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Evaluation on the Effect of Topping Frequency on Yield of Two Contrasting Sweet Potato (*Ipomoea batatas* L.) Genotypes

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Abstract: In this study, two dual sweet potato (*Ipomoea batatas* L.) cultivars (main plots) viz., SPN/0 and SP/93/23, differing in shoot morphology were subjected to vines and leaf harvests (sub-plots) under field conditions at Sokoine University of Agriculture, Horticultural Unit, Morogoro, Tanzania. The treatments were arranged in a split plot arrangement in RCBD using three replications during the 2003/2004 cropping season. The purpose of the study was to evaluate the effect of removing vines and leaves on yield of marketable roots and leaves. Vines and edible leaves were progressively removed during the growing season. The control treatments consisted of single final removing of vines. Vines and leaves removal treatments were imposed monthly and bi-weekly commencing at 40 and 54 days from planting, respectively. Varieties differed in all the variables tested except average marketable root diameter. SPN/0 was characteristically superior in all the variables including marketable root yield. SPN/0 variety gave a relatively higher final yield of 12.2 t ha^{-1} fresh marketable roots, over the SP/93/23 variety, which gave 2.9 t ha^{-1}. Among all four subplot treatments tested, there was no significant difference on number of slender roots, number of marketable roots, average marketable roots length, average marketable root diameter, total weight of vines and leaves and marketable root yield. However, significant difference ($p \leq 0.05$) among treatments of vines and leaf removal were obtained only on weight of fresh vines and leaves. Removing vines and leaves once per month starting 40 days after planting gave the highest weight of fresh vines and leaves of 6.1 t ha^{-1}. The control treatment gave 11.6 t ha^{-1} of fresh marketable roots, which out yielded all the other three treatments. Results indicate that the yield decrease depends on time of starting topping and frequency of topping. Continuous removal of vines and leaves, starting at early stage reduced root yield though not significantly. The none topping of sweet potato gave relatively higher yield of fresh root tuber compared with other treatments. Removal of vines and leaves once per month starting 54 DAP is recommended for optimizing aerial fresh weight and marketable root yield.

Key words: Leaf harvested, Sweet potato, topping, vines

INTRODUCTION

Subsistence farmers have to meet their daily food requirements from crops growing in the field. Sweet potato (*Ipomoea batatas* L.) is one of the food security crops because it thrives under marginal conditions of growth such as drought and sandy soils, yet, it gives a continuous supply of food and feed during the growing cycle (de Vries *et al*., 1967). The later includes leaves and root tubers both of which provide an excellent source of energy, protein, iron, vitamins A, C and fiber (Smart and Simmonds, 1995). Vines are also used as planting materials. Thus, vines and roots, in addition to providing a steady supply of food and feed during the season, can also be a source of income to farmers. However, removal of either vines or tuberous roots should not affect the overall performance of the crop in terms of yield of tops and roots.

The use of shoots as a vegetable or as forage necessitates some shoot removal while the plants are growing and might be expected to decrease the supply of photosynthates to the growing tubers (Hozyo, 1977). In fact, the initial sign of tuberous root formation is the accumulation of photosynthates consisting predominantly of carbohydrates from the tops (Austin *et al*., 1970). Therefore, the extent of root

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development and hence tuberous yield is to a large extent influenced by the vegetative part or top growth. In connection to this reason, Gonzales **et al.** (1977) and Villareal *et al.* (1979a) reported that frequent harvesting of the tops generally decreased tuberous root yields, due to low photosynthates production and translocation to developing roots.

However, top growths are not always suitable for root formation (Villareal and Griggs, 1982). A leafy plant with vigorous vine growth is quite often found to have a low root yield. Edmond and Ammerman (1971) reported that removal of 25% or less of the vines compared with 50, 75 and 100% would not seriously reduce the yield. It was concluded from this study that removal of 25% of the vines from one acre provided sufficient cutting to set an additional two acres leading to high total yields.

Leaf harvesting has been reported to have some detrimental effect on tuberous root yield of sweet potato. Dahniya (1980) compared the effects of harvesting shoots of two varieties of sweet potato TIS 2154 and TIS 2328. Harvesting the crop for shoots led to a reduction in tuber yield. The reduction was 48% in variety TIS 2328 and 31% in variety TIS 2154. Harvesting the shoots at base led to a reduction of 62% for variety TIS 2328 and 50% for variety 2154. Similarly, Gonzales *et al.* (1977) reported that topping the sweet potato plants reduced tuberous root yield. Highest tuber yield was obtained where no topping was done. Bartolini (1982), however, noted that timing of the leaf harvesting is important and that topping is detrimental to tuberous root production when done beyond two months from planting. According to Wilson (1974), rapid root formation and development takes place at this time. Villareal *et al.* (1979b) observed that frequent harvesting of leaves reduces tuber yield, but the degree of reduction differs with variety. Frequent or continuous topping increases yield of toppings (Dahniya, 1979) while Bartolini (1982) noted that topping sweet potato plants twice at the base resulted in higher shoot yield. Similarly, Villareal and Griggs (1982) reported that topping of sweet potato increased yield and starch content of the roots. The authors also reported that late topping gives high root yields while Villareal and Griggs (1982) observed that high root yield could be obtained by topping both at the early and later stages as compared to no topping.

Subsistence requirements of farmers are met by food, feed and revenue obtained from daily harvesting of tops (leaves and vines) and tuberous roots. The use of vines and leaves as a vegetable necessitates some shoot removal while plants are growing and might be expected to increase revenue from total amount of leaf vegetable harvested with a concomitant decrease of photosynthates to the growing tubers. Optimum levels of leaf, vines and tuberous root yields are necessary in this regard. However, there is little information on the optimum frequency of topping that optimizes both root and leaf yields of sweet potato during the season. The present investigation was set to evaluate the frequency of topping that optimizes both top and root yields during the season.

MATERIALS AND METHODS

Location and season: This experiment was conducted at Sokoine University of Agriculture in plots of the Horticulture Unit in Morogoro, Tanzania situated at 6°05'S, 37°37'E and 525 m above sea level. The experiment was carried out during the August to December 2003 growing season. The soil characteristic of the experimental site is clay loam.

Experimental design: The clones were planted on ridges. The ridges were made to the length of 4 m per variety. The clones were planted on 23rd August 2003 and roots were harvested on 23rd December 2003. The experiment was organized as split plot in Randomized Complete Block Design with three replicates. The lengths of the planting materials (clones) were 30 cm. The main plot (Factor A) constituted two sweet potato varieties viz., Vumilia (SP/93/23) and Simama (SPN/0). Both sweet potato varieties were collected from SUA Horticultural Unit. The sub-plot (Factor B) were four toppings of vines and leaves: The control of no topping (T1); removing 25% of vines and leaves once every month starting 40 days after planting and frequency of removing were three times per crop growing season (T2), removing 25% of vines and leaves twice per month starting 40 days after planting and the frequency of removing were six times per crop growing season (T3). The fourth treatment was removing 25% of vines and leaves per month starting 54 days after planting and the frequency of removing were three times per crop growing season (T4). Vines were cut 2 cm from the main vine or base and weighed.

Agronomic practices: Sweet potato vines were planted at a spacing of 1.0×0.3 m on ridges while the size of a replicate of 4×9 m was used. The distance between main plots was 4 and 1 m separated one replicate from the other. The field was kept free of weeds by hand weeding and the plants were irrigated once per week for the whole period of growing.

Data collected

Weight of fresh vines and leaves: The weight of vines and leaves which were removed during the study of the experiment were measured in kilograms. Weight of the vines and leaves was obtained for the whole period of the experiment before harvesting the crop for each treatment except the control.

Total aerial fresh weight: Cutting the upper portion of the plant at 2 cm from the base was done after 120 days from planting and measurements were taken on fresh weights then added to the leaf and vines fresh weights collected during the growing cycle in all the treatments except the control.

Number of slender roots: After 120 days from planting, harvesting of the roots was done and slender roots were separated from marketable roots. A criterion used was all roots with diameter less or equal to 25 mm were categorized as slender roots. The slender roots were then counted in order to obtain the total number per each sub-plot.

Number of marketable roots: Roots having diameters greater than 25 mm were categorized as marketable roots. The total number for each sub-plot was obtained.

Average root diameter: The diameters of all marketable roots were measured in millimeter using Vernier calipers. Then the average was calculated for each sub-plot.

Average root length: Only marketable roots were measured for length by using tape measure. Average length for all roots was found in centimeter for each sub-plot.

Yield of marketable roots (t ha^{-1}): The yield (kg) at 2.1 m^2 being harvestable area was converted to tons per hectare for each subplot.

Data analysis: The data collected were subjected to the analysis of variance (ANOVA) Procedure (SAS, 1990) and Multivariate analysis of variance (MANOVA) for calculating partial correlation coefficients for yield and yield components. All variables recorded were analyzed according to the following statistical model:

$$Y_{ijk} = \mu + R_i + V_j + (RV)_{ij} + T_k + (VT)_{jk} + (RVT)_{ijk}$$

Where:
Y_{ijk} = Marketable yield (t ha^{-1}), μ = General mean, R_i = ith Replication effect, V_j = jth variety effect, $(RV)_{ij}$ = ijth main plot error, T_k = kth treatment effect, $(VT)_{jk}$ = jkth Interaction of variety and treatment, $(RVT)_{ijk}$ = Experimental error.

RESULTS

Sweet potato varieties showed significant differences on numbers of slender roots and marketable roots, average marketable root length, weights of fresh vines and leaves and marketable root yield. On the other hand vines and leaf harvests displayed significant effects only on weight of fresh vines and leaves removed during the growing cycle (Table 1). SPN/O was consistently superior to SP/93/23 in all variables including yield and yield components of sweet potato (Table 2).

Removal of fresh vines and leaves significantly excelled the control treatment on weight of fresh vines and leaves harvested during the growing cycle, in which the control gave zero measurements. The former did not show significant difference between sub-plot treatments, however, removal of vines and leaves twice per month starting from 40 days after planting (T3) and removal of vines and leaves once per month starting from 54 days after planting (T4) gave relatively higher weights of fresh vines and leaves harvested during the season.

Significant and positive relationships were observed between number of marketable roots and marketable root yield; marketable root diameter and weight of fresh vines and leaves; marketable root length and root diameter and weight of fresh vines with leaves harvested during the growing cycle and total weight of fresh vines and leaves (Table 3).

DISCUSSION

Growing a crop is an exercise in energy transformation in which incident solar radiation is converted into more useful forms of chemical potential energy located in the harvested parts such as tuber roots in root crops (Hay and Walker, 1994). This study was therefore carried out to study the effect of removing vines and leaves on marketable root yields of sweet potato. It was noted that the two varieties under study showed significant differences in many variables investigated. The varieties under study have different characteristics and growing habits resulting into differences in performance. Genetic variation therefore exists for all the variables studied except average marketable root diameter, suggesting scope for improvement of the studied variables. However, the study used only two varieties of sweet potatoes and thus future work should include more varieties for a more comprehensive information on genetic variation.

The variety SPN/0 gave 12.3 t ha^{-1} of roots while SP/93/23 gave 2.9 t ha^{-1}. This difference could be attributed to the differences in canopy characteristics

Table 1: ANOVA summary for investigated variables (mean squares given)

Source of variation	df	No. of slender roots	No. of marketable roots	Average marketable root length (cm)	Average marketable root diameter (mm)	Weight of fresh vines and leaves (kg) removed during the experiment	Total weight of fresh vines and leaves (kg)	Marketable root yield (t ha^{-1})
Replication	2	0.38	0.50	67.33	509.63	3.40	158.09	8683.42
Variety	1	92.04**	210.04**	242.19**	580.17	21.87*	481.87***	533823.32***
Error (a)	2	9.54	32.17	0.56	25.04	2.57	80.42	68122.92
Treatment	3	5.38	28.04	31.88	243.89	44.61***	52.52	64126.50
Variety x Treatment	3	2.71	6.71	13.52	44.72	2.60	23.53	6927.25
Error (b)	12	8.96	8.83	16.62	249.72	2.88	24.72	20949.82
Total	23							
CV (%)		55.68	38.98	30.26	36.75	44.21	37.05	60.00
R^2		0.56	0.78	0.72	0.46	0.84	0.80	0.81

*, **, *** = p<0.05, p<0.01 and p<0.001, respectively

Table 2: Effect of variety and treatments on variables investigated

A. variety	Number of slender roots	Number of marketable roots	Average marketable root length (cm)	Average marketable root diameter (mm)	Weight of fresh vines and leaves (kg) removed during the experiment	Total weight of fresh vines and leaves (kg)	Marketable root yield (t ha^{-1})
SPN/O	7.33	10.58	16.65	47.92	4.79	17.90	12.34
SP/93/23	3.42	4.67	10.29	38.08	2.88	8.94	2.91
$\bar{X}$	5.38	7.63	13.47	43.00	3.84	13.42	7.63
$LSD_{0.05}$	2.66	2.64	3.63	NS	1.51	4.42	4.07
B. Treatments							
T1	4.83	10.17	15.88	47.83	0.00	13.72	11.63
T2	6.33	6.00	12.28	37.33	3.82	9.91	5.69
T3	4.33	5.67	10.86	37.66	6.07	12.95	4.34
T4	6.00	8.67	14.85	49.17	5.44	17.11	8.85
$\bar{X}$	5.37	7.63	13.47	43.00	3.83	13.42	7.63
SE	1.22	1.21	1.66	6.45	0.69	2.03	1.87
$LSD_{0.05}$	NS	NS	NS	NS	2.91	NS	NS

NS = Non Significant

Table 3: Partial correlations coefficients among variables investigated

Variables	1	2	3	4	5	6	7
Number of slender roots	1	0.22	0.15	0.22	0.28	-0.01	0.22
Number of marketable roots		1	0.69**	0.51	0.69**	0.16*	0.43
Marketable root yield (ton/ha)			1	0.46	0.31	0.54	0.43
Average marketable root length (cm)				1	0.84***	0.47	0.34
Average marketable root diameter					1	0.39	0.31
Weight of fresh vines and leaves (kg) Removed during the experiment						1	0.71**
Total weight of fresh vines and leaves							1

*, **, *** = p<0.05, p<0.01 and p<0.001, respectively

between the varieties (Peter *et al*., 1988). Donald (1968) and Peter *et al*. (1988) reported that crops with erectophilic leaf posture have an advantage in intercepting more light, with higher photosynthetic rate and hence higher photosynthetic efficiency. For this reason, SPN/O, which has erectophilic leaf posture produces higher number of marketable roots and hence higher yields than variety, SP/93/23, which has more horizontal leaf posture. It has also been reported by Chapman and Cowling (1965) that vertical leaf display, and by inference photosynthesis, might be directly involved in sweet potato yield. Gonzales *et al*. (1977) reported similar observations in which different varieties of sweet potato differed in canopy characteristics.

Both varieties, however, yielded more than 2.5 tons per hectare, the level usually obtained under ideal weather conditions and management practices in farmers' conditions (Kapinga *et al*., 1995). The difference is due to the experiment being well managed as compared to farmers' situation. However, the yield of the two varieties of sweet potato is low compared to the yield potential of between 20 and 40 tons of storage roots per hectare worldwide (Jennifer, 1992).

The SPN/0 variety gave more number of slender roots than SP/93/23. This might be because the SPN/0 had more number of marketable roots than SP/93/23, indicating that some roots failed to thicken due to competition for assimilates among developing roots. However, SPN/0 gave more number of marketable root diameter although the difference with SP/93/23 was not significantly different. More number of tuberous roots per given area may lead to some roots not to develop to marketable size due to competition for resources such as water and space (Ney *et al*., 1993).

In the present study, vines and leaf removal treatments did not differ significantly in terms of marketable root yield per hectare. The extent of root development and hence tuberous yield is largely influenced by the vegetative part through favourable environmental conditions (Villareal and Griggs, 1982; Dahniya *et al*., 1985). Gonzales *et al*. (1977) and Villareal *et al*. (1979a) obtained contrary results, which showed that topping sweet potato plants reduced tuberous root yield. The highest root tuber yield, however, was obtained where no topping was done. Edmond and Ammerman (1971) reported that removal of 25% or less of the vines compared with 50, 75 and 100% would not seriously reduce yield. In addition, Villareal and Griggs (1982) reported that topping of sweet potato increased yield and starch content of the roots because it minimized the competition between shoots and roots in drawing photosynthates. This is probably because of differences in environmental factors and that varieties may differ on the critical proportion of leaves and vines removal that is necessary to affect final yield (Marshner, 1997; Foyer, 1988). It seems there is a trend on yield reduction with more severe removal of vines and leaves, that is, with increased frequency of topping. Results show that relatively high yield was obtained from the control treatment (11.6 t ha^{-1}), followed by topping once per month starting after 54 days from planting (8.9 t ha^{-1}), while the least yield was obtained with topping twice per month starting from 40 days after planting (4.3 t ha^{-1}). Topping frequencies have been found to reduce root yield in sweet potato by other workers (Sasis, 1940; Yamda *et al*., 1962). Similar observations were reported by Gonzales *et al*. (1977) and Villareal *et al*. (1979a), in which tuberous root yields were generally decreased by frequency of harvesting of the tops. The swollen roots, which accumulate assimilates are predominantly sinks while the shoots and particularly leaves which produce assimilates are the source (Hahn, 1977). The varieties with large sink capacities were reported by Hahn (1977) that they show greater responses of transferring the assimilates from sink to source than those with small sink capacities. Thus, removal of shoots is expected to reduce the assimilate flow due to diminished concentration gradient between source and sink (Dahniya *et al*., 1982).

The positive correlations observed between marketable roots with root yield, root diameter, weight of fresh vines and leaves indicate that tuber development and thickening is correlated with top growth (Dahniya *et al*., 1981). This also indicates that the vines and leaves (source) played a major role in translocation of carbohydrates during the period of crop growth (Kato and Hozyo, 1974). The thickenings of tuberous roots exert an effect on the apparent photosynthetic activity of leaf blade (Dahniya *et al*., 1982). Thus, the property of root thickening exerts an influence not only on the distribution of dry matter to each organ, but also on dry matter production. The study shows that the rate of translocation of carbohydrates to roots was high with tuberous roots in SPN/O variety, which showed relatively higher number of marketable roots diameter as compared to SP/93/23 variety.

The investigation shows that varieties of sweet potato differ significantly on most of the yield components indicating potential for genetic improvement particularly on number and length of roots, weight of fresh vines and leaves and root yield. SPN/O was consistently superior to SP/93/23 on the studied variables. Topping, however, had significant effect only on weight of fresh vines and leaves whereby the control provided no fresh aerial parts at the time of final harvesting, while removing 25% of vines and leaves twice per month starting 40 days after planting and the frequency of removing of six times per crop growing season gave the highest weight of fresh aerial parts but with the least marketable root yield. To compromise for both root and aerial fresh weight for both home and market requirements, it is recommended that removing 25% of vines and leaves per month starting 54 days after planting and the frequency of removing of three times per crop growing season should be used by subsistence farmers.

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