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Research article

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Adapting sweetpotato production to changing climate in Mozambique

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Abstract: Vines are the major source of planting material in sweetpotato. Extended dry spells hinder conservation of vines and in turn affect the availability of planting material at the onset of rains in southern Africa. In some cases, improved sweetpotato germplasm has been lost by smallholder farmers in Mozambique due to prolonged dry spells. Small to medium roots provide an opportunity to conserve germplasm and get planting material at the beginning of the rainy season. The objectives of the study were to (i) measure sprouting ability of diverse germplasm of sweetpotato - farmer varieties, improved clones and released varieties and (ii) estimate their ability to provide planting material for the next crop in southern Mozambique. Trials with 29 genotypes were established in a randomized complete block design with two replications at Umbeluzi Research Station and Nwalate Farm in 2015, 2016 and 2017. At harvest, 14 small to medium roots were selected and stored in small plastic dishes filled with dry sand at Nwalate Farm. After four months in storage, 10 similar roots were taken and planted in 1 m row plots arranged in a randomized complete block design with two replications. The trials were irrigated to initiate sprouting and support plant growth during the first four weeks. Data collected were analysed using SAS 1996. All the tested genotypes sprouted after sowing. The number of sprouts per root were significantly affected by the genotype, location and genotype x location x year interactions. Caelan had the most sprouts per root. Sprout length measured at six weeks after sprouting was also significantly affected by genotype, location, year and genotype x location x year interactions. Caelan had vines each long enough to provide 10 cuttings of 10 cm length for rapid multiplication. The number of cuttings depended on the growth habit of the variety. Irene, a popular variety in Mozambique, is erect and bushy and could only provide four cuttings over the same period. Growth habit especially under a changing climate should be considered in breeding programs as an option of facilitating a sustainable and easy seed system.

Keywords: drought, seed system, sprouting, storage roots, sweetpotato

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1 Introduction

Sweetpotato (*Ipomoea batatas* [L.] Lam.) is cultivated in both tropical and sub-tropical climates, contributing to national food and nutritional security in many developing countries (FAO 2009; Truong et al. 2011). In Mozambique and other countries in sub-Saharan Africa, sweetpotato is used instead of bread and other food stuffs in low income households (Kapinga et al. 2005) and its sale can also generate incomes for smallholder farmers and traders (Rees et al. 2001).

In Mozambique, a total of 19 orange - and three purple-fleshed sweetpotato varieties were released since 2011 (Andrade et al. 2016a, 2016b). The varieties were released as drought tolerant and perform well in the drought prone regions of Southern and Western Mozambique. The agricultural sector is the most vulnerable to climate change, where drought tops the list among abiotic constraints to crop productivity in Mozambique. Approximately 95% of crop production areas are rainfed and under the custody of small-scale farmers. In these regions, the persistent droughts have forced farmers to diversify out of maize, the leading food grain, and other cereal crops (Andrade et al. 2006). Given its drought tolerance, adaptability to low external input requirements and nutritional qualities, sweetpotato has become a priority in crop based strategies for enhancing food and nutritional security in the tropics (Bouis and Islam 2012; Pfeiffer and McClafferty 2007). In

Mozambique, 24% of sweetpotato production derives from drought tolerant orange fleshed varieties. Increasing the diversity of crop varieties is important to achieve food security in the face of a changing climate (Cotter and Tirado 2008). The effects of climate change are predicted to increase the severity of drought, crop yield reductions and area under crop production (Li et al. 2011; Gregory et al. 2005). Irrigation technologies do not exist or are poorly developed and in most cases not accessed by smallholder farmers due to their prohibitive costs in Mozambique.

The most popular method of sweetpotato propagation in Mozambique and other countries in sub Saharan Africa is vine cuttings from existing crops (Loebenstein and Thottappilly 2009). Rains are unimodal in southern Africa and, in some places, dry periods between growing seasons can be 4-8 months. This poses great challenges in conservation of planting material (vines) from one season to another. The most commonly used method is to plant conservation plots near river banks and other lowlands with residual moisture. Recently, this method is under threat due to climate change where lowlands and rivers dry before the coming of the wet season. In Mozambique, drought prone areas are localized in all provinces lying south of Save River and Tete province in Western Mozambique. The driest is southern and southeast regions, where some areas receive 300 mm rainfall per annum (Climate Service Center 2013; World Bank 2011). Rainy season starts from November to April with the majority falling between December and February. The annual average rainfall has decreased by about 3% per decade between 1960 and 2006, with the southern parts of the country seeing the largest rainfall decreases (World Bank 2011). Lack or inadequate supply of planting material (vines) and drought are the commonly cited challenges contributing to low yield in southern Africa (Mutandwa 2008; Kapinga et al. 1995). Inadequate and insufficient planting material reduces planting area, potential yield, overall harvests and general agricultural performance (Ogero et al. 2012). In 2001, only 7% of the sweetpotato growers had access to healthy seed in Kenya where seed systems are better developed than Mozambique (Roy-Macauley 2002).

There is little published information on sweetpotato seed systems and available options of conserving varieties in the farming communities. The system is dominated by farmer to farmer seed exchange and farmers source planting material in their own fields. Due to diversity and complexity of smallholder farming system in Southern Africa, McEwan et al. (2016) discussed many methods used to conserve vines in the region. Low lying areas and groundkeeper storage roots for sprouting later in the season were mentioned prominently. Earlier on, Almekinders et al. (1994) had argued that different seed sources do not guarantee a viable seed system in sweetpotato because either smallholder farmers do not know of the technology or technology is not suitable for them. The challenges facing southern Mozambique and Tete province in Mozambique are prolonged dry spells and the disappearance of low lying areas with residual moisture due to climate change. In addition, mixed crop-livestock farming systems are practiced and rodents pose a threat for groundkeeper storage roots.

Storage of non-damaged small unmarketable roots in dry sand at smallholder farmers' homes during the dry period seems to offer a better avenue for conserving sweetpotato germplasm in drought prone regions. The roots are sprouted in protected beds, between 5 and 7 weeks before the onset of the rain season (Namanda et al. 2012). Vine cuttings from sprouted roots is a widespread practice in China and has a yield advantage of 30% above normal planting material (Fuglie et al. 1999). The current study was formulated to assess the ability of a diverse sweetpotato germplasm collection to provide vines from roots stored in dry sand for four months as sources of planting material for subsequent seasons in southern Mozambique where prolonged dry spells are common.

2 Materials and methods

2.1 Study material

A total of 29 sweetpotato genotypes (Table 1) were evaluated for sprouting and ability to provide planting materials for the next crop at Umbeluzi Research Station and Nwalate Farm (both sites are in southern Mozambique) in 2015, 2016 and 2017. The clones comprised 16 varieties released in Mozambique (CIP-Moz) and one elite genotype in the Mozambique breeding program, six farmer varieties collected in Mozambique, one genotype from Zimbabwe, one genotype from the USA and four from CIP, Peru. All genotypes were clean from viruses.

2.2 Study locations

Umbeluzi Research Station lies at an altitude of 12 m.a.s l. and experiences minimum temperatures between 11.5°C and 22.7°C, while maximum temperatures varies from 24.7°C to 37°C. The soil texture ranges from sandy loam in the topsoil to sandy at 1.75 m depth (Ripado 1986). Nwalate lies at an altitude of 8 m.a.s.l., 7 km west of Umbeluzi

Table 1: Genotypes evaluated for sprouting and ability to provide vines for the next crop at Umbeluzi Research Station and Nwalate Farm in southern Mozambique in 2015, 2016 and 2017

Number	Name of Genotype	Origin	Flesh colour	Year of release
1	Xitsekele	Inhambane*	White	-
2	Namanga	CIP-Moz	Orange	2011
3	Chissicuana 3	Inhambane*	White	-
4	Lourdes	CIP-Moz	Orange	2011
5	Melinda	CIP-Moz	Orange	2011
6	Irene	CIP-Moz	Orange	2011
7	Delvia	CIP-Moz	Orange	2011
8	Ininda	CIP-Moz	Orange	2011
9	Amelia	CIP-Moz	Orange	2011
10	Xiadla xa kau	Chokwe*	White	-
11	Jane	CIP-Moz	Orange	2011
12	Gloria	CIP-Moz	Orange	2011
13	Lawrence	CIP-Moz	Orange	2016
14	Mwazambane	Chokwe*	White	-
15	Bie	CIP-Moz	Purple	2016
16	Japon	CIP	Orange	2000
17	Victoria	CIP-Moz	Orange	2016
18	Chissicuana 2	Inhambane*	White	-
19	MUSG11016-1	CIP-Moz	Purple	-
20	Caelan	CIP-Moz	Purple	2016
21	Chingova	Zimbabwe	White	2000
22	Cinco houras	Chokwe*	White	-
23	Resisto	USA	Orange	2000
24	Bita	CIP-Moz	Purple	2016
25	Jonathan	CIP	Orange	2000
26	Alisha	CIP-Moz	Orange	2016
27	Tacna	CIP	White	2006
28	MGCL01	CIP	Orange	2000
29	Ivone	CIP-Moz	Orange	2016

*: farmer varieties from Mozambique, CIP-Moz: bred inside Mozambique, CIP: CIP bred outside Mozambique

Research Station. The soils are porous, cracking black alluval soils which are compact and sticky when wet. The soils are rocky from 1 m depth level.

2.3 Rainfall data

Rainfall, and maximum and minimum temperatures were measured on a daily basis using HOBO U30 NRC-SYS-B Weather station during the period of the trials at Umbeluzi Research Station and conventional weather station at Nwalate Farm (Table 2).

2.4 Experimental design and agronomic management of the production of roots which were used in the sprouting trials

Single row plots 4 m long were assigned to each genotype following a randomized complete block design with two replications. A row-to-row distance of 0.9 m and a plant-to-plant spacing of 0.3 m was maintained. The trials were planted in mid-January in 2015, 2016 and 2017 under rainfed conditions supported by irrigation during dry spells at both Umbeluzi Research Station and Nwalate Farm. A total of 60 mm of irrigation water was applied fortnightly during the dry spell. The trials were established without any basal or top dress fertilizer application at both locations. The fields were also kept weed and pest free by hand hoe weeding at weed appearance and chemical pest control at each location.

2.5 Data recording at 150 days after planting

Multiple traits were measured at different growth stages based on accepted sweetpotato trait ontology (http://www.cropontology.org/ontology/CO_331/sweetpotato). Harvesting was done at 150 days after planting (DAP) and 14 small to medium sized undamaged roots were selected

Table 2: Rainfall (mm) received at Umbeluzi Research Station and Nwalate Farm during the rainy and dry seasons in 2015, 2016 and 2017

	Umbeluzi Research Station			Nwalate Farm		
Year	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Month						
RAINY SEASON						
November	13.1	60.4	196.2	132.0	28.7	148.4
December	9.1	43.9	44.8	0.0	41.0	38.9
January	36.4	6.3	148.5	155.0	17.5	171.9
February	49.4	0.0	104.7	61.0	32.7	112.3
March	11.4	238.1	157.7	0.0	121.0	105.7
April	15.4	22.3	18.9	0.0	0.0	26.9
TOTAL	**134.8**	**371.0**	**670.8**	**348.0**	**240.9**	**604.1**
DRY SEASON						
May	12.9	62.7	20.7	0.0	98.5	48.0
June	0.0	19.9	0.0	0.0	0.0	0.0
July	6.3	54.3	4.6	0.0	28.6	0.0
August	0.8	0.0	21.1	0.0	0.0	0.0
September	13.7	69.8	35.1	0.0	29.5	17.7
October	16.8	58.9	70.6	0.0	22.5	33.0
TOTAL	**50.5**	**265.6**	**152.1**	**0.0**	**179.1**	**98.7**

at Umbeluzi Research Station and Nwalate Farm. The storage roots selected at Umbeluzi Research Station and Nwalate Farm were stored in a well-ventilated storage house in plastic dishes covered with dry sand at Nwalate Farm. The storage house mimicked smallholder farmers' granaries in Mozambique.

Another three good storage roots were randomly selected from each plot at harvesting and sent to CIP laboratory in Maputo for quality traits assessment. The following traits were measured:

- Dry matter content (DM, %). A sample of approximately 50 g was taken after bulking the three peeled roots for each genotype and replication and freeze dried at 72ºC for 72 hours. After freeze drying, the samples were reweighed to determine the dry matter content.
- Starch using the Near-infrared reflectance spectroscopy (NIRS) technology on the milled freeze-dried samples (Burgos et al. 2009).

2.6 Sprouting trials

Ten roots were drawn out of the storage room after four months of storage during the first week of November in 2015, 2016 and 2017 and planted in a seed nursery at Umbeluzi Research Station and Nwalate Farm for sprouting. Stored roots from Umbeluzi Research Station were planted at Umbeluzi and the same applied for those from Nwalate Farm. Single row plots 1 m long were assigned to each genotype following a randomized complete block design with two replications. Five storage roots were planted in a 1 m row at a plant-to-plant distance of 0.25 m. A row-to-row distance of 0.9 m was maintained with no space left at either the sides or ends of the plots. The trials were watered by a manual watering can along each row at planting and twice a week until seven weeks after sprouting. No fertilizer was applied to the trials.

2.7 Data recording for sprouting trials

Data on the number of sprouts per root at four weeks and length of the sprouts at six weeks were recorded.

2.8 Data analysis

SAS/STAT Software (SAS 1997) was used for the analysis of variance (ANOVA) and estimation of trait means across locations.

Ethical approval: The conducted research is not related to either human or animals use.

3 Results

The dry season was characterized by no to little rains and stretched for a minimum period of five months (Table 2). The dry seasons of 2015 and 2017 received the least rainfall during the three years and Nwalate Farm was most affected. The trials received enough rainfall after establishment in November 2017 at both locations for sprouting and growth of vines.

Genotype x location x year interactions had highly significant differences on the length of sprouts measured at six weeks after sprouting and significant effects on number of sprouts per root (Table 3). The expression of quality traits, dry matter and starch contents measured at harvest (150 DAP) and four months after storage at the two locations were highly and significantly influenced by the genotype x location x year interaction. Locations had highly significant differences for the length of sprouts measured at six weeks. Number of sprouts per genotype were significantly different between locations. Umbeluzi Research Station had higher means for both length of sprouts measured at six weeks after sprouting and number of sprouts per root than Nwalate Farm (Table 4). Years had highly significant effects on number of sprouts per genotype, length of sprouts measured at six weeks, dry matter and starch contents measured at harvest. The sowed roots gave the highest number of sprouts per root in 2017 while longest sprouts were produced in 2015 (Table 5).

Xitsekele and Caelan had the least and most sprouts per root across the two locations respectively (Table 6). In terms of length of sprouts measured at six weeks after sowing, MUSG11016-1 and Caelan had the shortest and longest sprouts respectively. The dry matter was higher than 30% in all purple, white and yellow fleshed genotypes and the same genotypes had most starch at harvest. At four months after storage, the same genotypes had higher than 26% dry matter contents and higher starch contents. There was a decrease in dry matter and starch contents by an average of 10.55 and 9.74% respectively when compared at harvest and after four months of storage (Table 6).

The Pearson correlation coefficients showed significant positive correlations between number of sprouts per root and the starch content at harvest and the length of sprouts measured at six weeks after sprouting (Table 7). Significant correlations above 0.15 also existed between the length of sprouts measured at six weeks after sprouting and the dry matter content at harvest

Table 3: P-values of number of sprouts per genotype, length of sprouts measured at six weeks after sprouting (cm), dry matter content at harvest and four months after storage (%) and starch content at harvest and four months after storage (%) analysed across data collected at Umbeluzi Research Station and Nwalate Farm in 2015, 2016 and 2017

		Number of sprouts/genotype		Length of sprouts (cm)		Dry matter at harvest (%)		Dry matter content 4 months after storage (%)		Starch content at harvest (%)		Starch content 4 months after storage (%)	
Source	**DF**	**F Value**	**Pr > F**	**F Value**	**Pr > F**	**F Value**	**Pr > F**	**F value**	**Pr> F**	**F Value**	**Pr > F**	**F Value**	**Pr > F**
Genotype (geno)	28	1.85	0.0129	1.5	0.0003	6.61	<.0001	4.4	<.0001	5.24	<.0001	3.42	<.0001
Location (loc)	1	10.45	0.0016	34.4	<.0001	0.84	0.3618	1.81	0.1847	1.31	0.2548	1.29	0.2606
Year (y)	2	26.74	<.0001	31.5	<.0001	24.1	<.0001	0.01	0.9261	104.46	<.0001	4.57	0.0373
Geno* loc* y	114	1.55	0.0101	7.01	<.0001	2.99	<.0001	3.72	<.0001	2.52	<.0001	2.48	0.0007
rep(loc)	2	1.97	0.144	1.92	0.1512	0.56	0.5732	0.19	0.8268	1.06	0.3503	3.19	0.0495

Table 4: Effect of locations on means of number of sprouts per genotype, length of sprouts measured at six weeks after sprouting (cm), dry matter content at harvest and four months after storage (%) and starch content at harvest and four months after storage (%) from analysed data collected at Umbeluzi Research Station and Nwalate Farm in 2015, 2016 and 2017

Location	Number of sprouts/root	Length of sprouts (cm) at six weeks	Dry matter content at harvest (%)	Dry matter content after 4 months of storage (%)	Starch content at harvest (%)	Starch content after 4 months storage (%)
Nwalate Farm	8.15	48.59	30.25	27.31	65.95	59.64
Umbeluzi Research Station	10.06	63.71	29.90	26.85	65.65	58.41
LSD	**0.86**	**6.46**	**0.72**	**0.64**	**0.86**	**1.31**

Table 5: Effect of years on means of number of sprouts per genotype, length of sprouts measured at six weeks after sprouting (cm), dry matter content at harvest and four months after storage (%), starch content at harvest and four months after storage (%) from analysed data collected at Umbeluzi Research Station and Nwalate Farm in 2015, 2016 and 2017

Year	Number of sprouts/ root	Length of sprouts (cm) at six weeks	Dry matter content at harvest (%)	Dry matter content after 4 months of storage (%)	Starch content at harvest (%)	Starch content after 4 months of storage (%)
2015	7.75	63.05	29.36	26.80	62.42	58.23
2016	6.94	44.44	29.00	27.17	65.11	59.62
2017	12.20	60.33	31.53	27.84	69.22	61.64
LSD	**1.05**	**7.92**	**0.88**	**0.71**	**2.07**	**1.73**

Table 6: Genotypic means for number of sprouts per genotype, length of sprouts at six weeks after sprouting (cm), dry matter content at harvest and four months after storage (%), starch content at harvest and four months after storage (%) analysed between locations (Umbeluzi Research Station and Nwalate Farm) and across the three years of evaluation (2015, 2016 and 2017)

Genotype	Number of sprouts per genotype	Average length of sprouts per genotype (cm)	Dry matter content at harvest (%)	Dry matter content 4 months after storage (%)	Starch content at harvest (%)	Starch content 4 months after storage (%)
Caelan	15.94	107.51	34.29	29.39	71.17	63.23
Delvia	14.37	78.42	32.48	30.32	68.70	64.61
Bita	12.08	76.84	32.73	27.89	69.44	61.64
Ivone	11.73	76.84	26.71	24.21	59.24	47.63
Tacna	11.27	100.90	24.37	21.54	61.99	57.07
Alisha	10.91	91.39	32.27	29.63	68.17	61.75
Lawrence	10.62	43.29	32.06	23.87	69.08	62.73
Victoria	10.49	50.33	26.62	24.92	59.19	47.82
Amelia	10.43	34.90	35.25	33.41	67.80	58.17
Irene	10.43	41.72	29.22	27.85	64.43	57.90
Jane	10.04	38.69	28.07	28.05	62.01	52.92
Mwamazambane	9.71	38.90	26.43	25.25	62.50	53.59
Japon	9.56	51.63	26.20	23.95	62.02	56.49
Chissicuana 2	9.18	60.46	26.99	24.04	63.60	59.13
Ininda	9.16	56.38	27.63	27.74	65.57	59.89
Gloria	9.10	34.52	35.61	34.06	68.10	62.92
Cinco horas	8.83	48.13	29.50	28.82	65.45	58.84
Chissicuana 3	8.40	67.44	32.41	28.39	69.99	62.08
Lourdes	8.33	40.75	26.64	23.14	64.39	60.50
Melinda	7.75	50.78	25.92	23.12	61.43	52.89
MUSG11016-1	7.46	36.05	27.39	25.64	67.49	61.95
Bie	6.98	46.81	31.41	23.33	64.85	59.89
Jonathan	6.96	54.69	24.93	21.70	59.01	52.62
Xiada xa kau	6.90	78.30	31.44	27.84	68.92	61.51
Namanga	6.65	43.31	29.91	28.16	65.54	55.24
MGCL01	6.52	37.36	36.22	32.03	68.85	65.41
Chingova	5.78	62.25	34.12	32.07	70.07	62.75
Resisto	5.00	67.25	32.26	27.99	64.55	60.25
Xitsekele	4.17	61.94	30.56	26.65	69.53	60.84
Mean	**9.13**	**57.85**	**29.99**	**27.07**	**65.62**	**58.70**
STDERR	**1.05**	**7.92**	**0.88**	**0.81**	**1.07**	**1.03**

Table 7: Pearson Correlation Coefficients among the field and quality traits measured at Umbeluzi Research Station and Nwalate Farm in 2015, 2016 and 2017

	Number of sprouts per genotype	Sprout length at six weeks (cm)	Dry matter content at harvest (%)	Dry matter content 4 months after storage	Starch content at harvest (%)	Starch content 4 months after storage (%)
Number of sprouts per genotype	1					
Sprout length at six weeks (cm)	0.146	1				
	0.019					
Dry matter content at harvest (%)	0.092	0.156	1			
	0.181	**0.023**				
Dry matter content 4 months after storage (%)	0.177	0.051	0.848	1		
	0.055	**0.586**	**<.0001**			
Starch content at harvest (%)	0.150	0.039	0.664	0.471	1	
	0.028	**0.569**	**<.0001**	**<.0001**		
Starch content 4 months after storage (%)	-0.215	-0.078	0.468	0.446	0.770	1
	0.034	**0.406**	**<.0001**	**<.0001**	**<.0001**	

The numbers bolded indicate the significance level at 95 % confidence level

(positive). The starch content measured at four months after storage had negative correlations with number of sprouts per genotype and sprout length at six weeks. The correlation between starch content at four months storage and number of sprouts per genotype was significant and slightly above 21%. Dry matter content were highly signficantly correlated to starch content.

4 Discussion

The small-scale farmers who make up 99.7% of total farmers are too resource poor to mitigate the effects of long dry season through irrigation yet conservation of sweetpotato germplasm/varieties is largely through vine cuttings. To minimize the losses associated with farmers not accessing enough – sometimes any - planting material at the beginning of the season, the current study proposes the use of vines sprouting from small to medium roots as basic seed/startup material for each season. Storing storage roots of little commercial value in cool dry sand during the dry season and sprouting them prior to the rainy season offers a practical solution to problems associated with enough planting material during the rainy season and the erosion of improved varieties in dry prone areas of Mozambique.

All the genotypes evaluated in the current study could be stored over the dry season and sprouted. However, genotypes had significant differences on the number of sprouts per root. The variation on sprouting from planted roots has been observed and heritability of sprouting was estimated to be low to moderate [h^2 =0.4 (Jones 1986); h2 =0.56 (Andrade et al. 2017)]. This offers good news to breeding programs that clones with greater sprouting ability could be developed. The top 10 ranking varieties in Mozambique were Caelan, Delvia, Bita, Ivone, Tacna, Alisha, Lawrence, Victoria, Amelia and Irene and all had >10 sprouts per root at four weeks after planting. The number of sprouts per root depended largely on the root size of the genotype. Sprouts can develop at any position of the root, but the distal and apical ends of the roots produced more sprouts than any other part in the current study. Farmers who consider sweetpotato production as a business are advised to reserve generous sized storage roots of marketable class depending on genotype as a source of seed for the next planting. This assures many sprouts per root.

Location and year showed significant differences on the number of sprouts per root. The weather conditions in each year are different. Rainfall commenced two weeks after sowing the storage roots at Umbeluzi Research Station and Nwalate Farm in 2017. This allowed even distribution of water in the soil as compared to irrigation by a watering can. More sprouts per root were realized in 2017 than 2016 or 2015 at both locations. The locations were different with different soil types and quality of irrigation water. Soils at Umbeluzi Research Station are sandy loams while Nwalate Farm has black alluvium soils which are sticky when wet. The number of sprouts per root were higher at Umbeluzi Research Station than Nwalate Farm. Most soil types under smallholder cultivation ranges from sandy to sandy loams offering a chance to realize many number of sprouts per root. Temperature also affects the rate of respiration, development of rooting micro-organisms and influences the rate of sprout growth.

Length of sprouts measured at six weeks were strongly affected by genotype, location, year and genotype x location x year interactions. Previous reports by Ravi and Indira (1999) indicated that location had major influence on length of vines. Caelan, Delvia, Bita, Ivone, Tacna, Alisha and Xiadla-xikau had sprouts longer than 75 cm. However, all the tested genotypes had sprouts of desirable length (20 - 30 cm) ready for harvest and normal planting at six weeks (Bautista and Vega 1991). The tested genotypes could provide 2 to 8 cuttings for rapid multiplication if vines of 10 cm in length are considered. The genotypes evaluated in the current study had different growth habits. In terms of growth habits in sweetpotato, varieties are categorized as either erect bushy, intermediate or spreading based on the length of their vines. For example, Irene which is an erect bushy variety had sprout length of 41.72 cm and could provide between two to four cuttings for planting depending on planting method. Spreading genotypes such as Caelan, Delvia, Bita, Ivone, Alisha, Tacna and Xiadla-xikau provided more vine cuttings (4 to 10) within the same period. Tacna, introduced from Peru as a drought tolerant variety is also good under drought.

Adoption of the sand storage and sprouting technology is a viable option of preserving genotypes in dry prone areas and as a source of planting material. Storing sweetpotato roots in the soil is not new to smallholder farmers in dry prone areas as farmers are already storing their harvest in soil pits, and ash is used as desiccating agent and reduce the incidences of rotting and sprouting (Hall and Devereau 2000). In these system, storage can go from 2 to 5 months depending on variety. Emphasis need to be put on the types of roots to be stored and when are the roots planted for sprouting. Per the current results, location influenced number of sprouts per root and length of the vines from the sprouts. Agronomic management of the nurseries are embedded into the effect of location. Farmers need to irrigate the nursery regularly to avoid water stress to the sprouts. In addition, weeding of the nursery is important to minimize competition for resources in the nursery.

Vines from the sprouts were virus free and reliable source of planting material for the subsequent crop. Studies by Campilan et al. (2002) showed that use of high quality planting material generated by farmers can result in yield increases of up to 37%. In China, where use of sprouts as a source of new seed is a widespread practice, yield advantages of 30% above normal planting material were recorded (Fuglie et al. 1999). Farmers in drought prone areas can conserve sweetpotato varieties through storage roots and get planting material through sprouting at a minimal expense. Diseases and pests must be eradicated during storage of roots in sand. The small-scale farmers should minimize injury at harvest and during transportation and storage. Root damage increase respiration and the dormancy period will be broken before long storage and sprouting will begin in storage. Damage from rodents should be avoided at all costs. The storage room should be dry and no wet roots should be placed in storage. In the current study, seasonal effects (year) were not significant for number of sprouts per root implying genotypes will always sprout from season to season under conducive environments.

Data on storage root quality were measured to assess the influence of nutrients on sprouting of genotypes. Starch is converted into sugar, the principal nutrient for respiration. A significant and positive correlation existed between starch content of roots at harvest and the number of sprouts per root. The accumulation of carbon dioxide and heat energy during the oxidation of starch breakdown, root dormancy and sprouting is initiated. In the current study, the dry matter and starch contents decreased by less than an average of 11% during the four months storage period indicating that storage in sand method had the ability to preserve the starch composition which is a critical energy reserve for sprouting. This was confirmed by the significant negative correlation that existed between starch content after four months of storage and the number of sprouts coming out of the roots.

5 Conclusions

Sand storage of sweetpotato roots and sprouting them at an appropriate time is a novel technology which needs promotion among smallholder farmers to increase sweetpotato production and harness healthy benefits associated with OFSP in drought prone areas. New markets are developing for sweetpotato in Mozambique, however, their viability will require continuous supply of storage roots in sufficient quantities. This requires a strong source of planting materials, like the one which does not fail due to prolonged dry periods. With appropriate varieties, suitable cultural and agronomic management practices it may be possible to successfully produce sweetpotato using roots in the dry areas of Mozambique.

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References

Almekinders C.J.M., Louwaars N.P., De Bruijn G., Local seed systems and their importance for an improved seed supply in developing countries Euphytica, 1994, 78, 207–216

Andrade M.I., Makunde G.S., Ricardo J., Menomussanga J., Alvaro A., Gruneberg W.J., Survival of sweetpotato (Ipomoea batatas [L.] Lam.) vines in cultivars subjected to long dry spells after the growing season in Mozambique, Open Agriculture, 2017, 2(1), 58-63

Andrade M.I., Ricardo J., Naico A., Alvaro A., Makunde G.S., Low J., Ortiz R., Gruneberg W., Release of orange-fleshed sweetpotato (Ipomoea batatas [L.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. The Journal of Agricultural Science, 2016b, 1-11

Andrade M.I, Alvaro A, Menomussanga J, Makunde G.S, Ricardo J, Gruneberg W.J, Eyzaguirre R, Low J., Ortiz R., 'Alisha', 'Anamaria', 'Bie', 'Bita', 'Caelan', 'Ivone', 'Lawrence', 'Margarete', and 'Victoria'. Hort. Science, 2016a, 51(5), 597–600

Andrade M.I., Naico A., Ricardo J., Improving Rural Livelihoods in Southern Africa Through Root and Tuber Crops., (October 2005 to September 2006), Annual Technical Report, 2006

Bautista A.T., Vega B.A., Indigenous knowledge systems on sweetpotato farming among Marano Muslims in northern Mindanao. In: Sweetpotao Cultivars of Asia and South Pacific, Proceedings of 2nd Annual UPWARD International Conference, Los Banos, Phillipines, 1991, 49-161

Bouis H., Islam Y., Delivering Nutrients Widely through Biofortification: Building on Orange sweetpotato – scaling up in Agriculture, Rural Development and Nutrition, Focus 19, Brief II. Washington, DC: International Food Policy Research Institute, 2012

Burgos G., Carpio R., Sanchez C., Sosa P., Porras E., Espinoza J., Grüneberg W., Guide for Using the RHS Colour Chart for Selecting for High β-carotene Sweetpotato. Lima, Perú; International Society for Tropical Root Crops, 2009

Campilan D., Basilio C., Laranang L., Aguilar C., Aganon C., Idion I., Participatory technology development for improving sweet potato livelihood in the Philippines. Makati City, Philippines: International Potato Center (CIP), 2002

Climate Service Center, Climate Fact Sheet: Mozambique, 2013

Cotter J., Tirado R., Food Security and Climate Change: The Answer Is Biodiversity. A review of scientific publications on climate change adaptation in agriculture. Greenpeace International, The Netherlands, 2008

FAO., Quality declared planting material protocols and standards for vegetatively- propagated crops. FAO Plant Production and Protection Paper, 2009, 195, 156

Fuglie K.O., Zhang L., Salazar L.F., Walker T., Economic impact of virus-free sweet potato seed in Shandong Province, China. Lima, Peru: CIP, 1999

Gregory P.P., Ingram J.S.I, Brklacich M., Climate change and food security. Philosophical Transactions of the Royal Society B, 2005, 360, 2139-2148

Hall A.J, Devereau A., Low cost storage of fresh sweet potatoes in Uganda: Lessons from participatory and on station approaches to technology choice and adaptive testing. Outlook on Agriculture, 2000, 29(4), 275-282

Kapinga R., Mafuru J., Jeremiah, S., Rwiza, E., Kamala R., Mashamba F., Mlingi N., Status of cassava in Tanzania. Implications for Future Research and Development, 2005

Kapinga R., Ewell P., Jeremiah S., Kileo R., Sweetpotato in Tanzania Farming and food system. Implications for Research. Working paper for International Potato Center (CIP), Nairobi, Kenya and Ministry of Agriculture, Dar es Salaam, Tanzania, 1995, p 47

Li X., Waddington S.R., Dixon J., Joshi A.K, de Vicente M.C., The relative importance of drought and other water related constraints for major food crops in Southern Asian farming systems. Food Security, 2011, 3(1), 19-33

Loebenstein G., Thottappilly, G. The sweetpotato (Springer, New York), 2009.

McEwan M., Sweetpotato Seed Systems in sub-Saharan Africa . A literature review to contribute to the preparation of conceptual frameworks to guide practical interventions for root, tuber and banana seed systems, RTB Working Paper, 2016, 4

Mutandwa E., Performance of tissue-cultured sweet potatoes among smallholder farmers in Zimbabwe, AgBioForum, 2008, 11(1), 48-57

Namanda S., Amour R., Gibson R.W., The triple S method of planting Sweet Potato planting material for areas in Africa with long dry seasons, Journal of Crop Improvement, 2012, 27(1), 64- 84

Ogero K.O, Mburugu G.N., Mwangi M., Ombori O., Ngugi M., In vitro micropropagation of cassava through low-cost tissue culture Asian Journal of Agricultural Sciences, 2012, 4(3), 205-209

Pfeiffer W.H., McClafferty B., HarvestPlus: breeding crops for better nutrition. Crop Science, 2007, 47, 88-105

Ravi V., Indira P., Crop Physiology of sweetpotato. Horticultural Reviews, 1999, 23, 277-338

Rees D., Kapinga R., Mtunda K., Chilosa D., Rwiza E., Kilima M., Kiozya H., Munisi R., Effect of damage on market value and shelf-life of sweetpotato in urban markets of Tanzinia. Tropical Science, 2001, 41, 1-9

Ripado M., Os solos da Estacão Agraria do Umbelúzi. IIAM. Communicacao. Maputo, Mozambique: Instituto de Investigação Agraria de Mozambique, 1986.

Roy-Macauley H., Improving the livelihood of the poor in Africa using crop biotechnology. Presented at the first IFS-CODESRIA workshop on Sustainable Agriculture Initiative, Kampala, Uganda, 2002

SAS Institute, Inc., SAS/STAT user's guide, release 6.12. SAS Institute, Inc. Cary, North Carolina, 1997

Truong V.D., Avula R.Y., Pecota K., Yencho C.G., Sweetpotatoes. In Handbook of Vegetables and Vegetable Processing (N.K. Sinha, ed.), Wiley-Blackwell, Ames, IA., 2011, 717–737

World Bank., Vulnerability, Risk Reduction, and Adaptation to Climate Change: Mozambique, 2011, http://sdwebx.worldbank.org/climateportalb/doc/GFDRRcountryProfiles/wb-gfdrr_climate_change_country_profile_for_MOZ_pdf