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Research Article

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Yield, nutritional quality and stability of orange-fleshed sweetpotato cultivars successively later harvesting periods in Mozambique

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Abstract: Long-term storage of sweetpotato roots is a great challenge for smallholder farmers in Mozambique. Piecemeal harvesting allows several months supply of roots for household consumption provided weevil infestation is avoided. The objectives of the present studies were to determine yield and changes in key macro- and micronutrients associated with early or late harvesting of orange-fleshed sweetpotato cultivars in Mozambique. Four trials representing harvesting periods of 3, 4, 5 or 6 months after planting were established at Gurue in 2015. The randomized complete block design with three replications was laid in each trial. Yield measurements were done in the field and samples were selected and scanned for dry matter, beta-carotene, iron, zinc and carbohydrate using Near Infrared Spectrometry. Collected data were statistically analysed (SAS 1997 software). Yield, dry matter, starch, iron and beta-carotene increased linearly in some cultivars as time to harvest was prolonged. Iron was not affected by harvesting period. Stability of micronutrients such as iron, zinc and beta-carotene is essential when piecemeal harvesting. The study allowed accurate grouping of the cultivars tested into maturity groups for the first time.

Keywords: sweetpotato, nutritional stability, storage root, maturity at harvest

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1 Introduction

Sweetpotato (*Ipomoea batatas* (L.)) is the seventh most important food crop in the world and is primarily grown for its starchy storage roots and immature leaves (Lebot 2009; Woolfe 1992). In Mozambique, sweetpotato is the third most important food crop after maize and cassava (INIA-IITA/SARRNET 2003). The 20 orange-fleshed sweetpotato (OFSP) cultivars grown in Mozambique share the market with white- and cream- fleshed cultivars. Growing OFSP as a food security crop is one way to alleviate vitamin A deficiency (VAD) (Low et al. 2007 which in Mozambique, is among the major health problems faced by women and children. Children with VAD are often deficient in other micronutrients such as iron and zinc, have impaired growth, are at increased risk of morbidity from common infections and become blind after extreme VAD (Birol et al. 2015).

Sweetpotato are normally harvested five months after planting in Mozambique but there is well-known variability in maturation rate amongst cultivars. Though equally important, root quality is not considered to set the harvest date. Root quality is associated with root appearance, flavor, texture, nutritional attributes, health benefits and suitability for industrial processing (Lewthwaite 1997). There have as yet been no studies to determine the stability of nutrition quality of OFSP cultivars harvested at different times in Mozambique. Beta-carotene, DM, protein, carbohydrates and sugar concentration are principal components of sweetpotato quality and these parameters of quality vary over the period of root development (La Bonte 2000) as well as between cultivars (Hagenimana et al. 1999).

Currently, there is increasing commercial interest in Sub-Saharan Africa for OFSP for bread and biscuit production and juice. This, in addition to piecemeal harvesting for domestic consumption, requires the continuous supply of storage roots. The objectives of the present study were to determine storage root yield and changes in key macro- and micro-nutrients associated with early or late harvesting of OFSP varieties in Mozambique.

2 Materials and methods

Four field experiments were planted on 18 December 2015 at Gurue Research Station. Table 1 shows the list of OFSP varieties evaluated. The trials were planted in a randomised complete block design with three replications. Row-row spacing was 0.9 m and plant-plant spacing within a row was 0.3 m. Each plot had five rows of four meters length with a total of 65 plants per plot. Each of the four trials was assigned to a harvest date; 90, 120, 150 or 180 days after planting (DAP). At each harvest date, the following agronomic traits were measured from the net plot:

- Storage root yield (t ha^{-1})
- Vine weight (t ha^{-1})
- Weevil damage using a 1–9 scale, where 9 = extremely severe damage, 7 = severe, 5 = moderate, 3 = light and 1 = no damage.
- Root size using 1-9 scale, 9 = extremely big, 7 = big, 5 = medium, 3 = small, 1 = very small.
- For each harvest date, starch, iron (Fe), zinc (Zn) and beta-carotene levels of each clone was determined in the laboratory. Three commercial roots were randomly selected from each plot and sent to laboratory for measurement of quality traits. Dry matter content (DM, %) was determined by taking approximately 50 g of peeled sample from each of the three roots and freeze drying at 70^{o} C for 72 hours.

The samples were reweighed for dry matter determination after freeze drying.

- Near-infrared reflectance spectroscopy (NIRS) (Shenk and Westerhaus 1993) was used to determine beta-carotene, starch, sucrose, fructose, glucose, protein, iron and zinc content in milled freeze-dried samples (Burgos et al. 2009).

Table 1: List of sweetpotato varieties evaluated for planting to maturity interval and nutritional changes over different harvest dates after a December 2015 planting at Gurue Research Station

Variety name	Breeding code	Plant type	Cultivar type	Flesh colour	Skin colour
Esther	MUSGO603-02	Semi-erect	Released	Intermediate orange	Brownish orange
Ininda	Tacna-2	Semi-erect	Released	Strongly pigmented with anthocyanins	Purple-red
Sumaia	UW119 06-289	Semi-erect	Released	Intermediate orange	Brownish orange
Delia	105369-4	Erect	Released	Pale orange	Purple-red
Bela	UW119 06-79	Semi-erect	Released	Pale orange	Purple-red
Erica	UW119 06-284	Semi-erect	Released	Intermediate orange	Brownish orange
Gloria	Ejumula	Erect	Released	Intermediate orange	Purple-red
Namanga	UW119 06-175	Semi-erect	Released	Pale orange	Brownish orange
Cecilia	Ejumula-25	Erect	Released	Pale orange	Brownish orange
Irene	Kakamega-7	Semi-erect	Released	Pale orange	Purple-red
Melinda	W119 – 15	Semi-erect	Released	Intermediate orange	Brownish orange
Tio Joe	MUSG 0616-18	Semi-erect	Released	Dark orange	Brownish orange
Lourdes	UW119 06- 140	Semi-erect	Released	Intermediate orange	Brownish orange
Jane	LO323-1	Erect	Released	Intermediate orange	Brownish orange
Amelia	Mafutha -1	Semi-erect	Released	Intermediate orange	Brownish orange
Alisha	Uejumula-U07-13	Spreading	Released	Intermediate orange	Cream
Ivone	MUSG11022-11	Semi-erect	Released	Towards deep orange	Red
MUSGP0646-126	MUSGP0646-126	Spreading	Elite	Dark orange	Red
Victoria	MCKSG0820-6	Spreading	Released	Dark orange	Brownish orange
Lawrence	MUSG11016-16	Semi-erect	Released	Intermediate orange	Orange
Bita	MUSG11016-12	Extremely spreading	Released	White with anthocyanins	Purple-reddish
Caelan	MUSG11016-6	Spreading	Released	Light orange with anthocyanins pigments	Red
MUSG11016-1	MUSG11016-1	Semi-erect	Elite	Strongly pigmented with anthocyanins	Dark purple
Bie	MUSG11049-7	Semi-erect	Released	Pigmented with anthocyanins	Dark purple
Chingova	-	Erect	Check	yellow	Cream
Jonathan	-	Erect	Check	orange	Light orange
Resisto	-	Spreading	Check	Deep orange	pink

2.1 Data analysis

Collected data were analysed using SAS 1997 software.

3 Results

3.1 Effect of genotype and harvest date on the traits measured

Combined analysis of data across the harvesting periods showed that genotype had a highly significant effect on both commercial and non-commercial root yield, total vine yield, dry matter, beta-carotene and starch (Table 2). Harvesting period also had a highly significant effect on commercial root yield, non-commercial root yield, weevil damage, other root injury, dry matter, zinc and starch. The overall mean for commercial and non-commercial root yield as well as total vine yield was below 10 tha^{-1} across the harvesting dates. Weevil damage was high, scoring a value of 5.31 across the harvesting dates. Harvesting date affected neither total vine yield nor iron content. Genotype had no effect on weevil damage and other physical injuries.

3.2 Stability of storage root yield and nutritional quality at different harvesting dates

No marketable yield of storage root was recorded at 180 DAP (Table 3). Non-marketable root yield was significantly higher at 180 DAP than the other harvesting dates. In general, total storage root yield increased as the harvesting days were prolonged from 90 to 150 DAP. However, no significant difference on total storage root yield was observed between 150 DAP and 180 DAP. Weevil damage and other root injury or damage was significantly higher at 180 DAP than other harvesting dates. Storage roots were significantly smaller at 90 DAP than other harvesting periods. Storage root size stabilized from 120 to 180 DAP.

Dry matter content increased with interval from planting to harvest upto 150DAP but not to 180DAP (Table 3). The iron content was stable from 90 to 180 DAP while Zinc content stabilized from 120 to 180 DAP. Beta-carotene was stable from 90 DAP upto 150 DAP and significantly increased at 180 DAP. The starch content also significantly increased from 90 DAP to 150 DAP and then dropped slightly at 180 DAP. Beta-carotene was stable from 90 to 150 DAP and significantly lower than at 180 DAP.

Table 2: P-values of harvesting dates and genotypes on storage root yield, vine yield, root size, weevil damage and nutritional traits analysed across four different harvesting periods at Gurue in 2015

	Traits measured										
Source of variation	**RYCHa**	**RYNCHa**	**RVY**	**RS**	**WED1**	**DAMR**	**DM**	**Fe**	**Zn**	**BC**	**Starch (%, DW)**
Harvest date	<.0001	<.0001	0.7721	0.0134	<.0001	<.0001	<.0001	0.7447	<.0001	0.0039	<.0001
Genotype	<.0001	<.0001	<.0001	0.0122	0.118	0.1152	<.0001	0.1514	0.0577	<.0001	<.0001
Mean	**1.30**	**6.18**	**8.83**	**5.02**	**5.31**	**3.91**	**25.44**	**1.83**	**1.86**	**16.95**	**52.84**
Range	**0.0-3.6**	**2.3-10.8**	**1.2-20.0**	**3.5-6.3**	**3.4-7.8**	**2.8-5.7**	**20.2-36.3**	**1.2-2.4**	**1.1-4.8**	**0.0-37.3**	**39.4-67.1**

DAP: days after planting; RYCHa: marketable storage root yield (tha^{-1}); RYNCHa: non-marketable storage root yield (tha^{-1}); RVY: total vine yield (tha^{-1}); RS: root size (1 = very small, 3 = small, 5 = medium, 7 = big, 9 = extremely big); WED1: weevil damage (1 = no damage, 3 = light damage, 5 = moderate damage, 7 = severe damage, 9 = extremely severe damage); DAMR: other root injury or damage (1 = no damage, 3 = light damage, 5 = moderate damage, 7 = severe damage, 9 = extremely severe damage); DM: dry matter (%); Fe: iron (mg 100g^{-1}, DW); Zn: zinc (mg 100g^{-1}, DW); BC: beta-carotene (mg 100g^{-1}, DW).

Table 3: Means for storage root yield, vine yield, root size, weevil damage and nutritional traits measured across four different harvesting dates at Gurue in 2015

Harvest date	**RYCHa**	**RYNCHa**	**RVY**	**RS**	**WED1**	**DAMR**	**DM**	**Fe**	**Zn**	**BC**	**Starch (%, DW)**
90 DAP	1.6 (B)	3.0 (D)	9.9 (A)	4.2 (B)	3.6 (C)	2.3 (C)	14.6 (C)	1.7 (A)	3.8 (A)	15.3 (B)	33.5 (C)
120 DAP	2.5 (A)	4.9 (C)	8.8 (A)	5.1 (A)	2.9 (C)	2.2 (C)	25.0 (B)	1.8 (A)	2.0 (B)	17.1 (A B)	53.2 (B)
150 DAP	1.4 (B)	6.8 (B)	8.8 (A)	5.0 (A)	5.7 (B)	4.3 (B)	28.1 (A)	1.9 (A)	1.4 (B)	15.4 (B)	59.0 (A)
180 DAP	0.0 (C)	8.4 (A)	8.4 (A)	5.4 (A)	7.5 (A)	5.8 (A)	29.1 (A)	1.9 (A)	1.3 (B)	19.0 (A)	56.9 (B)

DAP: days after planting; RYCHa: marketable storage root yield (tha^{-1}); RYNCHa: non-marketable storage root yield (tha^{-1}); RVY: total vine yield (tha^{-1}); RS: root size (1 = very small, 3 = small, 5 = medium, 7 = big, 9 = extremely big); WED1: weevil damage (1 = no damage, 3 = light damage, 5 = moderate damage, 7 = severe damage, 9 = extremely severe damage); DAMR: other root injury or damage (1 = no damage, 3 = light damage, 5 = moderate damage, 7 = severe damage, 9 = extremely severe damage); DM: dry matter (%); Fe: iron (mg 100g^{-1}, DW); Zn: zinc (mg 100g^{-1}, DW); BC: beta-carotene (mg 100g^{-1}, DW). Values with same letters in brackets are not significantly different ($p>0.05$).

4 Discussion

The current study focussed on storage root yield and quality traits against a background of the need for piecemeal harvesting for household consumption and sale of the surplus. While performance of the varieties evaluated at 150 DAP is well documented (Andrade et al. 2016a,b), harvests at 90DAP, 120DAP and 180DAP are not and the stability of root quality traits across these harvest dates are not known.

Storage root yield was lower compared to previous findings at Gurue Research Station (Andrade et al. 2016a,b). The trials were subjected to mid-season and terminal drought. Irrigation was necessary to mitigate effects of drought. Drought not only affected productivity but quality of roots as well. Weevil damage and other root injuries are often associated with drought and significantly increased as harvesting was delayed. All the storage roots harvested at 180 DAP were classified as non-marketable due to weevil damage and physical injuries. Azevedo et al. (2014) had similar findings after ceasing irrigation at 120 DAP.

Total storage root yield was not stable at all the harvest dates but increased with delayed harvesting date. The results agree with other studies which have assessed storage root yield over different harvest dates. Queiroga et al. (2007) recorded higher storage root yield after 155DAP harvests compared to 105DAP and 130DAP. In the current study, maximum storage root yields arose after harvesting between 150 and 180 DAP. However, weevils need to be controlled through agronomic or cultural practices. Harvesting can however, commence as early as 90DAP for varieties such as Irene, Victoria, Sumaia and Ivone. In keeping with the finding that maximum vine production is recorded between 45 to 90 DAP and later phases are devoted to accumulation of assimilates in storage roots, total vine yield was stable over the four harvesting dates.

Farmers pay particular attention to taste and quality traits before adopting a variety (Gruneberg et al. 2005). Population means for starch were 53.2 % (120DAP), 59.0 (150DAP) and 56.9 % (180DAP) and consistent with previous findings of 56.3 to 64 % (La Bonte et al. 2000; Brabet et al. 1999). A quantitative increase in DM% during development was observed though this was cultivar dependent. The DM% and starch % levels of some of the OFSP varieties evaluated in the current study were higher than previously described. The breeding program in Mozambique since 2009 has strived to improve DM in orange fleshed clones. Woolfe (1992) had described OFSP of Latin American origin as ‘soft’ with DM% ranging between 45% and 55%. The new ‘hardness’ status of recently released varieties in Mozambique may enhance consumer acceptance and help combat vitamin A deficiencies. Changes in micronutrient content was also monitored across the different harvesting periods. Iron content was very stable across all the four months of harvesting and zinc was stable from 120 until 180 DAP. Beta-carotene content was stable from 90 to 150 DAP. Farmers can do piecemeal harvest as early as 90 DAP in varieties such as Irene, Victoria, Sumaia and Ivone and enjoy nutritional benefits associated with OFSP. Varieties namely Irene, Sumaia, Victoria, Ivone, Bita and Caelan are early maturing and could be recommended for production in areas with short rainy seasons.

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