Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 10, pp.23177-23182, October, 2018

ORIGINAL RESEARCH ARTICLE | OPEN ACCESS

DEVELOPMENT OF HIGH ROOT YIELDING AND CONSUMER PREFERRED ORANGE FLESHED SWEET POTATO GENOTYPES FOR URBAN AGRICULTURE IN UMUDIKE RAIN FED AGRO-ECOLOGY OF SOUTHEASTERN NIGERIA

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ARTICLE INFO

Article History:
Received 28th July, 2018
Received in revised form
29th August, 2018
Accepted 17th September, 2018
Published online 29th October, 2018

Key Words:

Genotypes,
Harvest index,
Root yield and urban agriculture.

ABSTRACT

Agriculture in the urban is practiced in a limited land with high population density, this suggested reasons to develop sweetpotato genotypes with high root yield per unit area. On this premise, a study was conducted in Umudike Southeastern Nigeria using 13 selected open pollinated sweetpotato genotypes in a 3m x 3m plot size of $9m^2$ in a randomized complete block design and replicated 3 times. The planting material was of 4 node vine cutting, planted on ridges spaced at 1.0m and planting at 0.3m within rows of sweetpotato stands. Field maintenance included: application of 15:15:15 N.P.K fertilizer using band method. The field was kept weed-free until harvested 120 days after planting. Data collected included total number of enlarge roots, number of large roots, total root weight, weight of large root, and weight of above ground biomass. Consumer acceptability test was conducted in six metropolitan cities in the South eastern Nigeria using 9-point hedonic scale with 20 man panels from each of the urban areas. Analysis of variance and means separation using standard error of means were computed on the harvested parameters. Harvest index was used to select high yielding genotypes per unit area. However, Results obtained from the harvest index and culinary evaluation indicated that yield alone should not be the only criterion for variety selection. Culinary quality based on consumer preferred traits should also be considered. Based on this, the following genotypes were selected for metropolitan cultivation and consumption: 440293, EA/11/022, EA/11/024 and EA/11/030.

Citation: Nwankwo, I.I.M., Njoku, T.C., Opara, E.C., 1 Amanze, N.J and Olawoye, D.O. 2018. "Development of high root yielding and consumer preferred orange fleshed sweet potato genotypes for urban agriculture in Umudike rain fed agro-ecology of southeastern Nigeria", *International Journal of Development Research*, 8, (10), 23177-23182.

INTRODUCTION

Nigeria has limited arable land so the increasing demand for food especially from urban areas and for production for income cannot be expected to come from expanding area for cultivation indefinitely. Tan *et al*, (2007) observed that the issue of attaining and maintaining adequate food and raising income for the people based on sustaining practices is therefore a critical objective for the agricultural domain especially in Nigeria which is experiencing rapid urbanization.

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The demand for better performance of sweetpotato genotypes is not only because of the increasing population to feed on the crop but also because of dwindling natural resources caused by soil degradation, deforestation, genetic erosion, climate changes, urbanization and industrialization. The ever increasing and changing pests and diseases also present complex constraints. With such importance and demand on food in Nigeria and in urban areas in particular, it is imperative to develop and or improve on the yield of sweetpotato genotypes to tap on the available nutrient from the limited land area in the urbans for high yield since people no longer care for welfare of the soil. Moreover, many in the urban areas depend on farmers from rural areas for their food supply.

When the food eventually arrived, they are not cheap, and not fit for consumption. Although in Nigeria, Sweetpotao (*Ipomoea batatas* (L) Lam) are commonly grown in every part of the country. More than 60% of the farmers engage in sweetpotato farming and it remain a prominent food crop to many rural dwellers especially in Northern parts of the country (Edebiri, *et al*., 2001). The crop sweetpotato are of various varieties which ranged from white fleshed, cream fleshed, yellow fleshed, purple fleshed to orange fleshed varieties. The orange fleshed sweetpotato (OFSP) variety is rich in bioavailable beta-carotene, which the body converts into vitamin A (Sweetpotato knowledge, 2012). All parts of sweetpotato plants are consumed as food. The leaves are used as vegetable, the leaves and vines are used as fodder for animals, while the roots are used as food for humans and feed for livestock as well as means of economic empowerment to many poor resource farmers (Nwankwo and Afuape, 2013). The sweetpotato is an industrial crop. The enlarge roots yield starch while the vines of some coloured varieties could be used as dye by textile industries. The artistic foliage of some varieties could be used as ornamentals in landscaping and erosion prune sites (Loebenstein, *et al,* 2003)). The OFSP roots can be processed into different bakery products and the orange colour attracts consumers. Women in particular can make significant profit from selling sweetpotato products in urban areas, and higher female income translates into better household nutrition and welfare.

Urban agriculture is practiced in a limited land with high population density. This suggested reasons to develop sweetpotato genotypes with high root yield per unit area. Population increase and high rate of urbanization have given rise to the need for inexpensive but healthy foods for the urban poor and created concurrent demand for fast food outlets and healthier foods by a growing middle class. The nutritious advantage of OFSP offers a unique opportunity to promote increased marketing and processing of sweetpotato, which will boost demand and ultimately increases incomes (Sorense, 2009). The development of new orange fleshed sweetpotato varieties with higher productivity has largely focused on increasing root yield and resistance to biotic and abiotic factors. Improving the culinary qualities of sweetpotato has not enjoyed commensurate attention as increasing root yield on farmers' fields. This is probably why most of the cultivars available are only suitable for consumption as fresh roots for children, and not suitable for processing into adult foods. The food processing industries require high dry matter, high flour yield as well as high starch contents orange fleshed sweetpotato varieties.

These food quality traits make such product fit for industries like textile, paper, pharmaceutical etc that use starch as raw materials, and the bakeries that require high quality flour. Developing new orange fleshed varieties that satisfy these culinary qualities will rely on adequate information about the availability of the genes in the gene pool of the breeding programme. The relationships among the traits can have strong influence on the culinary quality. The identification of the desirable traits and hybridization will make the trait(s) have large influence on acceptability of the crop as quality culinary food for varied end users. Sweetpoto vine maintained in Nigeria is of a great importance for food availability due to its short maturity period (Sweetpotatoknowledge, 2012). It had increased the production of sweetpotato round the year creating food availability for rapid increasing population. Consumers were supported to take part in participatory variety selection trials so that better suited varieties could be selected for consumers. The consumers in the variety selection trials understand what they needed from the culinary quality, this enables the breeders to screen and produce varieties according to the consumers' selected criteria especially for urban usage. The high genetic variability offers the most effective condition for selection for a particular trait and to improve on it. Therefore the objectives of this work was for the selection of high yielding and consumer acceptability of Orange fleshed sweetpotato genotypes for urban agriculture.

MATERIALS AND METHODS

The study was conducted in Umudike Southeastern Nigeria using thirteen selected open pollinated sweetpotato genotypes in a 3m x 3m plot size of $9m^2$ in a randomized complete block design and replicated 3 times. The planting material was of 4 node vine cutting, planted on the crest of ridges at spacing of 1.0m x 0.3m. Field maintenance included: application of 15:15:15 N.P.K fertilizer using band method. The field was kept weed-free until harvested 120 days after planting. Data collected were on total number of enlarged roots, number of large roots, total root weight, weight of large root, and weight of above ground biomass. Analysis of variance and means separation using standard error of means were computed. Harvest index was used to select high yielding genotypes per unit area. Consumer acceptability of orange fleshed sweetpotato food was conducted using 20 panellists each from six urban areas (Umuahia, Calabar, Abakaliki, Enugu Owerri and Port Harcourt). Three large roots of the different sweetpotato varieties were processed into two food forms (boiled and fried) normally consumed in urban areas. Consumer acceptability test was conducted using 9-point hedonic scale with 20 man panels from urban areas. Sensory evaluation was carried out to evaluate sweetpotato consumers' preferences using the Sensory scale for sensory evaluation: Scoring scale were: 9 represented liked extremely, 5 represented neither liked nor disliked, and 1 represented disliked extremely. 5 and above = acceptability level.

RESULTS

The results of the root yield, above ground biomass and harvest index performances of the OFSP genotypes in 2016 and 2017 and for the two seasons combined are presented in Table 1.

Root yield: The result of the root yields of the sweetpotato genotypes in 2016 showed high significant (P<0.01) variation in total root yield. The total root yield ranged from 8.2t/ha (EA/11/024) to as high as 35.2t/ha for the genotype 440293 with grand mean of 10.7t/ha. The genotype significantly (P<0.01 gave a higher root yield of 29.9t/ha more than the genotype EA/II/014 which had 20t/ha of large root yield with grand mean of 7.8t/ha Also in 2017, the high significant (P<0.01) differences in total root yield of the sweetpotato genotypes indicated that EA/11/26 gave significantly (P<0. 01) high yield of 102.3t/ha of total root yield followed by TIS87/0087 with 38.2t/ha of total root yield while the least was EA/11/001 with 8.0t/ha of total root yield with grand mean of 31.8 root yield t/ha. In the same year, the genotype EA/11/026 gave significantly (P<0.01) large root yield of 54.0t/ha followed by EA/11/018 and EA/11/030 with 30.3t/ha of large root yield with grand mean of 27.3t/ha.

Table 1. Root yield, above ground biomass and harvest index performances of the OFSP genotypes in 2016 and 2017 and for the two seasons combined

	2016				2017				Two seasons combined				Rank
Genotypes	Total Root Yield (t/ha)	Large root yield (t/ha)	Above ground biomass (t/ha)	Harvest index	Total root weight (t/ha)	Large root weight (t/ha)	Above ground biomass (t/ha)	Harvest index	Total root weight (t/ha)	Large root weight (t/ha)	Above ground biomass (t/ha)	Harvest index	Root yield ranking
EA/11/031	10.4	9.6	25.6	0.41	30.0	23.0	46.3	0.65	20.2	16.3	36.0	0.53	7
EA/11/022	14.6	14.5	28.5	0.51	31.0	25.7	48.4	0.64	22.8	20.1	38.5	0.58	5
EA/11/014	9.3	3.8	16.8	0.55	31.0	16.7	46.1	0.67	20.2	10.3	31.5	0.61	7
EA/11/024	8.2	2.0	15.4	0.53	15.0	10.0	33.5	0.45	11.6	6.0	24.5	0.47	12
EA/11/026	10.4	8.1	17.9	0.58	102.3	54.0	147.2	0.69	56.4	31.1	82.6	0.68	1
EA/11/018	11.5	7.5	23.6	0.49	35.3	30.3	54.8	0.64	23.4	18.9	39.2	0.60	4
EA/11/030	12.2	10.0	19.4	0.63	26.0	30.0	48.5	0.54	19.1	15.0	34.0	0.56	10
EA/11/017	9.7	8.9	18.6	0.52	24.3	18.7	38.5	0.63	17.0	13.8	28.6	0.59	11
EA/11/003	9.5	9.0	13.7	0.69	30.0	18.7	45.0	0.67	19.8	13.9	29.4	0.67	9
EA/11/001	8.8	8.3	11.9	0.74	8.0	6.0	25.0	0.32	8.4	7.2	18.5	0.45	13
UM/11/002	12.6	5.2	25.5	0.49	29.3	19.7	48.3	0.61	21.0	12.5	36.9	0.57	6
440293	35.2	26.9	16.5	0.60	13.6	8.4	38.5	0.35	24.4	8.2	27.5	0.89	3
TIS/87/0087	12.6	6.8	25.3	0.50	38.3	24.0	67.4	0.57	25.5	15.4	46.4	0.55	2
Mean	10.7	7.8	19.9	0.56	31.8	27.3	52.9	0.57	22.3	14.5	36.4	0.60	=
Range	8.2-35.2	3.8-14.5	11.9-28.5	0.41-0.74	8.0-102.3	6.0-54.0	25.0-147.0	0.32-0.69	8.4-56.4	7.2-31.1	18.5-82.6	0.45-0.89	=
Prob. level	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	=
S.e.d	3.4	2.9	4.6	0.78	6.9	5.6	9.2	0.94	0.4	4.0	6.3	0.8	=

The result of the combined analysis on the total root yield showed that EA/11/026 significantly (P<0.01) had more total root yield of 56.4t/ha and was given the rank 1st, followed by TIS87/0087 with total root yield of 25.5t/ha with rank of 2nd and the least was EA/11/001 with total root weight of 8.4t/ha and was ranked 13.

Above ground biomass yield: The high significant (P<0.01) differences in the above ground biomass yield in 2016 showed that above ground biomass yield varied from 11.9t/ha as was produced by the genotype EA/11/001 to as high as 28.5t/ha as produced by the genotype EA/11/014 with grand mean of 19.9t/ha. In 2017, the above ground biomass yield significantly (P<0.01) varied from 25.0t/ha (EA/11/001) to as high as 147.2t/ha (EA/11/026) while the grand mean was 52.9t/ha. This result indicated that there was high yield of 52.9t in 2017 than in 2016 which had above ground biomass yield of 19.9t/ha. This may be as a result of variation in environmental factors). The combined results for the above ground biomass yield for the two seasons showed a high significant (P<0.01) variation in the performances of the sweetpotato genotypes in respect of above ground biomass yield. The least above ground biomass yield of 18.5t/ha was produced by the genotype EA/11/001, while the genotype EA/11/26 produced 82.6t/ha which was the highest biomass yield. This was followed by TIS87/0087which had 46.4t/ha. The grand mean was 36.4t/ha.

Harvest index: There was high significant (P<0.01) variation in the harvest indices of the sweetpotato genotypes. The harvest indices ranged from 0.41 for the genotype EA/11/031 to 0.74 for the genotype EA/11/001, while the grand mean was 0.56 in 2016. The harvest index (HI) in 2017 indicated high significant (P<0.01) differences among the sweetpotato genotypes. The least HI of 0.32 was obtained from the genotype EA/11/001 while the highest HI of 0.69 was from the genotype EA/11/026. The result of the combined analysis for the two years showed that the high significant (P<0.01) variation in HI of the sweetpotato genotypes indicated that HI varied from 0.45 to 0.89 for genotype EA/11/001 and genotype 440293, (Plate 1) respectively (Table 1).

Culinary qualities: The sensory evaluation of the culinary food quality of the sweetpotato genotypes (boiled and fried) food forms are presented in Table 2.

Colour: The panelists evaluated the visual appearance of the boiled and fried sweetpotato roots. Their appreciative rating of the flesh root colours ranged from 5.7 to 8.0 for EA/11/014, EA/11/001 and 440293 based on 9 point Hedonic scale. The grand mean was 6.7. The panelists appreciated the root flesh colour of 440293 which they rated 8.0 than that of EA/11/014 and EA/11/001 which they rated 5.7.

Taste: When the boiled roots of the sweetpotato were sampled to assess the effect on the sensory receptors on the surface of the tongue in the mouth, the result of the grand mean of the culinary evaluation scale was 6.7 on the 9.0 Hedonic sensory scale. The genotypes with the least appreciative flavour were: EA/11/031 and EA/11/017 which the panelist rated 4.5respectively on the 9.0 hedonic sensory scales. The genotypes they rated the flavour as the best was 440293 which was rated 8.8.This was followed by the following genotypes rated 7.4 and 7.2 respectively: EA/11/030, EA/11/003 and EA/11/022, EA/11/024, UM/11/002 (Table 2).

Texture: The way the boiled sweetpotato roots were feeling or when touched within the fingers of the hand was rated. The grand mean which rated 6.6 based on the 9.0 hedonic sensory scale showed that most of the panelist appreciated the feel of all the genotypes. Nevertheless, among the genotypes, the one they did not appreciate how it feels between the fingers was 440293 and it was rated 5.8 less than all the varieties evaluated. The genotypes the panelists appreciated how it feels when touched was EA/11/030 which they rated 7.5, followed by EA/11/022 and EA/11/003 scored 7.4 respectively.

Mouth feel: The panelists ate the boiled sweetpotato root flesh, how it feel in their mouth was scored, the grand mean score was 6.4 on the 9.0 point sensory scale evaluation. Although generally the mouth feel of all the genotypes were appreciated, the one they appreciated most was 440293 which was scored 7.5.

Plate 1. Yield per stand of the genotype 440293

Table 2. Sensory evaluation of boiled and fried OFSP roots from different genotypes

Genotypes	Colour	Taste	Texture	Mouth feel	Aroma	Crispness	General consumer acceptability	Rank
EA/11/031	6.5	4.5	6.4	6.9	6.5	6.7	6.3	10
EA/11/022	7.3	7.2	7.4	7.2	7.5	7.3	7.3	2
EA/11/014	5.7	6.7	6.2	4.7	5.7	7.1	6.4	8
EA/11/024	7.5	7.2	6.2	7.2	7.5	6.5	7.0	3
EA/11/026	6.0	6.1	6.4	5.5	6.0	5.5	5.9	13
EA/11/018	5.8	6.4	7.0	6.6	5.8	7.2	6.5	7
EA/11/030	7.4	7.4	7.5	6.7	7.4	5.4	7.0	3
EA/11/017	6.2	4.5	6.4	6.9	6.5	6.3	6.1	12
EA/11/003	7.3	7.4	7.4	4.7	7.5	5.4	6.7	4
EA/11/001	5.7	6.7	6.2	7.2	5.7	5.9	6.2	11
UM/11/002	7.5	7.2	6.2	6.2	6.5	6.4	6.7	4
440293	8.0	8.8	5.8	7.5	7.4	7.4	7.5	1
TIS/87/0087	5.8	6.4	7.0	6.4	5.8	7.0	6.4	8
Range	5.7-8.0	4.5-8.8	5.8-7.4	4.7-7.2	5.8-7.5	5.4-7.4	7.1	1-13
Mean	6.7	6.7	6.6	6.4	6.6	6.5	6.6	

Plate 2. Appearance after cook of some of the sweetpotato genotypes

This was followed by three other genotypes which the panelist scored 7.2. They were EA/11/022, EA/11/024 and EA/11/001 (Table 2).

Aroma: The grand mean score of 6.6 on the 9.0 point hedonic sensory evaluation showed that the panelists' impression was that all the root flesh of the sweetpotato genotypes evaluated has pleasant aroma/smell. However, the panelists appreciated the pleasant smell of EA/11/022, EA/11/024 and EA/11/003 which they scored 7.5. This was followed by 440293 which they scored 7.4. The genotypes the panelists gave the lowest score of 5.7 each were EA/11/014 and EA/11/001.

Crispness: The grand mean on the 9.0 hedonic sensory evaluation scale indicated that the panelists appreciated the crispness of the fried sweetpotato root flesh. However, the genotype rated 7.4 which was the highest rated on the scale was 440293, followed by EA/11/022 scored 7.3 while the least scored 5.4 respectively were for EA/11/030 and EA/11/003 (Plate 2).

General Acceptability: The grand mean culinary traits acceptability for all the sweetpotato genotypes indicated that all the metropolitans accepted the food forms of the genotypes. However, the mean acceptability of the sweetpotato genotypes indicated that of all the genotypes evaluated by the panelists in the metropolis generally rated 440293 as the highest they appreciated giving it the highest score of 7.5 and ranked it 1st followed by EA/11/022 which was scored 7.3 and ranked 2nd, while the least was EA/11/026 which was scored 5.9 and was ranked 13th. The overall grand mean was 6.6. This grand mean showed that most of the genotypes have good culinary quality since 5.0 and above on the 9.0 point hedonic scale indicated acceptability. However, genotypes with the highest score on the 9.0 point hedonic sensory scale were most preferred and acceptable.

DISCUSSION

The development of high root yielding sweetpotato genotypes is very crucial in sweetpotato root production and especially very important in areas with limited land area (Grüneberg *et al,* 2009). Large cities have within it small cultivable spaces where sweetpotato could be planted and harvested fresh. The results obtained from the genotypes evaluated indicated that the genotypes with the highest root yield were EA/11/026 with yield of 56.4t/ha followed by 440293 with the yield of 25.5t/ha of fresh root yield while the least which was EA/11/001 produced 8.4t/ha fresh root yield. The yield of the first two genotypes could be said to be high based on NARO (National Agricultural Research Organization) breeding programme grading. According to the grading, high yielding genotypes are genotypes yielding between 18 - 30t/ha, moderately yielding genotypes fell between 11 - 17t/ha while low yielding genotypes are genotypes yielding less than 11.0t/ha. Of all the genotypes evaluated, ten genotypes were high yielding, two yielded moderately while only one was low yielding (Table 1). However, Nwankwo *et al* (2018) reported that with the degradation of agricultural land, simply increasing plant population per hectare or increasing more areas under cultivation is no longer a viable option. New varieties of sweetpotato plants that generate an increase in yield per plant without relying on an increase in land area can be developed through plant breeding. ASPS (2016) observed that harvest index (HI) could be used to quantify the yield of a crop species versus the total amount of biomass that has been produced. Harvest index which ASPS (2016) defined as the ratio of commercial yield to total plant biomass (shoots plus roots) is used to measure the root yield of the sweetpotato genotypes per unit area and it is used to select sweetpotato genotypes that are high yielding. The potential values of the HI of various sweetpotato genotypes evaluated indicated that 440293 had the highest HI and the least was EA/11/001 with HI of 0.45. Genotypes with HI above the grand mean of 0.60 should be selected for cultivation in metropolitan cities (Table 1).

However, yield alone is not the only criterion to be considered in selection of a variety for cultivation by farmers. Other criteria such as culinary quality must come into play. Not considering the yield per unit area, consumers in the six metropolitan cities selected the following genotypes based on their culinary quality as the genotypes they preferred most according to their ranking: 440293, EA/11/022, EA/11/024 and EA/11/030. These genotypes were generally accepted by the consumers as the sweetpotato genotypes to be released for cultivation in the metropolitan cities (Table 2). It was based on this reason that Nwankwo *et al* (2017) reported that breeding programmes should involve farmers and consumers in variety selection. This is done by formalizing farmers and consumers' involvement in the variety testing process. The aim is to investigate the effect of the new varieties on the farmers, to introduce the varieties to farmers and consumers, to test farmers acceptance of the varieties and ranked preference of the varieties for yield and quality attributes including consumer/culinary acceptability assessment, and to obtain feedback in terms of what the farmers and consumers like in a variety to breeders. Often there is a mismatch of what the researchers and farmers/consumers consider as the best variety. This probably explains the low adoption rate of some of the research generated varieties and the dominance of farmer varieties in some areas. There are cases of varieties adopted by farmers which were previously rejected by the breeding programme. Involvement of consumers is aimed to bridge the gap during the variety development (Tsou and Hong, 1992).

Conclusion

The breeding programmes develop varieties to be accepted and adopted by farmers and consumers. In order to adopt the varieties evaluated, yield alone should not be the only criterion for genotypes selection. Genotypes that received the highest acceptability based on consumers preferred traits should be considered. The following genotypes: 440293, EA/11/022, EA/11/024 and EA/11/030 although their harvest index (except 440293) were lower than the grand mean harvest index, they were selected for possible release for metropolitan cultivation and consumption based on consumers' general culinary acceptability as the most preferred genotypes.

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