Upper West. In 2015, on-fam trials were planted at eleven locations in the three regions. These were Golinga, Tali, Nyohidan-yili, and Zugu-Yipala in Northern Region; Balungu, Nwan, Zimborg, Tindonmolgo, and Bus-natinga in Upper East Region; and Naawie and Buli in Upper West Region. In this method, 600 individual farmers were involved for the assessments. They were given a single genotype (baby) each to cultivate and consume for their independent assessment to determine acceptability, after which they participated in a group assessment of the mother trial. Three (3) genotypes (Nanugungungu, Obari and TU-Purple) were outstanding in their performances across trials, and are proposed for release as varieties. Demonstration and inspection plots are established at Wambong.

Table 1. List of genotypes evaluated in the Northern, Upper East and Upper West Regions

Clone	**Origin**	**Flesh Colour**
Kuffuor (local)	Farmer cultivar, Upper East	Orange
Nanugungugu	Farmer cultivar, Upper East	Orange
Voggu-O (local)	Farmer cultivar, Northern Region	Pale orange
Obari (local)	Farmer cultivar, Upper East	White
Apomuden	Improved check	Orange
TU-1-12 (only evaluated in some trials)	Tuskegee University	Orange
TU-Orange	Tuskegee University	Orange
TU-Purple	Tuskegee University	Purple

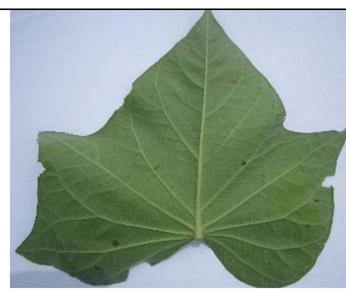
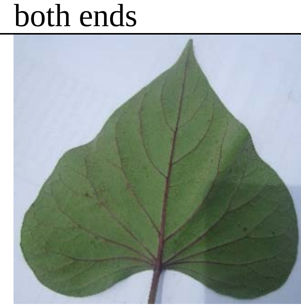
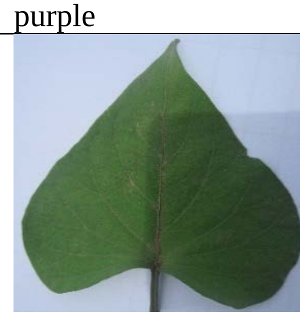
The clones were evaluated across the locations for their morphological (vine vigour, vine thickness, internode length, early root bulking) and agronomic characteristics (number of plants established, number of roots, root shape and size, root yield, as well as disease and pest tolerance). Farmer consumer preference was applied in the selection process.

Table 2. Morphological characters:

Character	**Nanugungungu**	**TU-Purple**	**Obari**
1. Vines			
Twining ability	Non-twining	Non-twining	Slightly-twining
Total vine length per plant (cm)	143.1	156.8	202.1
Plant growth habit	Semi-erect (75-150cm)	Spreading (151-250cm)	Spreading (151-250cm)
Mean vine girth (cm)	2.5	2.1	1.4
Mean number of branches	5	4	5
Vine apex colour	Yellow green	Greyish green	Green with purple veins

Vine internode length (cm)	Short (3-5)	Intermediate (6-9)	Short (3-5)
Vine internode diameter (mm)	Intermediate (7)	Intermediate (7)	Thin (4.5)
Ground cover	High (75-90%)	Total (>90%)	High (75-90%)
Predominant vine colour	Green	Green with few purple spots	Green
Secondary vine colour	Absent	Green base	Purple nodes
Mean number of nodes per vine	29	29	44
2. Leaf			
Colour of young leaf	Yellow green	Greyish-green (due to dense pubescence)	Green with purple veins on upper surface
Colour of petiole	Green	Green with purple at both ends	Green with purple at both ends.
Leaf vein colour (abaxial view)	Green	Green	All veins mostly purple
Leaf shape	Hastate (trilobular and spear-shaped with basal lobes more or less divergent)	Lobed	Triangular
Leaf lobe type	Slight	Slight	No lateral lobes
Leaf lobe number	3	5	1
Shape of central leaf lobe	Triangular	Triangular	Triangular

Leaf colour:

	Nanugungugu	Purple	Obari
Colour of young leaf	 Yellow green	 Greyish-green (due to dense pubescence)	 Green with purple veins on upper surface
Leaf petiole colour	 Green	 Green with purple at both ends	 Green with purple at both ends
Leaf vein colour (Abaxial view)	 Green	 Green	 Mostly or totally purple
Leaf shape (outline of the leaf)	 Hastate	 Lobed	 Triangular

3. Tuber

	Genotype		
Root characteristics	**Nanugungungu**	**Purple**	**Obari**
Storage root shape	 Long oblong	 Obovate	 Oblong
Storage root skin colour	 Brownish orange	 Purple-red	 Pale yellow
Storage root flesh colour	 Intermediate orange	 Strongly pigmented with anthocyanins	 White
Storage root DM	26 - 29.3%	32.8 - 35%	34.3 - 38%
Root Surface defects	Absent	Absent	Shallow horizontal constrictions

Multi-locational Evaluation

The elite genotypes (Nanugungungu, Obari, Kuffuor, TU-1-12, TU-Orange and TU-Purple) were evaluated both on-station (Guinea savanna, Transitional zone and Sudan savanna) and on-farm in the Savanna ecologies of Ghana. Results are as follows:

On-station Multi-locational trials:

Fresh storage root yields

The multi-locational evaluation results indicated three promising genotypes, namely Nanugungungu (orange-fleshed), Obari (white-fleshed) and Purple (purple-fleshed) with outstanding root yields performance compared to the local specific cultivars, as well as the Apomuden, which is a released variety, in 2014 (Table 3 - 7).

Nanugungungu was outstanding in both Nyankpala and Navrongo (Table 3) in 2014. Root mean yields of Nanugungungu at Nyankpala (21.81 t/ha) and Navrongo (27.55 t/ha) were generally high, with yields 20.2% and 17% higher than Apomuden, respectively (14.49 and 19.48 t/ha; Table 3). Obari recorded promising yields of 17.70, 15.98 and 10.30 t/ha at Nyankpala, Navrongo and Damongo, respectively.

TU-Purple also recorded promising mean root yield. These three genotypes had equally high biomass yields, across locations compared to the rest of the genotypes (Table 4).

Nanugungungu, Obari and TU-Purple had significantly, higher root yield performance at 3 MAP (Table 5), indicating outstanding root earliness in bulking, especially, Nanugungungu, which can be classified as early-medium (90-120 DAP) type. In 2015, Nanugungungu was particularly outstanding at Nyankpala and Wa for its higher storage root yield (Table 8 - 9). The 3 genotypes showed minor to no weevil damage of roots (Table 10), and no clear signs of virus recorded (Table 11).

Table 3. Storage root yield (t/ha) of 7 sweetpotato genotypes at five locations in northern Ghana, 2014

Genotype	Nyankpala	Navrongo	Babile	Bawku	Damongo	Mean
Apomuden	14.49	19.48	6.55	1.87	16.16	11.71
Kuffour (check)	12.87	9.66	7.01	2.95	6.97	7.89
Local	10.25	12.43	3.58	2.87	9.52	7.73
Nanugungungu	**21.81**	**27.55**	**4.88**	**6.22**	**12.69**	**14.63**
Obari	**17.70**	**15.98**	**4.44**	**2.45**	**10.30**	**10.17**
TU-Orange	10.74	11.88	4.5	2.88	12.95	8.59
TU-Purple	**11.62**	**7.98**	**0.76**	**2.5**	**9.47**	**6.47**
Mean	13.61	13.6	4.02	2.80	10.08	
Sed	2.49	4.13	1.42	1.12	3.12	

Table 4. Fresh vine yield (t/ha) of 7 sweetpotato genotypes at 4 locations in northern Ghana in 2014

Genotype	**Nyankpala**	**Navrongo**	**Bawku**	**Damongo**	**Mean**
Apomuden	9.8	16.52	1.36	6.97	8.66
Kuffour (check)	9.26	9.51	2.73	2.31	5.95
Local	11.35	16.21	7.61	5.91	10.27
Nanugungungu	**12.5**	**16.59**	**6.02**	**5.45**	**10.14**
Obari	**10.15**	**15.41**	**2.6**	**4.33**	**8.12**
TU-Orange	12.89	15.91	4.36	6.33	9.87
TU-Purple	**6.52**	**13.07**	**3.98**	**3.14**	**6.68**
Mean	*10.35*	*14.75*	*4.09*	*4.92*	8.53
Sed	*3.21*	*4.57*	*1.27*	*1.53*	

Table 5. Storage root yield (t/ha) of genotypes over 3 harvested dates in 2014 in Nyankpala

	Harvest dates			
Genotype	**90DAP**	**120DAP**	**150DAP**	**mean across**
Apomuden	8.21	14.49	12.85	11.85
Kuffour (check)	7.55	12.87	13.8	11.41
Nanugungungu	**12.18**	**21.81**	**16.57**	**16.85**
Obari	**7.30**	**17.70**	**16.52**	**13.84**
TU-1-12	5.37	9.44	11.45	8.75
TU-Orange	4.2	10.74	11.54	8.83
TU-Purple	**7.55**	**11.62**	**11.13**	**10.10**
Voggu-O	5.93	10.25	9.51	8.56
mean	7.29	13.61	12.92	
Sed	2.2	2.49	3.09	

Table 6. Weevil scores over 4 locations (score 1-9) in 2014

Genotype	**Nyankpala**	**Navrongo**	**Babile**	**Damongo**
Apomuden	4	3	5.67	3.33
Kuffour (check)	4	2.33	2.67	2
Local	4	1	3	1.66
Obari	**4**	**1**	**3**	**1.67**
Nanugungungu	**4**	**2**	**3.67**	**2**
TU-Orange	4	2.33	5.33	2.33
TU-Purple	**4**	**1**	**2.33**	**2**
mean	*4*	*1.81*	*3.38*	*2.14*
Sed	*NS*	*0.41*	*0.77*	*0.32*

Weevil rating scale: *1 = no damage, 3 = minor (few roots affected), 5 = moderate (10-30% damaged), 7 = heavy or severe (30-60% roots affected) and 9 = severe damage (>60% roots affected), with numbers in between representing intermediate ratings. Numbers in between represent intermediate ratings.*

Table 7. Virus (SPVD) scores over 4 locations -1 month to harvest, 2014

Genotype	**Nyankpala**	**Navrongo**	**Babile**	**Damongo**
Apomuden	3.33	3.67	1.33	1.33
Kuffour (check)	1.33	4.33	1.67	2.33
Local	3	3.67	1.33	2
Obari	**2.33**	**4.33**	**2**	**3**
Nanugungungu	**1.33**	**2.67**	**2**	**2**
TU-Orange	3.67	4.33	2	2.33
TU-Purple	**3.33**	**3.33**	**2**	**4.33**
Mean	*2.92*	*13.6*	*1.76*	*2.48*
Sed	0.78	4.13	0.27	0.44

Virus score ratings: *1 = No virus symptoms, 2 = Unclear virus symptoms, 3 = Clear virus symptoms at one plant per plot, 4 = Clear virus symptoms at two to three plants per plot, 5 = Clear virus symptoms at 5 – 10% of plants, 6 = Clear virus symptoms at 10 – 25 % of plants, 7 = Clear virus symptoms at 25 – 50% of plants, 8 = Clear virus symptoms at nearly all plant per plot, 9 = Clear virus symptoms and clearly reduced growth in all plants.*

Table 8. Storage root yield (t/ha) of 7 sweetpotato genotypes over 4 locations in Northern Ghana. 2015

Genotype	Bawku	Nyankpala	Wa	Navrongo	Mean
Apomuden	**6.13**	**14.05**	**19.37**	**16.43**	**14.00**
Kuffuor (check)	2.3	4.3	12.53	5.40	6.13
Local	1.83	8.51	13.81	0.32	6.12
Nanugungungu	**2.22**	**15.66**	**16.57**	**10.17**	**11.16**
Obari	**5.11**	**13.97**	**18.3**	**11.52**	**12.23**
TU-Orange	1.7	12.7	11.06	7.57	8.26
TU-Purple	**0.72**	**8.27**	**13.7**	**5.65**	**7.09**
Mean	2.86	11.07	15.05	8.15	9.28
Sed	1.17	2.11	1.8	1.68	1.76

Table 9. Storage root yield (t/ha) of 8 genotypes at 3 harvested dates at Nyankpala 2015

	Harvest dates			
Genotype	**90 DAP**	**120 DAP**	**150 DAP**	**mean**
Apomuden	9.86	14.05	19.66	14.52
Kuffour (check)	3.1	4.3	5.85	4.42
Nanugungungu	**11.49**	**15.66**	**13.41**	13.52
Obari	**10.56**	**13.97**	**15.09**	13.21
TU-1-12	7.11	13.9	14.37	11.79
TU-Orange	4.47	12.7	12.86	10.01
TU-Purple	**4.47**	**8.27**	**10.92**	7.89
Voggu-O	3.66	8.51	10.96	7.71
Mean	*6.84*	*11.42*	*12.89*	
Sed	*0.716*	*2.43*	*2.65*	

Table 10. Weevil scores of storage roots quality measured on the scale of 1-9 for 7 sweetpotato genotypes in trial at 4 locations in northern Ghana in 2015

Genotype	Bawku	Nyankpala	Wa	Navrongo	Mean
Apomuden	5.67	2.67	4.00	3.00	4.11
Kuffuor (check)	5.67	1.33	3.00	1.00	3.33
Local	1.67	1.33	2.00	1.00	1.67
Nanugungungu	**5.00**	**2.00**	**2.00**	**1.67**	**3.00**
Obari	**4.33**	**1.33**	**2.33**	**1.67**	**2.67**
TU-Orange	4.67	1.67	3.33	3.00	3.22
TU-Purple	**2.67**	**1.00**	**1.33**	**1.00**	**1.67**
Mean	4.24	1.62	2.57	1.76	2.81
Sed	1.03	0.621	0.42	0.26	0.776

Weevil rating scale: *1 = no damage, 3 = minor (few roots affected), 5 = moderate (10-30% damaged), 7 = heavy or severe (30 - 60% roots affected) and 9 = severe damage (>60% roots affected), with numbers in between representing intermediate ratings*

Table 11. Scores of virus rating (1- 9) of genotypes in trials in northern Ghana, 2015

Genotype	Bawku	Nyankpala	Wa	Navrongo	Mean
Apomuden	5.67	2.67	4	1	4.11
Kuffuor (Check)	5.67	1.33	3	2	3.33
Local	1.67	1.33	2	1	1.67
Nanugungungu	**5**	**2**	**2**	**1**	**3**
Obari	**4.33**	**1.33**	**2.33**	**2.67**	**2.67**
TU-Orange	4.67	1.67	3.33	2	3.22
TU-Purple	**2.67**	**1**	**1.33**	**3**	**1.67**
Mean	4.24	1.62	2.57	1.81	2.81
Sed	1.03	0.621	0.42	0.18	0.776

Virus score ratings: *1 = No virus symptoms, 2 = Unclear virus symptoms, 3 = Clear virus symptoms at one plant per plot, 4 = Clear virus symptoms at two to three plants per plot, 5 = Clear virus symptoms at 5 – 10% of plants, 6 = Clear virus symptoms at 10 – 25 % of plants, 7 = Clear virus symptoms at 25 – 50% of plants, 8 = Clear virus symptoms at nearly all plant per plot, 9 = Clear virus symptoms and clearly reduced growth in all plants.*

On-farm Evaluation:

Results of on-farm trials in 2014 showed that Nanugungungu out-performed other genotypes in storage root and vine yields (Table 12). Fresh storage root yields of Nanugungungu (5.19 t/ha) exceeded the average yield of Apomuden (4.78 t/ha), which is the best improved check by 4%. TU-Purple also performed better (3.33 t/ha), but lower after Apomuden. Obari on the other hand recorded a total root yield of 4.12 tons/ha. In 2015, Nanugungungu recorded a promising performance with a root yield of 10t/ha (Table 13), and Obari recorded 9.69 tons/ha.

Table 12. **S**torage root and vine yields of sweetpotato genotypes in "mother" trials across 9 sites in on-farm trials in northern Ghana in 2014

Genotype	Total root yield (t/ha)	Vine yield (t/ha)
Apomuden	4.78	2.53
Kuffour (check)	3.22	2.15
Nanugungungu	**5.19**	**2.83**
TU-Orange	2.96	2.42
TU-Purple	**3.33**	**2.65**
Obari	**4.12**	**2.97**
Mean	*3.93*	*2.59*
SED	*0.34*	*0.56*

Table 13. Total and commercial storage root yields (t/ha) of sweetpotato genotypes evaluated in "mother" trials across 11 sites in on-farm trials in northern Ghana in 2015

Main effects	Tot. root yld(t/ha)	% of Comm. Roots
Apaomuden	11.8	32.4
Kuffuor (check)	6.33	37.6
Nanugungungu	**10.11**	**32.1**
TU-Orange	7.29	33.8
TU-Purple	**5.56**	**38.1**
Obari	**9.69**	**82.0**
Mean	8.46	
SED	0.91	

Table 14. Overall field performance of "Baby trials" compared with local check ("Kuffuor") by farmers in percentage (%) of Response across all locations

Genotype	Equal)	Very good	Good	Fair	Worse
TU-Orange	0	46	50	4	0
TU-Purple	**2**	**38**	**47**	**9**	**4**
Apomuden	5	53	36	6	0
Nanugungungu	**0**	**63**	**37**	**0**	**0**
Obari	**1**	**51**	**46**	**2**	**0**
Average	*1.6*	*50.2*	*43.2*	*4.2*	*0.8*

Sensory evaluation of selected genotypes at On-farm locations

Consumer panel were 50 and comprised farm families, mostly women, including men and teenage school children in 5 different communities in the sweetpotato growing areas evaluated 6 genotypes namely Apomuden, Kuffour (check), Nanugungungu, Obari, TU-Orange and TU-Purple in 2014, where Apomuden was used as improved checks for the other genotypes in the test samples. The roots were boiled and cut into uniform small cubes. Sample cubes for each genotype were placed in labeled disposable bowls and passed round for each assessor to pick. Preferences were shown by the number of assessors in favour of a genotype.

Plate 1 Displayed boiled roots in cubes

Plate 2.Farmers in sensory evaluation.

The attributes evaluated were colour, flavour (aroma), taste, texture and overall acceptability. A 5-point hedonic scale was used to measure acceptability of each attribute (where 1=Bad, 2=Fair, 3=Good, 4=Very good, and 5=Excellent). Sensory score data were rated by mean average scores obtained from the attributes measured for each genotype. From the results, Nanugungungu and TU-purples ranked the best scoring 4.67 and 4.44 using the pairwise comparison of preference (Table 15) across 9 communities where the Mother-Baby trials were conducted. The overall sensory ranked Nanugungungu first among the genotypes by most of the communities. Similarly, Nanugungungu, TU-purple and Obari (local in some locations) were outstanding in the overall acceptability ranking in 2015 year of evaluation (Table 17).

Table 15. Pairwise ranking of acceptability of 6 genotypes across 9 communities. 2014

Community	Apomuden	Kuffuor	Purple	Orange	Nanugungungu	Obari
Buzunating	2	5	6	1	4	3
Nwan	1	5	3	5	2	5
Balungu	2	4	6	3	1	5
Zeamborg	2	4	1	3	6	5
Tindonmolgo	4	3	6	1.5	5	1.5
Golinga	5	3	4	2	6	1
Tali	3.5	1.5	5	3.5	6	1.5
Nyohindan-yili	3	5	4	1	6	2
Zugu-yepala	4	2	5	1	6	3
Sum	26.5	32.5	40	21	42	27
Mean	2.94	3.61	4.44	2.33	4.67	3.00

***Ranking scale**: 1=Sixth (last), 2=Fifth, 3=Forth, 4=Third, 5=Second, 6=First*

Table 16. Acceptance rating of boiled sweetpotato storage roots of 6 genotypes by 50 consumers across the 11 communities. 2014,

Genotype	Color	Smell	Taste	Texture	Overall Acceptability
Apomuden	4.2	4.1	3.8	4.0	4.0
Kuffour (check)	4.5	4.3	4.3	4.3	4.3
Obari	**4.7**	**4.6**	**4.6**	**4.5**	**4.7**
Nanugungungu	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**
TU-Orange	3.8	3.8	3.4	3.4	3.6
TU-Purple	**3.6**	**3.6**	**3.7**	**3.7**	**3.6**
Mean	*4.3*	*4.2*	*4.1*	*4.1*	*4.2*

Table 17. Acceptance evaluation of boiled sweetpotato storage roots of 8 genotypes by 50 consumers. 2015

Genotype	Color	Smell	Taste	Texture	Overall Acceptability
Apomuden	4.7	4.7	4.3	4.7	4.7
Kuffour (check)	4.8	4.6	4.6	4.8	4.7
Nanugungungu	**4.9**	**4.7**	**4.7**	**4.9**	**5.0**
Obari	**4.8**	**4.8**	**4.7**	**4.8**	**4.7**
TU-1-12	4.7	4.6	4.7	4.7	4.8
TU-Orange	3.6	3.8	3.8	3.8	3.8
TU-Purple	**4.8**	**4.7**	**4.7**	**4.8**	**4.8**
Voggu-Orange	4.1	4.1	4.1	4.2	4.2
Mean	*4.6*	*4.5*	*4.5*	*4.6*	*4.6*

Table 18. Sensory Ranking of 6 genotypes based on Overall Acceptability across 9 communities

	Genotype Preference Ranking					
Community	**Apomuden**	**Kuffuor**	**TU-Purple**	**TU-Orange**	**Nanugungungu**	**Obari**
Buz-nating	2	5	6	1	4	3
Nwan	1	5	3	5	2	5
Balungu	2	4	6	3	1	5
Zeamborg	2	4	1	3	6	5
Tindonmolgo	4	3	6	2	5	2
Golinga	5	3	4	2	6	1
Tale	4	2	5	4	6	2
Nyohidayili	3	5	4	1	6	2
Zugu-yipelga	4	2	5	1	6	3
Mean Rank Score	*3*	*4*	*4*	*2*	*5*	*3*

***Ranking scale**: 1=Sixth (last), 2=Fifth, 3=Forth, 4=Third, 5=Second, 6=First*

Table 19. Overall Ranking of 6 genotypes in on-farm trials by farmers.

Rank	Genotype
1st	**Nanugungungu**
2nd	**TU-Purple**
3rd	Kuffuor (local)
4th	**Obari**
5th	Apomuden
6th	TU-Orange

Beta-Carotene and Anthocyanin levels

Among the three genotypes proposed for release, Nanugungungu is the only orange-fleshed type with relatively high (15.74mg/100g sample) level of Beta (β)-carotene, but lower than that of Apomuden, the only released OFSP variety in Ghana (Table 20). TU-Purple is a purple-fleshed type, with no beta-carotene content, but with anthocyanins content, in the range of 109.2–240.1mg/100g DW, which is also a very important nutrient element. Total anthocyanin level in 80% of the flour of TU-Purple roots were within anthocyanin content values of most purple-fleshed sweetpotatoes (0-210 mg/100g fresh weight) as reported by Truong et. al., (2014). Obari is a white-fleshed type but high yielding local cultivar, which is being proposed for official release.

Table 20. Beta-carotene content of storage roots of 8 sweetpotato genotypes. 2014

Genotype	β-Carotene (mg/100g Sample)	Anthocyanin (mg/100g dwt)	Root flesh Colour
Apomuden**	20.3	-	Dark Orange
Kuffour (check)	13.87	-	Pale Orange
Nangungungu	**15.74**	**-**	**Intermediate Orange**
Obari	**0**	**-**	**White**
Local	4.94	-	Pale Yellow
TU-1-12	18.25	-	Dark Orange
TU-Orange	19.41	-	Pale Orange
TU-Purple	**0**	**171.04**	**Purple**

*****Released variety***

Dry matter and Starch contents

Dry matter and starch contents are important parameters in sweetpotato quality. Products such as flour and gari require high dry matter, especially, the form in which fresh roots are consumed, as well as other processed products in Northern Ghana. Dry matter of Nanugungungu, Obari and TU-Purple are quite higher, especially the Nanugungungu (orange-fleshed genotype) recording higher DM% above that of the officially released orange-fleshed sweetpotato in Ghana, Apomuden (Table 24-26). The starch contents of the proposed materials are also better compared to the rest of the genotypes. .

Socio-Economics Assessment

Economic analysis was performed to compare the profitability of the proposed genotypes of sweetpotato for release and the farmer's cultivar. The crop enterprise budget technique was used to estimate the cost of production, total revenue, net revenue and the benefit-cost ratio of the genotypes to compare their profitability (Table 21). The analysis indicated that, Apomuden and Nanugungungu had the highest benefit cost (B/C) ratios of 3.4 with net revenue of 7,524.97GHS and 7,549.97GHS per hectare respectively. TU-Purple, Kuffour, and the local check all had a B/C ratios of 1.8 which was the lowest of all the genotypes under consideration. This implies that for each 1 GH₵ invested in an enterprise, the farmer will recover his 1 GH₵, plus an extra 0.8 GH₵ as net revenue. TU-Purple had a gross revenue of 5,649.98GHS and a total variable cost of 3,191.65GHS per hectare. Obari also had an average yield of 11.2 tons per hectare and a gross benefit of 9,333.30GHS. The benefit cost ratio of Obari was 2.9 implying that among the treatments Obari is the second most profitable variety after Nanugungungu and Apomuden respectively.

All things being equal, farmers should be willing to accept a variety if the B/C ratio of that variety is greater than the minimum acceptable B/C ratio of 1 (B/C >1). An enterprise with a ratio greater than 1 (B/C >1) is economically profitable. and B/C ratio =1 is the breakeven point.

Table 21. Economic evaluation of proposed sweetpotato varieties

Variables	**(Proposed varieties)**						
	Apomuden	**Kuffuor**	**Local**	**Nanugungungu**	**Obari**	**TU-Orange**	**TU-Purple**
Average yield (t/ha)	12.86	7.01	6.93	12.89	11.2	8.43	6.78
Price per (¢/t)	833.33	833.33	833.33	833.33	833.33	833.33	833.33
Gross revenue	10,716.62	5,841.64	5,774.98	10,741.62	9,333.30	7,024.97	5,649.98
Cost							
Land Preparation	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Cost of ridging	125.00	125.00	125.00	125.00	125.00	125.00	125.00
Cost of vines (Gh¢/ha)	1,666.65	1,666.65	1,666.65	1,666.65	1,666.65	1,666.65	1,666.65
Planting	250.00	250.00	250.00	250.00	250.00	250.00	250.00
Harvesting	250.00	250.00	250.00	250.00	250.00	250.00	250.00
Carting	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Cost of weeding	500.00	500.00	500.00	500.00	500.00	500.00	500.00
Total cost	3,191.65	3,191.65	3,191.65	3,191.65	3,191.65	3,191.65	3,191.65
Net revenue	7,524.97	2,649.99	2,583.33	7,549.97	6,141.65	3,833.32	2,458.33
Benefit cost (B/C) ratio	3.4	1.8	1.8	3.4	2.9	2.2	1.8

Conclusion:

Improved nutrition through the consumption of biofortified foods is one of the sustainable and effective ways of combating malnutrition particularly in Sub-Saharan Africa. The candidate varieties have various unique attributes in terms of dry matter compared with the check varieties, betacarotene and anthocyanin levels which will enhance nutrition of consumers. The proposed genotypes showed satisfactory on-station and stable multilocational evaluations as well as farmers' field. When they are released and adopted, it will help improve the health of consumers, increase the income of producers, reduce poverty and ensure improved livelihood of small holder farmers particularly in Northern Ghana. The potential yield and other attributes of the the different candidate varieties are presented below

Table 22. Summary of Outstanding Characteristics

Nanugungungu	**TU-Purple**	**Obari**
• Best fresh storage root yield (Potential~24t/ha) • On-station yields 33.6% over Apomuden, and 53% over local check. • Maturity: 3-4 months • High Dry Matter OFSP (26-29%) • Vigorous foliage (Thick vines) • Beta-carotene level 15.74 mg/100g • High starch content (60 % mg/100g DW) • Tolerant to SPVD • Moderate tolerance to *Cylas sp*. • Good plant establishment • Drought tolerant	• Medium yields (Potential~14t/ha) • Purple-fleshed (Average anthocyanin up to 171mg/100g) • Maturity(4-5months) • Regular root shape. • High Dry Matter (32-35%) • Vigorous foliage (thick vines) • Mild sweetness • High starch content (63% mg/100g DW) • Excellent ampesi • Tolerant to SPVD • Tolerant to *Cylas sp.* • Good plant establishment	• Medium-high yields (Potential~16t/ha) • White-fleshed storage roots. • Maturity: 4-5 months • High Dry Matter (34-38%) • High starch content (63% mg/100g DW) • Thin and long vines. • Excellent ampesi • Tolerant to SPVD • Moderately tolerance to *Cylas sp.*

Table 23. **PROPOSED LOCAL NAMES AND MEANING FOR THE SWEETPOTATO GENOTYPES PROPOSED FOR RELEASED**

Genotype	Local name	Language	Meaning
Nanugungungu	Nan		Named in honour of Mrs. Annan
TU-Purple	TU-“Diedi”	Dagbanli	Collect and eat
Obari	“Nyumingre”	Nankana	Proper yam

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Planting material multiplication and dissemination plan:

Seed conservatory nursery has been established at the irrigation fields at Botanga for the four genotypes namely Nanugungungu, Obari and TU-Purple, in addition to the officially released variety, Apomuden. Aside the open field conservation, these genotypes are being raised under net tunnels to ensure the availability of clean planting materials. The project will follow a seed system dissemination scheme that involves all actors in the sweet potato value chain from breeders through planting materials multipliers to the growers. Currently we have established decentralized vine multipliers (DVMs) in ten (10) sweetpotato producing communities in the Northern, Upper East and West Regions where they have been provided with low-cost net tunnels for the conservation of the elite sweetpotato materials. Small to medium scale vine multiplication is on-going at Botanga, northern region, Sumbrungu in the Upper East Region.

In order to enhance the availability of vines during the growing season due to the awareness created about the benefits of the OFSP many farmers have expressed the willingness to conserve and multiply sweetpotato vines.

Demonstration plots for the varieties when released will be established in collaboration with Association of Church Development Projects (ACDEP), based in Northern, iDE-Ghana in the Upper East and Upper West Regions. The ten (10) decentralised vine multipliers (DVMs) have been trained on good agronomic practices (GAP) and clean vine conservation and multiplication using the net tunnels at different communities of major sweetpotato growing areas. In collaboration with MoFA, a radio programme which has been used in the past to sensitize farmers will be further used to direct potential farmers to where to obtain planting materials for these varieties. Phone contacts of DVMs within the various farming localities. We are also in touch with the CSIR-CRI tissue culture laboratory in Femesua for periodic cleaning of vines, after several seasons of cultivation, to ensure virus-free plants. We will thus be able to massively deliver healthy planting material of the newly released varieties through commercial seed system.

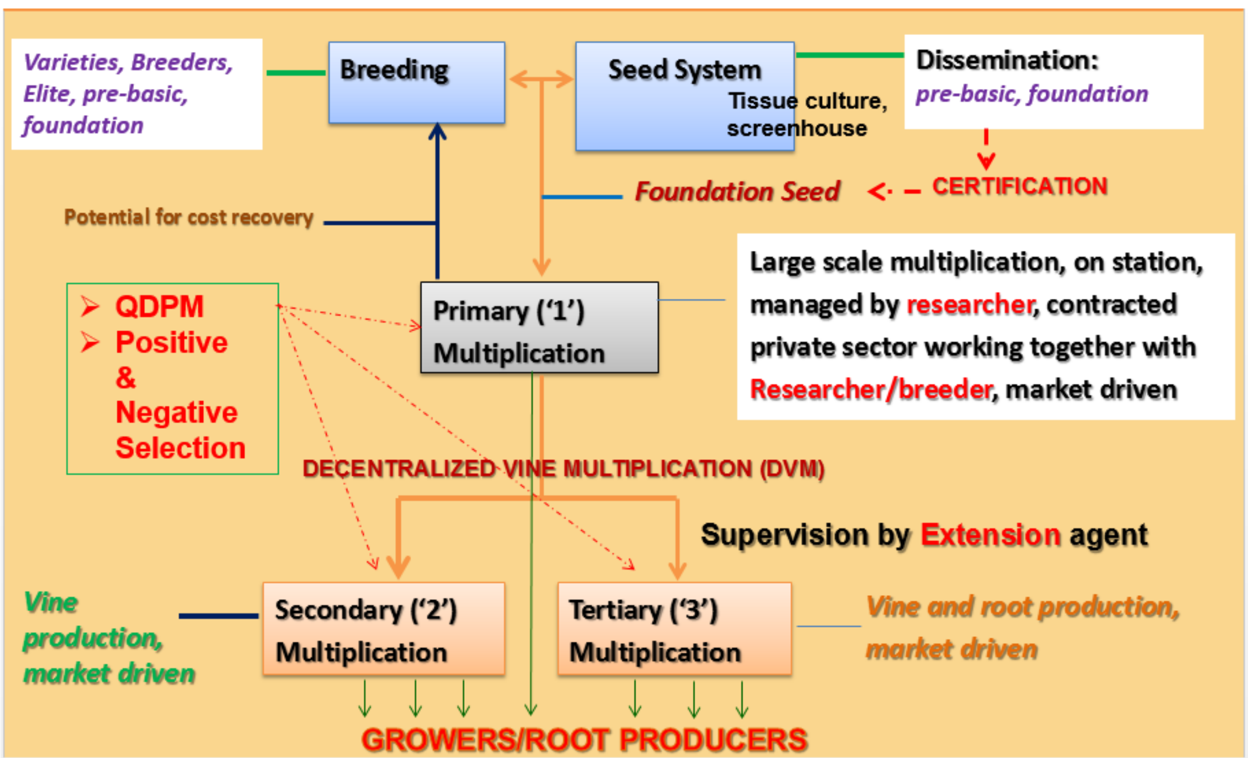

Plate 3: Proposed seed flow with reference to 1-2-3 system, and linkage of seed and breeding programs

DATA ON PROPOSED RELEASE GENOTYPES

CROP/ BOTANICAL NAME	PROPOSED NAME OF VARIETY	ORIGIN/ SOURCE	PEDIGREE/ LINE	PREFERRED ECOLOGY	CHARACTERISTICS		BREEDER & INSTITUTION
					DUS	**VCU**	
Nanugungungu	SARI-Nan	Farmer variety, Upper East	Not known	Guinea savannah	Plant type:semi-erect; Foliar colour-Mature leaf:Green; Young leaf :yellow green; Petiole pigment:Green; Storage root shape:Long oblong; Storage root skin colour:Brownish orange; Storage root flesh colour: Intermediate orange; Storage root DM %age: 27.7	Moderately tolerant to weevil; Disease reaction: Tolerant; Potential root yield:24t/ha; Good plant establishment; Maturity period: 3-4months;	K. Acheremu/ J. Adjebeng-Danquah/ I. A. Abukari/ K. Adofo/ E. Carey. CSIR-SARI/CRI, CIP
Obari	SARI-Nyumingre	Farmer variety, Upper East	Not known	Guinea savannah	Plant type:Spreading; Foliar colour-:Matured leaf:Green; Young leaf: Green with purple veins on upper leaf surface; Petiole pigment:Green with purple at both ends; Storage root shape:	Moderately tolerant to weevil; Disease reaction: Tolerant; Potential root yield:16t/ha; Maturity period: 4-5months; Storage root DM	K. Acheremu/ J. Adjebeng-Danquah/ I. A. Abukari/ K. Adofo/ E. Carey. CSIR-SARI/CRI, CIP

					Oblong; Storage root skin colour:White; Storage root flesh colour: White;	%age: 36.0; Starch content: 63%; Excellent for ampesi	
TU-Purple	SARI-TU-Diedi	Tuskegee University, USA	TU-2-12	Guinea savannah	Plant type:Spreading; Foliar colour-Matured leaf:Green with few purple spots; Young leaf: Greyish green(due to dense pubescence); Petiole pigment:Green with purple at both ends; Storage root shape:Obovate; Storage root skin colour:Purple-red; Storage root flesh colour: strongly pigmented with anthocyanins; Storage root DM %age: 34	Tolerant to weevil; Disease reaction: Tolerant; Potential root yield:14t/ha; Good plant establishment; Maturity period: 4-5months; Storage root DM %age: 33.0; Starch content: 63%; Excellent for ampesi; Mild sweetness; Purple-fleshed(contains high anthocyanins)	K. Acheremu/ J. Adjebeng-Danquah/ I. A. Abukari/ K. Adofo/ E. Carey. CSIR-SARI/CRI, CIP

Nutritional components:

Table 24. Nutritional qualities of fresh storage root of 7 genotypes at 4 MAP. Navrongo

Genotype	DM	Fructose (%)	Glucose (%)	Iron (mg/100g)	Protein (%)	SkinCol (1-9)	Starch (%)	Sucrose (%)	Zinc (mg/100g)
Apomuden	22.1	4.46	6.9	2.86	5.44	6	48.91	5.8	1.58
Kuffuor	35.77	4.73	6.56	2.26	5.49	6	55.28	9.79	1.14
Local	35.3	3.09	4.7	1.78	4.54	9	66.23	4.97	0.82
Nanugungungu	**27.5**	**3.47**	**4.98**	**1.97**	**4.1**	**5**	**51.9**	**8.03**	**0.95**
Obari	**36.0**	**3.02**	**4.81**	**1.81**	**4.4**	**3**	**65.4**	**4.65**	**0.83**
TU-Orange	31.7	6.69	9.21	2.02	3.8	3	57.09	4.95	0.86
TU-Purple	**35.0**	**2.91**	**4.2**	**2**	**3.67**	**-**	**60.12**	**4.78**	**0.9**
Mean	*31.91*	*4.05*	*5.91*	*2.1*	*4.49*	*5.86*	*57.85*	*6.14*	*1.01*
Sed	*1.21*	*0.94*	*1.24*	*0.12*	*0.42*	*0*	*1.9*	*1.01*	*0.68*

Table 25. Nutritional qualities of fresh storage root of 7 genotypes at 4 MAP. Nyankpala

Genotype	DM	Fructose (%)	Glucose (%)	Iron (mg/100g)	Protein (%)	Starch (%)	Sucrose (%)	Zinc (mg/100g)
Apomuden	22.5	6.67	10.34	2.18	4.97	53.52	5.85	1.29
Kuffuor	36.07	3.87	5.79	1.62	4.94	60.4	7.93	1
Local	35.07	2.84	4.75	1.56	4.63	61.62	6.76	1.02
Nanugungun	**28.3**	**2.44**	**4.26**	**1.94**	**6.66**	**60.89**	**7.81**	**1.1**
Obari	**36.4**	**3.02**	**3.81**	**1.68**	**3.89**	**60.84**	**3.6**	**0.77**
TU-Orange	34.13	7.22	10.04	1.68	4.16	58.91	2.18	0.79
TU-Purple	**34.5**	**2.34**	**3.78**	**1.75**	**6.39**	**63.11**	**7.31**	**0.94**
Mean	*32.42*	*4.06*	*6.11*	*1.77*	*5.09*	*59.90*	*5.92*	*0.99*
Sed	*1.14*	*0.72*	*1.01*	*0.17*	*0.84*	*2.16*	*0.82*	*0.09*

Table 26. Nutritional qualities of fresh storage root of 7 genotypes at 4 MAP. WA

Genotype	DM	Fructose (%)	Glucose (%)	Iron (mg/100g)	Protein (%)	Starch (%)	Sucrose (%)	Zinc (mg/100g)
Apomuden	23.4	1.879	3.46	2.7	6.89	48.74	19.83	1.79
Kuffuor	33.17	1.85	2.79	2.13	6.31	62.27	10.14	1.22
Local	40.44	1.02	2.04	1.79	5.59	67	6.27	1.11
Nanugungun	**28.8**	**1.6**	**2.57**	**2.16**	**6.38**	**55.76**	**15.72**	**1.2**
Obari	**37.2**	**1.3**	**2.45**	**1.7**	**5.6**	**65.4**	**7.01**	**1.12**
TU-Orange	32.94	2.54	3.53	2.24	5.77	60.06	9.23	1.22
TU-Purple	**34.4**	**1.15**	**1.92**	**2.09**	**6.29**	**61.05**	**10.39**	**1.13**
Mean	32.91	1.62	2.68	2.12	6.12	60.04	11.23	1.26
Sed	0.77	0.15	0.26	0.09	0.69	1.03	0.79	0.067

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