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Evaluation of β-carotene rich orange flesh sweet potato lines for high yield and quality

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ABSTRACT

Sweet potatoes are most valuable food security and climate-resilient crops that sustain many livelihoods in the tropics and subtropics. Orange-fleshed sweet potatoes (OFSP) are rich in β-carotene and it is the cheapest staple food, an easily accessible and year-round source of vitamin A. The main objective of the study was to evaluate superior orange flesh sweet potato entries for yield and cooking quality. The experiment was conducted for two consecutive years 2017 and 2018 in randomized block design with ten sweet potato entries and three replications at Horticultural College and Research Institute, TNAU, Coimbatore. The sweet potato variety CO5 was used as a local check. Out of these local check CO 5 recorded significantly the highest yield (28.88t ha^{1}) which was on par with TSp 16-2 (27.25 t ha^{-1}). The marketable tuber yield was significantly the highest in CO5 (20.94 t ha^{-1}) which was on par with TSp 16-10 (19.88 t ha^{-1}) TSp 16-10 (19.88 t ha^{-1}). Significantly maximum dry matter content (27.28 %), and starch content (20.03 %) was recorded in TSp16-7 and sugar content (2.74 %) in TSp-16-3. Among the entries TSp16-6 recorded the highest organoleptic score (8.13), and Tsp. 16-7 recorded the highestβ-content (8.62 mg 100g^{-1})

Keywords: *Sweet potato;β-carotene;yield; Cooking quality; OFSP.*

Introduction

Sweet potato, *Ipomoea batatas* (L.) Lam., is a tropical perennial, cultivated as an annual; and grown in more than 100 countries. Sweet potato is an important food and nutrition security root crop andit ranks on the world's seventh most important food crops and worldwide more than 133 million tons are produced every year. Sweet potato yields are high per area (Nwankwo *et al*., 2012) per unit of time (Nedunchezhiyan *et al*., 2012) to its higher productivity and drought tolerance, the crop can play vital role in achieving food self-sufficiency (Amare *et al*., 2014). Asia is the world's largest sweet potato-producing region, with 125 million tons/year; China with 117 million tons/year accounts for 88% of world production. African farmers produce around 7 million tons of sweet potato annually, but unlike in Asia, most of the crop is grown for human consumption (Collins, 1998; CIP, 2007).

Sweet potato, is an important food crop widely cultivated in the world. It has wide genetic diversity for the most desirable traits, which could be exploited by breeders (Adebisi *et al*., 2001; Afuape *et al*., 2011; Chaudhary and Singh 1982; Veasey *et al*., 2008). Sweet potato is cultivated primarily for the enlarged edible storage roots which provide high amounts of starch.

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In some countries tender leaves are consumed as vegetables and mature vines are also fed to livestock, especially dairy cows and pork. Over 95% of the global sweet potato is produced in developing countries where it is a staple or alternative style food. Manyof the cultivars and landraces grown are unique to countries or smaller regions within countries.

Sweet potato are evaluated on the basis of morphological and agronomic characters coupled with reactions to pests, diseases. Sweet potato cultivars are generally distinguished based on morphological traits and have very wide variability of botanical characteristics. Sweet potato is a cross-pollination species, allowing the exchange of favorable alleles between varieties through hybridization. Determination of close, or diverse, relationships between genotypic and phenotypic traits are done by genetic diversity analysis (Karuri *et al*., 2010). In addition to morphological characters, quality characters are preferred for nutritive value and market demand (Nicolle *et al*., 2004; Singh *et al*., 2002; Tsegaye *et al*., 2007). The genetic relationship reflects the difference of genetic background between accessions, thus selection of genetically distant accessions as hybrid parents in breeding is more possible to generate elite varieties.

Micronutrient malnutrition is caused by a deficiency of essential vitamins and minerals (micronutrients) such as vitamin A, iron and zinc. Vitamin A deficiency affects over 140 million preschool children in 118 countries. Since the symptoms of micronutrient deficiency are not always visible, it is commonly referred to as hidden hunger. Vitamin A deficiency (VAD) poor cognitive development and nutritional blindness, causes morbidity, reduced immunity, and in some cases, death in children under the age of five years and poor productivity in adults.

VAD is considered a major public health problem and appropriate nutritional interventions are required to alleviate the problem.

Beta-carotene is a red-orange pigment abundant in plants and fruits. Orange-fleshed sweet potato (OFSP) is a special type of bio-fortified sweet potato that contains high levels of beta-carotene. The orange pigment in the flesh of OFSP tubers is due to the presence of beta-carotene and is converted to Vitamin A in the body after consumption to provide additional nutritional benefits. The nutritional value of staple food crops can be increased by increasing the density of vitamins and minerals in a particular crop through either conventional plant breeding methods, agronomic practices or biotechnology intervention. Vitamin A deficiency is a big challenge in developing countries, especially in children and the consumption of orange-fleshed sweet potato is a good solution. Vitamin A helps to increase morbidity, prevents dry eyes and improve resistance to infectious diseases. Additionally, it helps to reduces mortality in pregnant women and lactating mothers and their children. The orange flesh sweet potato lines having high beta carotene content are used as health and functional food. Moreover, sensitization of orange-fleshed sweet potato as source of vitamin A has created a demand for these varieties, hence generating a market. Moreover, this also shows that farmers were receptive to improved and released varieties compared to local landraces.

Materials and Methods

Study area

The study was conducted in the Department of Vegetable Crops, Horticultural college and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India (longitude: 77°E and latitude: 11°N and elevation 426 M). The soil texture varies from clay loam to sandy clay. This region has tropical climatic conditions which receive both South West and North East monsoon and the annual rainfall ranges from 650-700 mm. The average annual temperature ranges from 25°C-38°C.

Plant Materials

The experiment was conducted for two consecutive years 2017 and 2018 in randomized block design with ten sweet potato entries and three replications at Horticultural College and Research Institute, TNAU, Coimbatore. The sweet potato variety CO5 was used as a local check. The entries were received from different centers of the All India Coordinated Research Project on Tuber Crops located in different agro-climatic regions of the country. Thus, a total of 10 entries were evaluated, including the commercial variety CO5 released from the Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. These entries were planted in the field under *ex situ* conditions in Coimbatore, Tamil Nadu, India. In this study, vine cuttings of 15-20 cm are planted 10 cm deep and 60 x 20 cm spacing at the onset of the planting season. Prior to establishing the plants in the field, they were multiplied in pots in the nursery, where part of the assessment was undertaken. In the main field, the accessions were planted in Randomized Block Design with three replications.

Observations recorded: Yield and quality traits *viz*., total yield, marketable yield, dry matter (%), starch (% dry weight), Sugar (%), cooking quality including organoleptic score, β carotene content (mg/100g fresh weight) were recorded along with sweet potato weevil incidence.

Total yield (t/ha): This was determined by multiplying the average fresh tuber weight of the sampled plants by the number of plants present per hectare of land.

Marketable yield (t/ha): Tubers that are free from any damage, and uninfected by insect pests were considered as marketable roots. This was calculated by multiplying the average marketable storage root yield of the plants in the sample by the number of plants per hectare of land.

Dry matter content (%): From each plot, 10 g slices of sweet potatoes were taken and weighed right away after slicing them, and then after being left out in the open air for five days, the samples were dried in oven for 24 h at 80°C in the laboratory. The dry matter content (DMC %) wasthen estimated using the formula below (Yildirim *et al*., 2005).

$$DMC\ \% = \frac{Dry\ weight(g)}{Fresh\ weight\ (g)} x\ 100$$

Starch: To determine starch concentration, the weight of glucose obtained (spectrophotometry method) was multiplied by a factor of 0.9 divided by sample weight by using the following equation

$$Starch\ concentration = \frac{Gulcose\ weight\ x\ 0.9}{Sample\ weight\ (g)} x\ 100$$

Sugar: The sugar content was estimated by modified Anthrone method utilizing a spectrophotometer (Tokusoglu *et.al.* 2005) using saccharose as standard anhydroglycose for sweet potato which was measured at 620nm. Standard analytical calibration was found to be R^2 = 09942.

Beta-Carotene: The Beta- carotene was estimated by following Yildirim *et al*., (2005) method. Two grams of sweet potato flesh was grounded in a container containing 5 ml of acetone and then with acetone–petroleum ether (20:80;v/v). This was filtered and the filtrate was processed using rotary evaporation at 35 °C. The remaining solvent was removed through N2 atmosphere and 2 ml petroleum ether was added. The standard solutions and sample solutions were measured for 450 nm utilizing UV-Vis spectrophotometer.

Data analysis

The phenotypic and estimated data were subjected to analysis of variance (ANOVA), coefficient of variation, and critical differences were estimated in the PrismPad Ver.10 software.

Results and Discussion

Ten entries of orange fleshed sweet potato were evaluated for yield, cooking quality and β-carotene content. The yield and yield contributing characters of the OFSP entries studied varied significantly. Out of these, the check CO 5 (Table 1) recorded significantly the highest yield (28.88 t ha^{-1}) which is onpar with TSp 16-2 (27.25 t ha^{-1}), TSp 16-6 (27.55 t ha^{-1}), TSp 16-7 (26.84 t ha^{-1}), TSp 16-9 (26.66 t ha^{-1}) and TSp 16-10 (27.88 t ha^{-1}). The marketable tuber yield was significantly the highest in CO5 (20.94 t ha^{-1}) which was on par with TSp 16-10 (19.88 t ha^{-1}) TSp 16-10 (19.88 t ha^{-1}). These results are in good agreement with Anonymous, (2011-12), where the yield of marketable tubers per hectare was about 19.44 tonnes in CIP 194513.15. Rahman *et al*. (2013) evaluated four orange fleshed sweet potato (OFSP) genotypes collected from International Potato Centre (CIP) *viz*., CIP 194515.15, CIP 194513.15, CIP 440267.2 and CIP 441132 and four hybrid orange flesh sweet potato genotypes viz., H16/06, H19/06, H3/07 and H6/07 from Bangladesh

Agricultural Research Institute (BARI) for yield and quality. The highest (31.59 t/ha) tuberous root yield was found in CIP 194513.15 which was followed by CIP 440267.2 (30.97 t/ha) and the lowest yield (13.34 t/ha) was obtained in BARI SP 3.

The current finding is relatively in good agreement with Omiat *et al.* (2005), who indicated that the varietal effect had a significant influence on the total tuberous root yield and marketable tuberous root yield of sweet potato as well. Similarly, Kathabwalika *et al.* (2013) also observed significant differences in the total tuber yield of sweet potato varieties in their trial. Desai *et al.* (2013) reported that, the highest tuber yield (33.18 t ha-1, 58.11% higher than the check variety, Gouri) was produced by genotype 440127, which was statistically on par with genotype 440038 (32.20 t ha-1, 53.41% higher than the check variety, Gouri) and 362-7 (31.23t ha-1, 48.84% higher than the check variety, Gouri).

According to Niringiye *et al.* (2014) the highest total tuberous root yield was recorded from sweet potato varieties 23/60/19, 23/60/31, 91/282-5, Sowola (OP)/2 and 282/94/3 while the lowest total tuberous root yield was obtained from varieties 23/60/90, Jewel (OP)/2005/6, Diallel 3, Zapallo/94/8 and the standard checks Dimbuka and New Kawogo, which is in consistent with the result of the current investigation. Antiaobong (2007) reported that, the differences in total tuber yield could be attributed to varietal differences among the OFSP varieties. This result is in line with Amare *et al.* (2014), who also found significant differences in total tuber yield among varieties in their study. Similarly, Wariboko and Ogidi (2014) also conducted studies on OFSP and reported that improved OFSP varieties were higher in total tuber yield.

Significant maximum dry matter content (27.78 %), starch content (20.03 %) was recorded in TSp16-7 and sugar content (2.74 %) in TSp-16-3 (Table 2). In sweet potato, the dry matter content is most preferred by both farmers and consumers and this determines the marketability and adoption of any variety (Gad and George, 2009). The percentage dry matter content ranged from 20.23% (TSp 16-3) to 27.78% (TSp 16-7) with mean of 23.51% for all the entries. Dry matter content of above 27% has been found to be acceptable to most consumers of sweet potatoes (Carey *et al.*, 1997). High dry matter content is an indication of high starch content for that particular variety.

The present study is relatively in agreement with the findings of Jahan *et al.* (2001) that the variety Daulatpuri contained the highest dry matter (33.5 %). Rahman *et al.* (2013) reported that, maximum dry matter (29.83%) was obtained in H6/07 while minimum dry matter (17.61%) was obtained in CIP 441132. Desai *et al.* (2013) reported that, the highest dry matter content (34.70%) was observed in the genotype ST-14, which was on par with the genotype S-1281 (31.20%). These results were in line with the findings of Adebisi *et al.*, 2001; Afuape *et al.*, 2011 and Veasey *et al.*, 2008.

Among the entries tested, TSp16-6 (8.13) recorded the highest organoleptic score (Fig 1.) and TSp 16-7 recorded the highest carotene content (8.62 mg 100g^{-1}). This is a good range since most of the orange fleshed sweet potato varieties contain 3 to 16 mg 100g-1 of β-carotene. Total carotenoid contents (TCC) assessed in these varieties of OFSP certainly contributed to their total antioxidant contents (TAC). High correlation was noticed between TCC and TAC, confirming the positive impact of TCC on TAC (Koala *et al.*, 2013). According to Rahman *et al.* (2013), the highest Vitamin A (approximately 919.2 μg/100 g on fresh weight basis) was recorded in CIP 440267.2, which had red skin and latex absent flesh and the lowest was (approximately) in H6/07 (Vit A 0.0 μg/100 g).

OFSP are a rich source of vitamin A, indeed, they contain between 300 and 4620 equivalents of beta carotene (provitamin A) per 100 g of OFSP (Tumwegamire *et al.*, 2004). OFSP, rich in beta carotene is well received by children and can contribute to increased retinol concentrations in the serum of young consumers (Low *et al.*, 2007).

The flesh colour of the entries evaluated were white, light orange to orange. The flesh colour of the genotypes, which is an indication of the amount of β-carotene content in the roots, ranged from pale orange to deep orange. The higher the intensity of the orange colour, the higher will be the β-carotene content (Mcharo and LaBonte, 2007; Burgos *et al.*, 2009; Vimala and Hariprakash, 2011).

Conclusion

Sweet potato has high levels of genetic diversity because of the cross-pollination behavior. This finding is of particular significance for the evaluation of elite sweet potato lines and there is a need to promote the breeding and production of OFSP varieties which are rich in beta carotene. The yield of sweet potato tubers differed significantly among the orange flesh genotypes. TSp 16-10 (27.88 t ha^{-1}) the highest yield which is on par with the ruling variety CO5. The cooking quality was similar to both white and OFSP, however, the degree of β-carotene content varied significantly across genotypes.

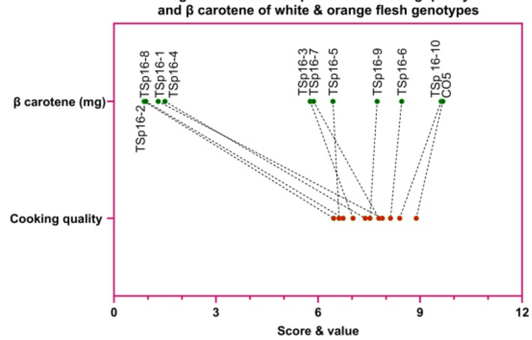
Table: 1 Performance of orange fleshed sweet potato entries

Genotypes	Flesh colour	Total yield (tha^{-1})	Marketable yield (tha^{-1})
TSp16-1	White	24.65	16.65
TSp16-2	White	27.25	19.44
TSp16-3	Light orange	23.64	15.29
TSp16-4	White	25.32	18.14
TSp16-5	Orange	22.87	15.89
TSp16-6	Orange	27.55	17.53
TSp16-7	Orange	26.84	18.97
TSp16-8	White	25.37	17.34
TSp16-9	Orange	26.66	17.26
TSp 16-10	Orange	27.88	19.88
CO5	Orange	28.88	20.94
Sem		0.74	0.51
CD		2.24	1.55
CV		14.23	17.63

Table 2. Quality parameters of sweet potato genotypes

Genotypes	Dry matter (%)	Starch (% dry weight)	Sugar (%)
TSp16-1	24.67	17.35	2.08
TSp16-2	23.76	18.31	2.05
TSp16-3	20.23	19.37	2.74
TSp16-4	21.19	18.21	2.37
TSp16-5	26.57	18.76	1.84
TSp16-6	21.45	19.12	1.97
TSp16-7	27.78	20.03	1.92
TSp16-8	23.14	19.15	2.06
TSp16-9	22.38	18.34	1.99
TSp 16-10	21.64	19.27	1.68
CO5	25.78	19.67	2.59
Sem	0.68	0.53	0.06
CD	2.05	1.61	0.18
CV	12.82	15.77	11.55

Figure 1. Relationship between cooking quality and β carotene of white & orange flesh genotypes



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