

Full Length Research Paper

Evaluation of dry matter, starch and beta-carotene content in orange-fleshed sweet potato (*Ipomoea batatas* L.) genotypes tested in three agro-ecological zones of Malawi

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Received 31 May, 2016; Accepted 3 August, 2016

Evaluation of dry matter, starch, beta-carotene content and stability of eight orange-fleshed sweet potato genotypes was conducted at Bunda College in Malawi. Genotypes LU06/0527, LU06/0252, LU06/0428, LU06/0299, LU06/0258, BV/009, Kenya and Zondeni were evaluated. The genotypes were grown in three agro-ecological zones of Malawi namely Maseya in Chikhwawa District representing low altitude areas with hot climate; Bunda in Lilongwe District representing medium altitude with warm climate and Bembeke in Dedza District representing high altitude areas with cool climate. Harvested tubers were evaluated for dry matter, starch and beta-carotene content using spectrophotometry. Analysis of variance on the main effects between genotypes and environments as well as Interaction Principle Component Analysis (IPCA) for the residual multiplication interaction between genotypes and environments for beta-carotene content in the eight genotypes were conducted. Results showed significant differences in dry matter, starch and beta-carotene content among genotypes and across sites. Zondeni produced highest dry matter (34.4%) while BV/009 was the least (26.8%). Genotype LU06/0252 produced highest beta-carotene (6793.2 µg/100 g) followed by Zondeni (5620.9 µg/100 g). Beta-carotene content increased significantly with decreasing altitude and was highest at Maseya (4258.5 µg/100 g) followed by Bunda (3556.2 µg/100 g). Stability analysis showed that Kenya (SPN/O) was the most stable genotype in beta-carotene content across the sites. Bembeke was the most stable site while Maseya recorded highest beta-carotene content but was unstable site.

Key words: Orange-fleshed sweet potato, agro-ecological zones, beta-carotene content, starch content, dry matter content.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is an important root crop in sub-Saharan Africa (SSA) region and ranks

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Table 1. Description of locality and elevation in metres above sea level (masl) of the sites.

Study site	Locality	Average temperature (°C)	Soil type	Elevation (masl)	Average rainfall (mm/annum)
Maseya	16° 04' S 34° 80' E	29.5	Alfisols	200	600
Bunda	14° 12' S 33° 46' E	20.0	Lithosols	1200	1030
Bembeke	14° 35' E 34° 43' S	15.0	Lithosols	1600	1500

second after cassava in Malawi (Chipungu et al., 1999). Sweetpotato are mainly grown for human consumption and take different forms according to a particular locality. In Malawi, both roots and leaves are extensively utilized. Traditionally, peeled roots are boiled and groundnuts flour is added to produce local food product, *futali*. Sweet potato also forms part of the breakfast for the majority of both rural and urban dwellers in the country. Harvested leaves are also utilized as delicious relish when cooked after adding groundnuts flour.

Use of orange fleshed sweet potato (OFSP) has become a promising intervention in addressing vitamin A deficiency (VAD) which according to Kapinga et al. (2010) is at 32% level of the population in sub-Saharan Africa. This is mainly due to the fact that sweet potato already exists in consumer diets of most communities and OFSP have wide acceptance among women and children (Kapinga et al., 2010) who are at great risk of VAD (NSO, 2006).

Despite this potential, Malawi as a country faces challenges in successfully benefiting from OFSP. One of the major challenges is lack of improved varieties as the current literature indicates that over 95% of sweet potato produced in Malawi is white or cream fleshed (Chipungu, 2008). These varieties are also responsible for the low beta-carotene as well as dry matter contents (Brabet et al., 1999; Carey et al., 1999; Chipungu, 2009). It is against this background that a series of on-station and on-farm trials on elite orange fleshed sweet potato genotypes was conducted across the country to evaluate growth, yield stability as well as beta-carotene content (Chipungu, 2009; Kathabwalika et al., 2013).

However, there are contradicting findings on trend of beta-carotene content in OFSP grown at different altitudes. Studies conducted elsewhere have shown that an increase in altitude leads to subsequent increase in beta-carotene (Manrique and Hermann, 2000; Ndirigwe et al., 2007). On the other hand, beta-carotene content showed no clear trends with increasing or decreasing altitude in Tanzania (Mbwaga et al., 2007). Additionally, such studies have not been conducted in Malawi. Therefore, the aim of the study was to evaluate dry matter, starch and beta-carotene content in orange-fleshed sweet potato (*Ipomoea batatas* L.) genotypes in

three agro-ecological zones of Malawi.

MATERIALS AND METHODS

Sites and farmers selection

The first phase of this study was conducted at three sites representing three different agro-ecological zones of Malawi. The sites were Bembeke in Dedza District representing the high altitude, cool and wet plateau zone, Bunda in Lilongwe District representing middle altitude warm plain zone and Maseya in Chikhwawa District representing low altitude hot and dry agro ecological zone (Table 1). Classification of the agro ecological zones was based on altitude, soil conditions, temperatures and amount of rainfall (Saka et al., 2006; Kathabwalika et al., 2013).

Three farmers were selected to carry out the study at each site within agro ecological zone. Planting and management of sweet potato genotypes were reported in the previous study by Kathabwalika et al. (2013). During harvesting, fifteen sweet potato tubers for each genotype were randomly sampled and collected from each farmer's field in the three agro-ecological zones where the genotypes were grown. The samples were transported under cool conditions for laboratory analysis to reduce dehydration.

Sweet potato genotypes used

Eight promising orange fleshed sweet potato (OFSP) genotypes sourced from Kasinthula Agricultural Research Station namely, LU06/0299, LU06/0258, LU06/527, BV/009, LU06/0252, LU06/0428, Zonden and Kenya, were selected for evaluation of their dry matter, starch and beta-carotene contents. Zonden and Kenya, both released varieties, were used as checks for beta-carotene content. Table 2 shows descriptions of the genotypes.

Determination of dry matter, starch and β -carotene content

Dry matter content was determined by oven drying triplicates of 5 g samples at 80°C for 24 h and quantified as DM% = dry weight/fresh weight x 100 (Kwach et al., 2010; Yildirim et al., 2011). For beta-carotene content, five roots of each genotype were manually cut into small pieces of about 1 cm and mixed. The pieces were homogenized rapidly (2-3 min) to prevent enzymatic degradation of carotenoids. Celite and petroleum ether (PE) were used for extraction and partitioning of beta-carotene from prepared samples to get the filtrate (Rodriguez-Amaya and Kimura, 2004; Ukpabi and Ekeledo, 2009).

The filtrate for each sample was put in 1 x 1 cm cuvette and absorbance readings were taken at $\lambda = 450$ nm to determine beta-carotene content using UV/Vis spectrophotometer (Jenway 6405) and quantified as follows: beta-carotene ($\mu\text{g}/100$ g) = A x volume

Table 2. Genotype source, growth habit, skin and flesh colours, maturity in months after planting (MAP) and potential yield (t/ha).

Genotype	Female parent/source	Growth habit	Skin colour	Flesh colour	Maturity (MAP) *	Potential yield (t/ha)*
BV/009	LU96/374	Spreading	Cream	Deep orange	5	20-25
LU06/0252	Mafutha from RSA	Spreading	Purple	Pale orange	5	25-30
LU06/0258	Kakoma (TIS 3017) from IITA	Spreading	Cream	Yellow	5	20-25
LU06/0299	Kakoma (TIS 3017)	Spreading	Cream	Yellow	5	20-25
LU06/0428	Mugamba (Mogamba, CIP, Nairobi)	Spreading	Cream	Pale orange	3.5	30-35
LU06/0527	Kenya (SPN/O)	Spreading	Orange	Orange	5	30-35
Kenya (SPN/O)	Introduced cultivar	Semi-erect	Cream	Pale yellow	4 to 5	25-30
Zonderi	Local cultivar	Erect	Orange	Deep orange	5	10-15

*Data obtained from on-station results during the initial stages of the genotypes evaluation

(ml) $\times 10^4$ /Ac \times sample weight (g) where A is the absorbance, volume is the total volume of extract and Ac is the absorption coefficient of beta-carotene in petroleum ether (2592). For starch extraction, five raw tubers from each genotype were randomly sampled, washed clean and peeled. The peeled sweet potato samples were sliced with a knife and ground into small pieces after recording their initial weight. Thereafter, they were placed in a mixture of water and stirred for one to two minutes. The grinding process was repeated for three to four times till a homogenous suspension was obtained. The suspension was strained through fine cheesecloth into another beaker. Thereafter, the mixture was allowed to stand for few minutes and then the deposition of starch was noted at the bottom. The supernatant fluid was poured out and the beaker, containing the starch, was filled with water. The mixture was stirred well and allowed to settle. The process was repeated four to five times by separating starch that can be washed thoroughly. The compact white starch deposit was collected onto watch glass and dried in an oven. After weighing the sample gravimetrically, the amount was converted into percentage over the initial weight of the extracted potato sample.

Data analysis

Data was analyzed using Genstat 14th Edition statistical package where analysis of variance (ANOVA) was done on treatment means and Additive Main effects and Multiplicative Interaction (AMMI) model (Gauch, 1993) was

used to carry out stability analysis of beta-carotene content for the genotypes and environments.

RESULTS

Dry matter content

The interaction between genotype and environment was significant ($p < 0.001$) on root dry matter. Genotype LU06/0527 was the highest (34.4%) at Bunda, while BV/009 was the least (23.3%) (Table 3).

Genotype LU06/0428 was the highest at Bembeke with 34.1% followed by Zonderi with 33.7%, whereas Kenya was the lowest (27.5%).

The average dry matter content at Maseya was 28.6% with Zonderi being the highest with 35.4%, while LU06/0299 was the lowest with 22.5%. However, Zonderi consistently produced highest dry matter across sites with an average of 34.4%.

Starch content

Starch content showed significant differences ($p < 0.05$) across sites. Bembeke recorded the

highest percentage of starch (27.7%) followed by Bunda (22.4%), while Maseya had the lowest percentage (21.5%). Genotypes percentage and the interaction between sites and genotypes were not significantly different ($p > 0.05$) (Table 4). Kenya recorded the highest starch content (27.3%) across the agro ecological zones while the lowest starch percentage (23.5%) was recorded in BV/009 and LU06/0252.

Beta-carotene content

Beta carotene content was significantly different ($p < 0.001$) across sites and among genotypes. Beta carotene was highest at Maseya (4258.5 $\mu\text{g}/100\text{ g}$) followed by Bunda (3556.2 $\mu\text{g}/100\text{ g}$), while Bembeke was the least (3104.2 $\mu\text{g}/100\text{ g}$). Genotype LU06/0252 was the highest (6793.2 $\mu\text{g}/100\text{ g}$) followed by Zonderi (5620.9 $\mu\text{g}/100\text{ g}$) and BV/009 (5066.9 $\mu\text{g}/100\text{ g}$) (Table 5).

Kenya variety was the lowest in beta-carotene content. The interaction between sites and genotypes was significant ($p < 0.001$). Genotype LU06/0252 was the best performer at both Bunda and Bembeke, whereas BV/009 was the best at

Table 3. Dry matter (%) content of sweet potato genotypes across sites.

Genotype	Site			Mean
	Bunda	Bembeke	Maseya	
BV/009	23.3	31.7	25.5	26.8
LU06/0252	27.5	31.5	29.9	29.7
LU06/0258	31.2	31.5	23.5	28.7
LU06/0299	28.2	29.9	22.5	26.9
LU06/0428	26.2	34.1	32.8	31.0
LU06/0527	34.4	31.3	27.7	31.1
Zondeni	34.0	33.7	35.4	34.4
Kenya	33.7	27.5	31.5	30.9
Mean	28.8	31.4	28.6	30.0
Genotypes	P<0.001	LSD	0.01	
Sites	P<0.001	LSD	0.01	
G x E	P<0.001	LSD	0.03	
CV (%)	5.2			

Table 4. Starch content (%) of eight orange fleshed sweet potato genotypes across sites.

Genotype	Site			Mean
	Bunda	Bembeke	Maseya	
BV/009	24.6	28.4	17.6	23.5
LU06/0252	20.4	34.1	16.2	23.5
LU06/0258	24.5	25.8	25.3	25.2
LU06/0299	19.9	28.5	28.5	25.6
LU06/0428	20.1	26.9	15.6	20.9
LU06/0527	19.9	25.9	15.8	25.0
Zondeni	21.5	27.0	24.8	24.4
Kenya	28.5	25.3	28.2	27.3
Mean	22.4	27.7	21.5	23.9
Genotypes	P= 0.45			
Sites	P= 0.01	LSD	0.04	
G x E	P= 0.41			
CV (%)	24.0			

Maseya. On Maseya. On the other hand, Kenya was the least performer at Bunda and Maseya, while LU06/0299 performed poorly at Bembeke.

Stability of beta-carotene content

The variations due to genotypes, environment and interaction between genotype and environment accounted for 76.9, 15.2 and 7.9%, respectively, indicating that beta-carotene differences were mainly due to genotype (Table 6). The decomposition of interaction into principle components showed that IPCA1 and IPCA2 accounted for 78.1 and 21.9%, respectively, as such, IPCA1 was

Table 5. Beta-carotene content ($\mu\text{g}/100\text{ g}$) of orange-fleshed sweet potato genotypes across the study sites.

Genotype	Site			Mean
	Bunda	Bembeke	Maseya	
BV/009	3441.3	4238.1	7521.3	5066.9
LU06/0252	7869.9	5941.5	6568.3	6793.2
LU06/0258	1480.7	1882.6	2695.1	2019.5
LU06/0299	1241.2	649.4	2578.4	1489.7
LU06/0428	6336.8	3234.3	3234.6	4235.2
LU06/0527	2160.5	3542.9	3674.4	3125.9
Zondeni	5452.5	4446.3	6963.8	5620.9
Kenya	467.0	898.3	932.2	765.8
Mean	3556.2	3104.2	4258.5	3639.64
Genotypes	P<0.001	LSD	77.7	
Sites	P<0.001	LSD	47.6	
G x E	P<0.001	LSD	134.6	
CV (%)	2.3			

used to explain the stability of beta-carotene. Genotypes LU06/0252, Zondeni, BV/009 and LU06/0428 contained higher beta-carotene than LU06/0258, LU06/0299, LU06/0527 and Kenya.

Genotypes LU06/0428 and LU06/0252 showed negative interactions while the rest had positive interactions (Figure 1). However, Zondeni, LU06/0527, LU06/0299 and LU06/0299 had low positive interactions than the rest of the genotypes. Kenya had IPCA score close to zero. Bembeke and Maseya showed positive interactions while Bunda had negative interaction.

DISCUSSION

Results from this study indicated that dry matter content of most new genotypes, particularly LU06/0527, were comparatively similar to Kenya variety (a released check variety), hence suggesting their potential to be accepted by consumers. Dry matter content is an important quality parameter in sweet potato production as it indicates mealiness in the boiled or roasted sweet potato and is a property most preferred by consumers (Kathabwalika et al., 2013). The combination of high dry matter (>25 %) and starch helps in selection of cultivars (Brabet et al., 1999; Lebot, 2009). One of the major challenges for adoption of OFSP is their low dry matter content (Carey et al., 1999). These results also suggests that current breeding programmes which aim at producing OFSP with high dry matter are able to incorporate desirable traits. In this study, the highest beta-carotene content was produced at Maseya followed by Bunda and Bembeke. The beta-carotene trend could be attributed to prevailing environmental conditions in the study sites. Maseya is located at low altitude and is characterized by high temperatures, high nitrogen and organic matter levels.

Table 6. Analysis of variance according to Additive Main effects and Multiplicative Interactions (AMMI) of beta-carotene ($\mu\text{g}/100\text{ g}$).

Source of variation	Degree of freedom	Sum of squares	Mean square	Variation (%)
Total	71	364781123.0	5137762.0	
Genotypes (G)	7	288288827.0	41184118.0***	76.9
Environment (E)	2	16240269.0	8120134.0***	15.2
Reps (within E)	6	22761.0	3794.0	
GxE interaction	14	59929311.0	4280665.0***	7.9
IPCA1	8	49486262.0	6185783.0***	78.1
IPCA2	6	10443050.0	1740508.0	21.9
Error	42	299954.0	7142.0	

***Denotes significant at 1%.

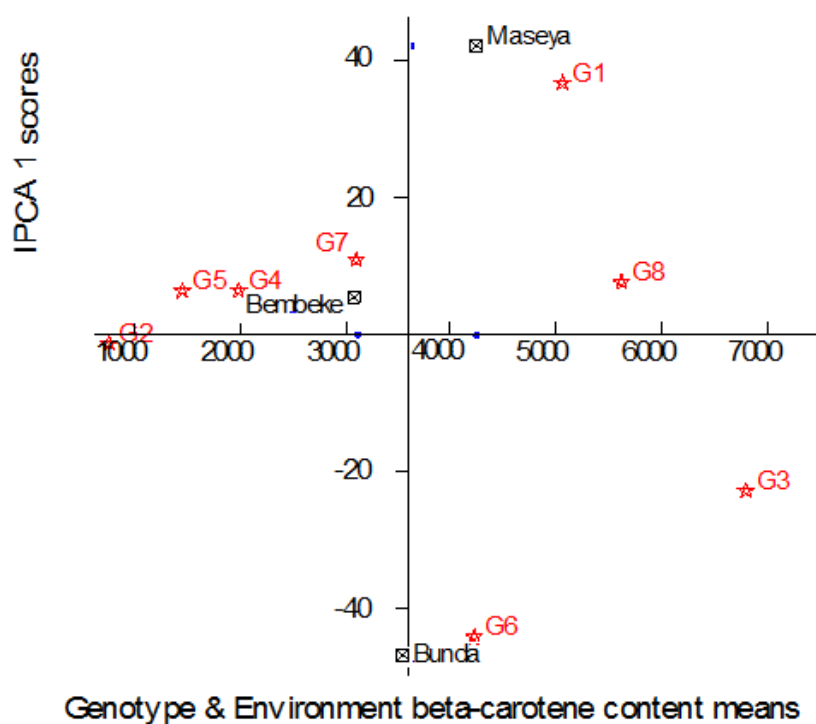


Figure 1. Biplot of IPCA 1 scores against beta-carotene content ($\mu\text{g}/100\text{ g}$) for eight OFSP genotypes grown in three locations. Genotypes: G1=BV/009, G2=Kenya, G3=LU06/0252, G4=LU06/0258, G5=LU06/0299, G6=LU06/0428, G7=LU06/0527, G8=Zondeni.

Bembeka is at high altitude and is characterized by cold temperatures, high soil nitrogen content and low organic matter. Bunda is at medium altitude and is characterized by warm temperature, moderate soil nitrogen content and moderate organic matter. These results compare well with findings of Ukoni et al. (2009) and Nedunchezhiyan et al. (2010) who reported that high nitrogen supply and organic matter increases beta-carotene content in OFSP.

Additionally, sweet potato is a tropical crop (Nedunchezhiyan et al., 2010), the high levels of beta-

carotene at Maseya were in agreement with Rodriguez-Amaya and Kimura (2004) who reported that high temperatures promote synthesis of carotenoids in tropical fruit crops. On the contrary, it is also reported that beta-carotene increases with increasing altitude (Mbwaga et al., 2007; Ndirigwe et al., 2007; Manrique and Hermann, 2000). The variations within genotypes would be a result of genetic make-up of the cultivars in the synthesis of carotenoids (Rodriguez-Amaya and Kimura, 2004). Some genotypes produce more beta-carotene than others due

to the differences in their genetic makeup. For example, LU06/0252 produced highest beta-carotene while Kenya consistently produced low levels of beta-carotene. In this study, the beta-carotene content values were comparatively similar to findings reported by Kapinga et al. (2010) where the OFSP cultivars grown in Eastern and Southern parts of Africa had values ranging from 5 000 to 10 000 µg/100 g.

Stability analysis of beta-carotene showed that Bunda and Maseya were favorable environments for genotypes LU06/0428 and BV/009, respectively while genotypes LU06/0299, LU06/0258 and Zondeneni were moderately stable across sites. Kenya variety, though contain low beta-carotene, was the most stable among the genotypes. The differences in stability of genotypes could be attributed to variations in ability to utilize available resources such as temperature, light, soil nutrients and water. The results also revealed that Zondeneni and Kenya, which had low tuber yield (Kathabwalika et al., 2013) and beta-carotene content, were most stable, suggesting that genotypes with low yields are not responsive to environmental changes. Differences in beta-carotene stability have also been reported elsewhere (Mbwaga et al., 2007; Ndirigwe et al., 2007; Manrique and Hermann, 2000). Among the production sites, Maseya had the overall highest beta-carotene content as indicated by its position found on the right side of the IPCA1 in the study. This site could, therefore, be suitable for selection of genotypes with high beta-carotene content (Egesi and Asiedu, 2002; Sanni et al. 2009; Tiawari et al. 2011 Mwale et al., 2009).

Conclusion

The study revealed significant differences in dry matter, beta carotene content and stability of OFSP genotypes. Dry matter is one of the most important quality aspects in sweet potato and in this study, most of the OFSP genotypes ranged between 25 and 30%. Beta-carotene content differed within genotypes and across production sites. Genotypes LU06/0252 and Zondeneni consistently produced highest amounts of beta-carotene across sites, while Kenya consistently recorded the least amount. Furthermore, the study showed that beta-carotene increased with increasing temperature of the agro ecological zones, indicating that temperature, as one of the crucial environmental factors, should be considered when producing orange-fleshed sweet potato. The findings also indicate that Kenya variety was the most stable variety in beta-carotene content, while LU06/0258, LU06/0299 and Zondeneni were moderately stable.

Conflict of interests

The authors have not declare any conflict of interest.

ACKNOWLEDGEMENT

This work was funded by Agri-Food Systems Project under International Development Research Center (IDRC).

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