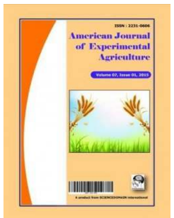

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Growth and Yield Components of Sweet Potato (*Ipomoea batatas* L.) and their Relationships with Root Yield

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Authors' contributions

This work was carried out in collaboration between all authors. Author SUY designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SGM and SOA reviewed the experimental design and all drafts of the manuscript. Authors SUY and AMS managed the analyses of the study. Author SOA identified the plants. Authors SUY and AMS performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the extent of the relationships of various growth and yield related characters. To evaluate the direct and indirect contributions of these characters to root yield, a basis of selection for further improvement.
Study Design: Field Experiment, in Randomized Complete Block Design.
Place and Duration of Study: Teaching and Research Farm of Bayero University, Kano (11°58'N and 8°25'E) and Agricultural Research Station Farm, Minjibir (12°11'N and 8°32'E) located in the Sudan Savanna of Nigeria between July-October, 2014.
Methodology: Sixteen (16) sweet potato advanced lines: Centennial, AYT/08/055, TIS8164, TIS87/0087, NRSP/12/097, UMUSPO/2, UMOSPO/1, SOLOMON1, EA/11/022, EA/11/025,

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EA/11/003, UM/11/015, NRSP/12/095, UM/11/001, UM/11/022, and a local check (Kantayi idda) were evaluated using a randomized complete block design with three replications. Data were collected on number of leaves per plant, vine length, vine weight, number of roots per plant, average root weight and the root yield. Simple and partial correlations between root yield (Y), growth and yield components (X) and within the growth and yield components themselves were worked out.

Results: Root yield was found to be significant (p<.01) and positively correlated with number of leaves per plant, number of roots per plant and average root weight. Vine length was negatively correlated to average root weight and root yield, whereas number of roots per plant was positively correlated to the average root weight and root yield. The path analysis also revealed that average root weight registered the highest direct contribution to root yield. The highest indirect effect on root yield also came from the number of roots per plant via the average root weight.

Conclusion: The average root weight contribution to root yield was much higher than those of vine length and vine weight both directly and indirectly. Thus, emphasis should be given towards increasing the average root weight and number of roots per plant as criteria and basis of selection of sweet potato for higher root yield.

Keywords: Sweet potato; correlation; path analyses; growth; yield components; root yield.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is a member of the morning glory family *Convulvulaceae,* producing edible roots and leaves. The crop originated from Latin America with China being the top producer, growing 85 million ton annually with Uganda being the major producer in the sub-Saharan Africa [1]. The crop has great potential to alleviate hunger, malnutrition and poverty in developing countries, since it is source of food, feed and processed products [2,3]. Sweet potato production in Nigeria has increased over the last two decades from 143,000 tonnes in 1990 to over three million tonnes in 2013 [4]. The crop is presently cultivated in all agro-ecologies of Nigeria. Low resistance to sweet potato virus disease, susceptibility to sweet potato weevil, lack of tolerance of some important cultivars to random drought, poor soil fertility are among the production constraints of sweet potato. Erroneous beliefs tied to its consumption such as male sterility, impotence, pile and poor marketing mechanism and utilization as well as lack of improved desirable varieties have militated against its consumption in the country [1]. Developing appropriate genetic and/or crop management strategies towards increasing the yield of any crop require the knowledge of important traits that influence it, and the relationships among those traits. This is because increasing total yield is easier by improving its components [5]. This is because many economically important traits of plants are often related to each other in several ways [3]. Thus understanding the nature and magnitude of genetic diversity and interrelationships among sweet potato genotypes for these traits is vital to its effective improvement [6]. In a study of some growth attributes and their interrelationships with yield, leaf size and number of roots per plant were reported to be closely connected with yield in sweet potato [7]. Other authors have also reported findings on relationships among important yield components and yield [8-11]. However, there was no adequate information on the character associations as well as percentage contributions of the various growth and yield related components to root yield in the study area. Therefore, this study was aimed to assess the extent of the relationships of the various growth and yield related components, as well as to evaluate their direct and indirect contributions to root yield so as to form a basis of selection for further improvement.

2. MATERIALS AND METHODS

2.1 Study Areas

Two field trials were conducted in 2014 rainy season at the Teaching and Research Farm of Bayero University, Kano (BUK11°58'N and 8°25'E) and Agricultural Research Station Farm, Minjibir (MJB12°11'N and 8°32'E) between July to October, 2014.

2.2 Soil Sampling and Analysis

Soil samples were collected from the experimental fields at 0-30 cm depths prior to planting. These were bulked and composite samples used to determine their physical and chemical properties (Table 1). The soils were sandy loam and moderately acidic with low organic matter and organic carbon contents, and high available phosphorus.

2.3 Treatments and Experimental Design

The treatments consisted of sixteen (16) sweet potato genotypes: Centennial, AYT/08/055, TIS8164, TIS87/0087, NRSP/12/097, UMUSPO/2, UMOSPO/1, SOLOMON1, EA/11/022, EA/11/025, EA/11/003, UM/11/015, NRSP/12/095, UM/11/001, UM/11/022, and a local check (Kantayi idda). These were arranged in randomized complete block design and replicated three times.

2.4 Agronomic Practices

Sweet potato vines of 30 cm long bearing at least four nodes were planted on 40 cm high erected ridges at 30 x 75 spacing. Dead stands were replaced after 7 days of planting. Each plot consisted of 4 rows of 3 meter long with a net plot of 4.5 m^2 (1.5 x 3 m). Weeds were controlled manually using hoe at 3 and 6 weeks after planting, while NPK 15 – 15 – 15 was applied at 400 kg/ ha as recommended [12]. Vines were cut at the soil surface to facilitate curing at physiological maturity and left for 7 days after which the roots were manually harvested using hoe.

2.5 Data Collection and Analysis

Data were collected on number of leaves per plant, vine length, vine weight, number of roots per plant, average root weight and root yield. Simple correlation coefficients between root yield (Y), growth and yield components (X) and within the growth and yield components themselves were worked out using the following equation [13]

$$Rxy = SPxy\,\sqrt{ssx}.ssy$$

Where

Y = Correlation coefficient,
SPxy = Sum of products of x and y
SSx = sum of squares of x
SSy = sum of squares of y

The calculated coefficients were further used to develop the following simultaneous equations in order to partition the correlations into cause and effect relationships by working out the path coefficients (P_i)

$$r_{16} = p_1 + p_2r_{12} + p_3r_{13} + p_4r_{14} + p_5r_{15}$$
$$r_{26} = p_1r_{12} + p_2 + p_3r_{23} + p_4r_{24} + p_5r_{25}$$
$$r_{36} = p_1r_{13} + p_2r_{23} + p_3 + p_4r_{34} + p_5r_{35}$$
$$r_{46} = p_1r_{14} + p_2r_{24} + p_3r_{34} + p_4 + p_5r_{45}$$
$$r_{56} = p_1r_{15} + p_2r_{25} + p_3r_{35} + p_4r_{45} + p_5$$

Table 1. Physico-chemical properties of soils (0-30 cm) at experimental sites

Character	Values		Methods
	BUK	MJB	
Particle Size (%)			
Sand	72.96	80.76	Bouyous Hydrometer
Silt	16.00	5.70	
Clay	11.04	6.54	
Textural class	Sandy loam	Sandy loam	
Chemical properties			
pH (H2O)	5.27	6.10	Glass Electrode pH meter
Organic carbon (gkg^{-1})	0.618	0.487	Walkley-Black Method
Total Nitrogen(gkg^{-1})	0.28	0.18	Micro Kjeldahl Method
Available Phosphorus ($mgkg^{-1}$) soil	15.90	14.43	Bray 1 Method
Organic matter(gkg^{-1})	1.07	0.84	Multiplying Organic Carbon by 1.724
Exchangeable bases (Cmol kg^{-1})			
Ca++	2.12	0.30	Ammonium Acetate
Mg++	1.01	2.12	Ammonium Acetate
K+	0.61	0.54	Ammonium Acetate
Na+	0.32	0.32	Ammonium Acetate
CEC	4.31	4.11	Ammonium Acetate (pH7) Extraction

BUK – Bayero University Kano; MJB - Minjibir

From the above equations p_1, p_2, p_3, p_4 and p_5 are the path coefficients (direct effects) while p_1r_{13}, p_1r_{23}, p_1r_{34}, p_1r_{45}, p_2r_{23}, p_2r_{24}, p_2r_{25}, p_3r_{25}, p_3r_{34}, p_3r_{35} and p_4r_{45} are the indirect effects while r_{12} ….. r_{56} are the correlation coefficients. The individual and combined percentage contributions of any two characters were also computed using the following relation [14]

$$E = (p_i)^2 \times 100., \quad E_{ij} = 2p_ip_jr_{ij} \times 100$$

Where

E = Percent individual contribution
E_{ij} = Combined percent contribution of characters i and j
r_{ij} = Coefficient of correlation between i and j
p_i and p_j= Path coefficients of characters i and j

The residual factor (Rx), which represents the unaccounted error by the direct and combined effects were calculated by the following relation:

$$Rx = 1 – (p_1r_{16} + p_2r_{26} + p_3r_{36} + p_4r_{46} + p_5r_{56})$$

While the sum of the percent contribution (individual and combined) as well as the residual should add up to 100%.

3. RESULTS AND DISCUSSION

3.1 Simple Correlation

Results of simple correlation between root yield, growth and yield components in sweet potato is shown in Table 2. Number of leaves per plant, number of roots per plant and the average root weight were significantly ($p<0.01$) and positively correlated to root yield. Similar results have been reported [15] in which root yield in sweet potato was positively and significantly ($p<0.01$) correlated to root diameter, average root weight and number of roots per plant. Close relations between root yield and number of roots per plant were also reported [6]. On the other hand, vine length was negatively correlated to average root weight and root yield, whereas number of roots per plant were positively correlated ($p<0.01$) to the average root weight and root yield. This is an indication of the roles of these characters in influencing yield. Similar observation was reported for improved yield in garlic [16].

3.2 Partial Correlations

The direct, indirect effects and the total contributions of some growth and yield components to root yield of sweet potato are presented in Table 3. The total contribution of the number of leaves per plant was highly significant (0.6210), while its direct contribution was small and negative (-0.0443). Similarly, the indirect contribution of number of leaves via vine length was found to be -0.0006, while those via the vine weight, number of roots per plant and the average root weight were 0.0199, 0.0929 and 0.5531, respectively.

This implied that improvement of any of these characters could result in a partial decrease in the other character [17].

The results of the study further indicated that 0.0060 was the total contribution of the vine length to root yield. Out of this, only 0.0098 was directly contributed by the vine length. Similarly, 0.0026, 0.0063, 0.0252 and -0.0499 were contributed indirectly via number of leaves, vine weight, number of roots and average root weight, respectively. The total contribution of vine weight and root yield was 0.2880. Out of this, only 0.1243 was directly contributed by the vine weight. The indirect contributions of vine weight via the number of leaves, vine length, number of roots and average root weight were -0.0071, 0.0063, 0.0528 and 0.1117, respectively. This might be due to the influence of fresh leaf weight on root and the number of roots per plant [18].

The total contribution of number of roots per plant and root yield under this study was found to be 0.4391, out of which 0.1814 was directly contributed by the number of roots per plant. However, -0.0227, 0.0014, 0.0362 and 0.2428 were contributed indirectly via number of leaves, vine length, vine weight and average root weight, respectively. Similar results have been reported. [6].

The results of the path analysis also indicated 0.8120 as the total contribution of the average root weight and the root yield. Out of this, 0.7682 was directly contributed by the average root weight. This indicated average root weight as important in contributing to root yield in sweet potato and hence could be given prime importance in selection of trait for yield improvement [15]. Similarly, the indirect contributions via number of leaves, vine length, vine weight and number of roots were 0.0319, -0.0006, 0.0190 and 0.0573, respectively. This is expected because more roots will translate to increased yield, hence this is important in deciding the root yield in sweet potato [15].

3.3 Percentage Contributions

When the individual percent contributions of the growth and yield components were examined, it was noted that the percentage (direct) contribution of number of leaves was 0.1961 (Table 4). Similarly, the individual percentage (direct) contributions of the vine length, vine weight, number of roots and average root weight were 0.0096, 1.5442, 3.2907 and 59.0114, respectively. This re-emphasize the importance of number of roots and the average root weight in contributing to root yield in sweet potato [15,7].

The combined contributions of number of leaves and vine length to root yield was small (0.0050). Negative trend was observed for the combined effects of number of leaves and vine weight, number of leaves and number of roots, as well as number of leaves and average root weight in which -0.1761, -0.8227 and -4.8991 were contributed, respectively.

Similarly, the combined contribution of vine length and average root weight was negative (-0.0980). However, 0.0124, 0.0495, 1.3119, 2.9210 and 8.8070 were contributed by the combined effects of vine length and vine weight, vine length and number of roots, vine weight and number of roots, vine weight and average root weight and number of roots and average root weight, respectively. These characters were reported as significant in influencing root yield in sweet potato [18]. Out of these contributions, 28.8368% could not be accounted for and were regarded as residuals (Table 4). This could be attributed to the effect of new environment as reported in cowpea [19]. Similarly, the delayed leaf senescence observed in some varieties may account for these large residuals [20].

Table 2. Matrix of simple correlation coefficients showing association among some growth and yield related components to root yield of sweet potato genotypes

	Number of leaves per plant	Vine length	Vine weight	Number of roots per plant	Average root weight
Number of leaves per plant	1.00				
Vine length	-0.058	1.00			
Vine weight	0.160	0.051	1.00		
Number of roots per plant	0.512**	0.139	0.291*	1.00	
Average root weight	0.720**	-0.065	0.153	0.316*	1.00
Root yield	0.621**	-0.006	0.288	0.439**	0.812**

*** P< .01   * P< .05*

Table 3. Direct, Indirect and total contributions of some growth and yield components to total root yield of sweet potato genotypes

	Effect through					
	Number of leaves per plant	Vine length	Vine weight	Number of roots per plant	Average root weight	Total correlation
Number of leaves per plant	-0.0443	-0.0006	0.0199	0.0929	0.5531	0.6210**
Vine length	0.0026	0.0098	0.0063	0.0252	-0.0499	0.0060
Vine weight	-0.0071	0.0063	0.1243	0.0528	0.1117	0.2880
Number of roots per plant	-0.0227	0.0014	0.0362	0.1814	0.2428	0.4391**
Average root weight	0.0319	-0.0006	0.0190	0.0573	0.7682	0.8120**

Underlined = Direct effect

Table 4. Direct, combined contributions (%) and residual effects of some growth and yield characters to root yield of sweet potato genotypes

Character		Percentage contribution
Direct contributions	**$(P_1)^2$ x 100**	
Number of Leaves per Plant	$(P_1)^2$	0.1961
Vine Length	$(P_2)^2$	0.0096
Vine Weight	$(P_3)^2$	1.5442
Number of Roots per Plant	$(P_4)^2$	3.2907
Average Root Weight	$(P_5)^2$	59.0114
Combined contributions	**$(2r_{ij}p_ip_j)$ x 100**	
Number of Leaves and Vine Length	$(2r_{12}p_1p_2)$	0.0050
Number of Leaves and Vine Weight	$(2r_{13}p_1p_3)$	-0.1761
Number of Leaves and Number of Roots	$(2r_{14}p_1p_4)$	-0.8227
Number of Leaves and Average Root Weight	$(2r_{15}p_1p_5)$	-4.8991
Vine Length and Vine Weight	$(2r_{23}p_2p_3)$	0.0124
Vine Length and Number of Roots	$(2r_{24}p_2p_4)$	0.0495
Vine Length and Average Root Weight	$(2r_{25}p_2p_5)$	-0.0980
Vine Weight and Number of Roots	$(2r_{34}p_3p_4)$	1.3119
Vine Weight and Average Root Weight	$(2r_{35}p_3p_5)$	2.9210
Number of Roots and Average Root weight	$(2r_{45}p_4p_5)$	8.8070
Residual	$1 - (p_1r_{16} + p_2r_{26} + p_3r_{36} + p_4r_{46} + p_5r_{56})$	28.8368
Total		**100.0000**

4. CONCLUSION

Significant and positive correlations were observed between number of leaves per plant, number of roots per plant, average root weight and root yield of sweet potato genotypes. Upon partitioning the correlation coefficients into direct and indirect effects, average root weight had the highest contribution to root yield, while the highest indirect effect to root yield came from the number of roots per plant via the average root weight. This indicates that average root weight is the significant contributor to root yield. Breeders must therefore, pay attention to average root weight when breeding for storage root yield in sweet potato.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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