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Evaluation of Dual Purpose Sweet Potato [*Ipomea batatas* (L.) Lam] Cultivars for Root and Fodder Production in Eastern Province, Rwanda

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Abstract: Sweet potato is an ideal crop for densely populated areas because it enables farmers to produce food and fodder concurrently on the same piece of land. But, the use of the technology in sub-Saharan Africa is sporadic because dual purpose sweet potato varieties and knowledge of vine harvesting without compromising root yields are rare. This study evaluated 11 sweet potato genotypes for dual-purpose attributes and the effects of ratooning on biomass yield in three ecozones in Eastern Province of Rwanda. The experiment was a randomized split-split-plot design with the ecozones. Varieties and ratooning treatments as main, sub and sub-sub-plots, respectively. General linear model analysis with replicates nested on ecozones, revealed that root ($p = 0.0021$) and vine yields ($p = 0.0381$) differed across ecozones but not in root-to-vine ratios ($p = 0.0509$). Varieties differed significantly in root ($p = 0.004$) and vine ($p = 0.017$) yields but not root-to-vine ratios ($p = 0.0958$). Ratooning increased vine yields by approximately 64% without reducing root yield. Local landraces had higher yields of roots and vines than introduced genotypes. No varieties had strong dual-purpose attributes. Ratooning induced the dual-purpose attributes in all varieties. Ratooning at 80 days after planting was recommended a practice for sweet potato production as a dual purpose crop in Rwanda.

Key words: Dual-purpose sweet potato, root yield, vine yield, root-to-vine ratio, Rawanda

INTRODUCTION

Since its introduction into Rwanda in 18th century, sweet potato has become a major staple crop in the country (FAOSTAT, 2011). Sweet potato vines are good quality fodder for ruminant livestock (Lam and Ledin, 2004; Etela *et al*., 2008). It is particularly attractive, as a food-feed crop in mixed crop-livestock systems where land pressure is a constraint to fodder production (Claessens *et al*., 2009) and stall feeding is legally mandatory (Andrade *et al*., 2009). Yields and quality of vines depend of variety and stage of maturity at harvests (Karachi, 1982; Larbi *et al*., 2007; Nasakar and Nedunchezhiyan, 2009). Development of dual-purpose varieties has gained credibility in sweet potato germplasm development agenda for food security and poverty reduction (Andrade *et al*., 2009). Using the ratio of root to vine biomass sweet potato has been classified into four groups depending on their genetic potential to apportion nutrients to forage and roots (Leon-Velarde, 2000). Breeding efforts in Rwanda has focussed on roots for food and number of genotypes has been introduced. There is no information on the dual-purpose attributes of these varieties and best vine cutting regimes to optimize fodder yields and quality without compromising root yields. This study was conducted to evaluate existing genotypes including local landraces for dual-purpose attributes in Rwanda and to determine effect of ratooning vines on fodder and roots yields.

MATERIALS AND METHODS

About 11 varieties including introduced ($n = 6$) and local ($n = 5$) genotypes were planted on 4 farms in each of three major milk producing ecozones in Eastern Province of Rwanda (Table 1). Each cultivar was subjected to two treatments: Ratooning and no ratooning in a randomized split-split plot design where the ecozones were the main-plot; the cultivars were sub-plots and the ratooning treatments were sub-subplots, respectively. The cultivars were planted on six ridges in 6×6 m plots. Within row spacing was 30 cm between plants. The harvest area was

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Table 1: Geographic and agro-ecological characteristics of eco-zones targeted for dual purpose sweet potato variety development in Rwanda

	Districts		
Characteristics	Nyagatare	Gatsibo[1]	Rwamagana
Latitude	1°18'14" S	1°34'33" SS	1°56'55" S
Longitude	30°20'34" E	30°14'39" E	30°26'04" E
Altitude (m a.s.l)	1400	1587	1507
Rainfall[1]	800-1000	800-1000	1000-1200
Temperature	25-35	16-20	20-30
Soil types	Loamy soil	-	Black cotton soil
Livestock management system	Fenced grazing on natural/improved pastures	Agro-pastoral on native pastures and crop residues after harvest	Semi-intensive and intensive dairy

[1]Nyagatare and Gatsibo share weather station

two innermost rows 2.5 m in length and 50 cm from both ends of the ridges. The number of plants per harvest area was counted before harvesting.

The vines were cut at stubble height of 20 cm. In the ratooning treatment, ratooning started 80 days After Planting (DAP). The regrowth was cut immediately before root harvests at 160 DAP. In the no ratooning treatment the vines were cut only once immediately before root harvests at 160 DAP. The roots were harvested from the same harvest areas as the vines. The fresh materials (roots and vines) from each harvest area were weighed and sampled for dry matter determinant at 60°C for 48 h. For the ratooning treatment, cumulative vine yield was estimated, as the sum of vine yield from the same harvest area corrected for dry matter content.

Statistical analysis: Data on plant establishment 80 DAP; herbage biomass yields and root-to-vine ratio were examined using split-split plot general linear model for SAS where replicates were nested with (ecozone):

$$y_{ijk} = \mu + \rho_j + \alpha_i + \beta_k + (\alpha\beta)_{ij} + \eta_{ij} + \varepsilon_{ijk}$$

Where:

- y = Yield associated with the kth level of the cutting management (sub-plot) within the cultivar (main-plot) within the ecozone receiving the ith level of cultivar
- ρ_j = The component common to all sub-plots (cutting regimes)
- α_i = Main effect component of the ith level of cultivar
- β_k = Main effect component of kth level of cutting management
- $\alpha\beta$ = Interaction component
- η_{ij} = Random component common to all sub-plot in the (i, j)th main-plot
- ε_{ijk} = Random component peculiar to the subplot with the kth level cutting regimes in the (i, j)th main-plot

Means were separated using Least Significant Difference (LSD) at 5% probability level.

Table 2: Chemical and textural properties of soil in selected eco-zones in Eastern Province, Rwanda

Soil characteristics	Gatsibo	Nyagatare	Rwamagana
Nitrogen (g kg^{-1})	2.1±0.640	2.22±0.55	2.13±0.64
Phosphorus (ppm)	1.18±0.67^{b}	3.51±0.58^{a}	1.26±0.67^{b}
Organic carbon (g kg^{-1})	15.33±5.86	23.27±5.07	20.66±5.86
pH	4.7±0.2400	4.9±0.2100	4.9±0.2400
Sand (g kg^{-1})	659.33±91.95	460.00±79.63	453.00±91.90
Silt (g kg^{-1})	264.63±58.16	73.48±50.37	73.53±58.16
Clay (g kg^{-1})	76.03±82.02	466.52±71.03	473.46±82.01

Means with different superscripts in a row differed significantly ($p<0.05$)

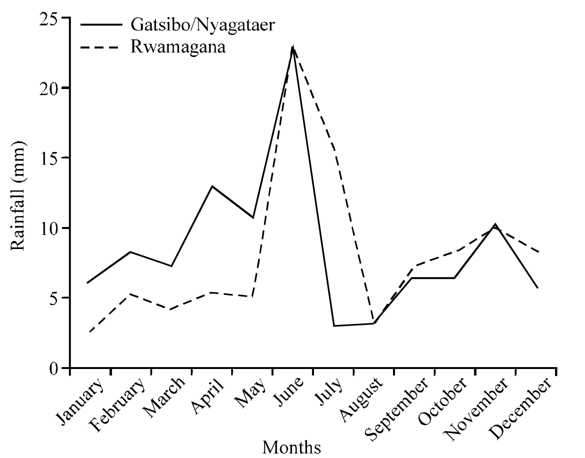

Fig. 1: Monthly rainfall (mm) at the eco-zones of the study sites (Byumba meteorological station; 2011)

RESULTS AND DISCUSSION

Soil characteristics: The difference in soil properties (Table 1) and climatic conditions (Fig. 1) was shuttle. The soils were similar in chemical and textural properties except phosphorus which was higher in Nyagatare than in the other two eco-zones. Soils from Gatsibo had >40% more sand and over 70% more silt than Nyagatare and Rwamagana. Clay content was more than six-fold as high in Nyagatare and Rwamagana as it was in Gatsibo (Table 2). Therefore, soils in Nyagatare and Rwamagana tended to be similar in textural properties and slightly different from soils in Gatsibo. All the sites had suboptimal levels of pH. Most extension guides recommend pH level above 5 and below 7 to reduce susceptibility to diseases.

Plant establishment: The study encountered the problem of poor establishment of some cultivars during the first 80 DAP. Plant establishment differed significantly across ecozones ($p = 0.0026$) and among cultivars ($p<0.0001$). The magnitude of the difference between cultivars also differed between ecozones ($p<0.0001$). The frequency of cutting did not affect plant establishment (p = 0.4835) but the magnitude of the differences in plant establishment between cutting regimes differed significantly among ecozones (p = 0.0023). At all sites cultivars 2000-040, 2002-154 and 2002-155 had the least plant counts per harvest area at 80 DAP than other cultivars (Table 3).

Establishment was best at Nyagatare than at Gatsibo and Rwamagana ($p<0.05$). Plant counts per harvest area were also higher at Rwamagana than at Gatsibo. The unique attribute of the Nyagatare among the eco-zones was high phosphorus levels in the soil (Table 2). It could partly explain differences in plant establishment the ecozones. However, responses to phosphorus is often very low (Neducnchezhiyan *et al.*, 2012) except in volcanic ash soils with very low phosphorus levels (Lewthwaite, 2004).

Moisture stress was the most probable reason for low establishment in cultivars 2000-040, 2002-154 and 2002-155. During the year of the study rainfall (Fig. 1) was lower than the historical average (Table 1). Sweet potato is considered to be resilient to prolonged water stress (Bouwkamp, 1985). But in some varieties, drought induced lignification impair lateral root growth (Lewthwaite and Triggs, 2009). In this respect, sweet potato is more sensitive to moisture stress than cassava (Pardales and Yamauchi, 2003). This phenomenon is used in selecting for drought tolerance in sweet potato (Agili *et al.*, 2012; Lewthwaite and Triggs, 2012). According to Neducnchezhiyan *et al.* (2012), sweet potato requires 2 mm of water per day in the early stages of growth. This should gradually increase 5-6 mm day^{-1} towards harvest. Belehu (2003) reported that optimal conditions for optimal sweet potato root growth were 80% soil moisture capacity and high temperature (28°C).

In this study, expected plant population was 40000 plant ha^{-1} in accordance with extension advisory in East and West Africa (Mbanaso *et al.*, 2012). In Swaziland, 33,333 plants ha^{-1} was recommended for a sole sweet potato crop (Osom, 2010). Onunka *et al.* (2011) recommended the plant population of 50,000 plants ha^{-1} to optimize root yield unless the land was being used for other purposes at the same time.

Frequency distribution (not shown) showed that approximately 2% met the expect plant population; 8% were within range of recommended levels of 28-40 plants ha^{-1} (Onunka *et al.*, 2011). This observation underscored the importance of timely planting for good sweet potato crop establishment. It also underscored the need for breeding for drought tolerance in anticipation of climate change and variability.

Root biomass: With the exception of cultivar 2002-154 in Gastibo and Locale in Nyagatare, overall root yields were similar to root yields reported elsewhere. Hypothesis testing showed that root biomass yields differed significantly between districts (p = 0.0021) and varieties (p = 0.0040). The magnitude of the difference among varieties differed among ecozones (p = 0.0177). The highest average root yield was in Rwamagana (4679.1 kg DM ha^{-1}) followed by Nyagatare (3299.3 kg DM ha^{-1}) and Gatsibo (2485.6 kg DM ha^{-1}), respectively. Dimbuka was found only in Nyagatare and had the highest yields in both ratooned and intact crops. Cultivar locale was found in Nyagatare and Rwamagana. It had the least yield in Nyagatare and the highest yield in Rwamagana. Location differences reflected differences that is often associated with yield stability in sweet potato genotypes (Nasayao and Saladaga, 1988; Osiru *et al.*, 2009; Haldavanekar *et al.*, 2011; Moussa *et al.*, 2011; Mcharo and Ndolo, 2013). Overall Dimbuka, outyielded all varieties, followed by Kakamega, Kwezikumwe and Cacerpedo. Cultivar 2002-155 and Akarakgenda had the lowest yields (Table 4). Osiru *et al.* (2009) reported Dimbuka among the top yielding varieties in several production zones of Uganda.

Table 3: Number of plants per harvest area (7.5 m^2) at trial sites in three eco-zones of Eastern Province Rwanda

	Districts			
Cultvar	Gatsibo[1]	Nyagatare[1]	Rwamagana[1]	Variety mean[1]
2000-040	4.9±9.1[d]	16.0±8.4	0±0[c]	8.9[c]
2002-154	5.8±7.5[cd]	16.9±9.2	3.2±4.4[c]	10.3[bc]
2002-155	8.3±11.0[bcd]	13.7±8.0	4.5±5.7[c]	10.0[bc]
Cacaerpedo	14.9±8.6[ab]	16.1±7.8	17.4±7.1[ab]	16.1[ab]
Kakamega	14.1±8.7[ab]	14.3±8.3	20.4±4.8[a]	15.6[ab]
Locale	18.1±5.4[a]	17.4±7.0	20.0±5.6[a]	9.6[bc]
Kwezikumwe	12.9±7.6[abc]	14.6±9.0	14.5±4.0[b]	14.1[ab]
Mugande	16.4±6.0[ab]	19.1±8.6	18.2±5.4[ab]	18.1[a]
NASPOT1	15.5±9.0[ab]	12.5±9.0	21.3±5.3[a]	15.5[ab]
District means[2]	11.6[b]	15.3[a]	12.4[b]	15.5[a]

[1]Means wit the same superscripts in the same column do not differ significantly ($p>0.05$); [2]Means with the same superscript in a row do not differ significantly ($p>0.05$)

Vine biomass yield: Vine yields were also in the range reported elsewhere (Nasakar and Nedunchezhiyan, 2009). It also affected by ecozones (p = 0.0381), variety (p = 0.0170) and treatment (p = 0.0024). The yield was similar in Rwamagana (5321.6 kg DM ha^{-1}) and Nyagatare (4955.6 kg DM ha^{-1}), both of which were higher than vine yield at Gatsibo (3188.8 kg DM ha^{-1}). Dimbuka, locale and mugande had the highest and akarakagenda had the least vine yield (Table 5). Other varieties were intermediate between the two extremes with shuttle difference among each other.

Ratooning increased vine yield by approximately 64% (Table 4). The magnitude of this effect depended on the variety (p = 0.0048). Akarakagenda responded by 27 and 10% reduction in yield, respectively. Cultivars 2000-040,

Table 4: Root biomass yield (kg DM/ha) of sweet potato genotype in selected districts in Eastern Province, Rwanda

	Intact				Ratoon				
Variety	Gatsibo	Nyagatare	Rwamagana	Mean	Gatsibo	Nyagatare	Rwamagana	Mean	Variety mean
2000-040	na	2944.3	na	2944.3	na	1812.6	2343.0	1812.6	2413.0^{bc}
2002-154	789.4	3669.8	1551.3	1890.4	834.5	2733.0	2941.5	2063.4	2378.0^{bc}
2002-155	na	2550.9	2537.1	2543.4	na	1492.1	na	2282.7	1976.9^{c}
Akarakagenda	2713.1	na	na	2713.1	1193.4	na	6108.0	1193.4	1953.0^{c}
Cacaerpedo	3856.7	2881.7	6874.7	4732.3	3435.4	1514.0	na	3757.5	4245.0^{b}
Dimbuka	na	7422.6	na	7422.6	na	6495.9	6357.0	6495.9	6959.3^{a}
Kakamega	3362.2	4272.9	3808.6	3966.4	3774.1	3930.2	5233.6	4713.1	4339.8^{b}
Kwezikumwe	1980.5	4392.4	4324.1	4120.5	1899.9	4219.3	4795.2	4443.8	4282.0^{b}
Locale	na	319.9	8375.9	4347.9	na	751.1	5791.0	2773.1	3560.6^{bc}
Mugande	1760.2	3478.1	4179.1	3533.1	5708.1	2316.7	4523.1	4290.2	3911.0^{bc}
NASPOT1	1740.4	4126.4	4817.6	4081.8	1388.7	3361.1	4897.2	3577.3	3829.6^{bc}
District mean	2331.4	3680.5	4679.1	3806	2640.1	2918	3606.4	3606.0	3748.0

Means with the same superscript on a column are not significantly different ($p>0.05$); na = Missing entry

Table 5: Effects of ratooning on vine biomass yields (kg DM/ha) of sweet potato cultivars planted at three ecozones in Eastern Province, Rwanda

	Intact				Ratoon				
Variety	Gatsibo	Nyagatare	Rwamagana	Mean	Gatsibo	Nyagatare	Rwamagana	Mean	Variety mean
2000-040	na	3212.9	na	3212.9	na	4482.8	na	4482.0	3846^{dc}
2002-154	3433.0	2816.6	2620.8	2872.8	2142.4	4471.5	4920.0	4113.4	3493^{cd}
2002-155	na	2640.1	6811.7	4915.5	-	4537.6	8692.1	6803.7	5860^{abc}
Akarakagenda	2727.2	na	na	2727.2	1989.2	na	na	1989.2	2358^{d}
Cacaerpedo	3554.1	1727.6	3734.0	2848.9	4611.2	3554.6	6813.9	5102.4	3976^{cd}
Dimbuka	na	5964.0	na	5964.3	na	10147	na	10147.5	8056^{a}
Kakamega	3669.1	4136.0	3481.3	3839.9	2574.7	7296.1	5950.0	6060.6	4950^{cd}
Kwezikumwe	1324.3	2813.6	2680.0	2604.8	2865.2	7206.0	5848.5	6161.4	4383^{cd}
Locale	na	6005.0	8983.1	7494.0	na	5397.0	8099.4	6748.0	7121^{ab}
Mugande	3410.0	5009.6	4032.6	4362.4	5109.6	9487.4	7307.0	7927.5	6145^{abc}
NASPOT1	2832.9	3259.5	3268.6	3202.5	3669.8	5631.9	8983.1	5670.4	4436^{cd}
District mean	3076.4^{b}	3301.1^{b}	6645.2^{a}	3662.8^{b}	3301.1^{b}	6367.4^{a}	6645.2^{a}	6040.0	4851.4

Means with the same superscripts in a column do not differ significantly ($p>0.05$); na = Missing entry

Table 6: Effects of ratooning on root-to-vine ratio of sweet potato genotypes in selected eco-zones in Eastern Province, Rwanda

	Intact				RatoonED				
Variety	Gatsibo	Nyagatare	Rwamagana	Mean	Gatsibo	Nyagatare	Rwamagana	Mean	Variety mean
2000-040	na	2.012	na	2.012	na	1.429	na	1.429	1.721^{bc}
2002-154	1.426	2.450	1.713	1.862	1.461	1.686	1.55	1.562	1.705^{bc}
2002-155	na	2.161	1.729	1.926	na	1.352	1.378	1.366	1.646^{bc}
Akarakagenda	2.113	na	Na	2.113	2.233	na	na	2.233	2.173^{ab}
Cacaerpedo	2.211	3.002	2.9	2.845	1.751	1.603	2.000	1.795	2.320^{a}
Dimbuka	na	2.234	Na	2.234	na	1.835	na	1.835	2.035^{abc}
Kakamega	1.939	2.236	2.128	2.15	2.586	1.628	2.019	1.918	2.034^{abc}
Kwezikumwe	2.704	2.751	2.837	2.785	1.661	1.671	1.954	1.797	2.291^{a}
Locale	na	1.165	2.107	1.73	na	1.17	1.658	1.414	1.558^{c}
Mugande	1.457	1.695	2.143	1.853	2.812	1.275	1.884	1.756	1.804^{abc}
NASPOT1	2.095	2.378	2.605	2.435	1.501	1.625	1.738	1.659	2.047^{abc}
District mean	1.984	2.324	2.353	1.289	2.018	1.539	1.840	1.717	2.001

Means with different superscripts in a column differ significantly ($p<0.05$); na = Missing entry

2002-154 and 2002-155 had 38-43% increase. Dimbuka, Cacaerpedo, NASPOT1, Mugande had 70, 79, 77 and 72% increment in vine yield. The highest response was in Kwezikumwe (137%).

Olorunnisomo observed 33% lower vine yield when sweet potato vines were harvested 21 weeks after planting compared to yields at 4, 6 and 8 weeks harvest. His data suggested optimum vine yield at 114 days after planting. Etela and Kalio reported 21-61% more vine yields in ratooned than in unratooned sweet potato which they attributed to leaf shedding due to senescence. Ratooning delayed maximum development that is reported to trigger leaf shedding. MacLaurin and Kays showed that leaf-shedding due to senescence account for 1.2-2.6 ton ha^{-1} of vine DM loss in high yielding varieties without causing root yield.

Root-Vine-Ratios (RVRs): RVRs tended to differ by ecozones ($p = 0.0509$). It was higher in Rwamagana (2.079) and Nyagatare (2.002) than in Gatsibo (1.928). It also tended to differ by variety ($p = 0.0958$). Cacaerpedo, Kwezikumwe and Akarakagenda had the highest RVRs and cultivars 2000-040, 2002-154, 2002-155 and Locale had the lowest RVRs. NASPOT, Dimbuka and Mugande were similar to both extremes. The most conspicuous effect on RVR was ratooning (p = 0.0252). RVR in intact and ratooned plots were 2.289 and 1.717, respectively (Table 5).

According to the classification of Leon-Velarde (2000), all the cultivars that were evaluated were low-forage, high root genotypes. Their dual-purpose attributes were improved by ratooning at 80 DAP but not significantly enough to put them in the high dual-purpose category (Table 6).

CONCLUSION

Sweet potato genotypes that were currently available in Rwanda lacked strong dual-purpose attributes. However, the amount of vines and roots they can produce under ratooning management made them valuable cultivars for food and fodder production in Eastern Province of Rwanda. However, the eco-zones of Rwamagana and Nyagatare are better suited for dual-purpose cultivars than Gatsibo. Poor establishment of cultivars 2000-040, 2002-154 and 2002-155 underscored the importance of breeding for drought tolerant sweet potato and timely planting in Rwanda. Ratooning vines 80 DAP can be recommended to farmers. All varieties except cultivar 2000-040, 2002-154 and 2002-155 can be used for root and fodder production.

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