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Correlation and Path Analysis between Yield and Yield Components in Cassava (*Manihot esculenta* Crantz) in Southern Tanzania

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Abstract
An experiment to study the relations among root yield and some traits of cassava using correlation and path coefficient analysis was conducted in the Sothern Tanzania during the 2011 – 2012 cropping season. The design of the experiment was a Randomized Complete Block with three replications using twelve genotypes. Highly significant and positive correlations were found between plant height and stem girth (r = 0.5900***), plant height and roots per plant (r = 0.4463***), plant height and harvest index (r = 0.3005***), branches per plant and roots per plant (0.2441***), stem girth and roots per plant (0.5046***) and roots per plant and harvest index (0.2647***). Also, highly significant and positive correlations were found between root yield and plant height (r =0.5436***), stem girth (r = 0.3874***), roots per plant (r = 0.7053***) and harvest index (r = 0.3025***). Compared to the simple correlation analysis, path analysis of roots per plant, plant height and root size evolved the highest direct influence 0.619, 0.290 and 0.153, respectively. Therefore, indirect selection for higher root yield may be effective for improving these characters. This study suggests the relative higher value of residual effect (0.51) indicated more yield components should be considered in the future to account for the variation in cassava root yield.
Key words: Correlation, Path analysis, Cassava, Yield, Yield components.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is from the family *Euphobeaceae*. It is among the most important root crops worldwide and provides food for one billion people (Bokanga, 2001; Nuwamanya *et al.,* 2009). It is an important food crop in developing countries and is the fourth source of calories after rice, sugar cane and maize worldwide (Akinwale *et al.,* 2010). The edible roots supply energy for more than 500 million people worldwide (Ceballos *et al.,* 2006). It is a perennial crop, native to America and grown in agro ecologies which differ in rainfall, temperature regimes and soil types (Olsen and Schaal, 2001). Cassava constitutes an essential part of the diet of most tropical countries of the world (Calle *et al.,* 2005). In Africa the crop is the most important staple food grown and plays a major role in the effort to alleviate food crisis (Hann and Keyer, 1985).

High yield with good quality is the most important objective in cassava breeding. Cassava root yield is a complex character associated with many interrelated components. Generally, path coefficients describe relationships between characteristics; whereas correlation coefficients describe relationships in a simple manner. Path coefficient analysis shows the extent of direct and indirect effects of the causal components on the response component. In most studies involving path analysis, researchers considered the predictor characters as first-order variables to analyze their effects over a dependent or response variable such as yield (Ntawurunga *et al.,* 2001). This approach might result in multi collinearity for variables, especially when correlations among some of the characters are high (Samonte *et al.,* 1998). There may be also difficulties in interpretation of the actual contribution of each variable, as the effects are mixed or confounded because of collinearity. Samonte *et al.* (1998) adopted a sequential path analysis for determining the relationships between yield and related characters in rice (*Oryza sativa* L.) by organizing and analyzing various predictor variables in first, second and third order paths. Agrama (1996) and Mohammed *et al.* (2003) used this model for determining interrelationships among grain yield and related characters in maize. Yildirim *et al.* (1997) suggested that mass selection with few cycle of recurrent selection could be practiced for its improvement. Selection for storage root yield, which is polygenic trait, often leads to changes in other characters and also interrelationships among various characters is necessary to be able to design appropriate selection criteria in cassava breeding program. According to Grafuis (1959), increasing total yield would be made easier by selecting for components because the components are more simply inherited than be the total yield itself. Thus studies on correlation enable the breeder to know the mutual relationship between various characters on which selection can be used for genetic improvement (environment). In a study by Hossain *et al.* (2000), average root weight and average number of roots per plant had highly positive direct effect on cassava root yield. The aim of this study was to evaluate cassava root yield and its components by path analysis.

2. 0 Materials and Methods

2.1 Description of Study Area

The study was conducted in three locations of Southern Tanzania at Naliendele (Coastal low land plains), Mtopwa(Makonde plateau) and Nachingwea(Masasi-Nachinwea plains), during the 2011 – 2012 cropping season under rain fed conditions.Naliendele is located at 10^o 22'S and 40^o 10'E, 120m above sea level and receives mean annual rainfall of 950mm with monthly mean temperature of 27^{o}C and average relative humidity of 86%. Nachingwea is located at 10^o 20′S and 38^{o}46'E, 465 m above sea level has a mean annual rainfall of 850mm, mean monthly temperature of 25^{o}C and annual mean relative humidity of 78%. Mtopwa is located at 10^o 41'S and 39^o 23'E, 760m above sea level receives a mean annual rainfall of 1133mm with monthly mean temperature of 23^{o}C and mean relative humidity of 75%. All the three sites experience a mono-modal type of rainfall. These data are according to the report by the Planning Commission Dar es Salaam and Regional Commissioner's Office Mtwara, Tanzania (2008).

2.2 Experimental Material and Design

Twelve genotypes were used in this study. The genotypes were arranged in a Randomized Complete Block Design with three replications. The plot size was28m^2 and in each plot four rows were made. The spacing was 1m between plants and 1 m between rows making 7 plants per row and thus 28 plants per plot. A distance of 1m was maintained between the plots. No herbicides or fertilizers were applied to the trial, but all other agronomic practices were treated accordingly.

2.3 Data Collection

All the data were collected from the net plot area of 10m^2 (ten plants/plot) during harvesting and were from ten inner plants in each plot. Plant height (cm), number of branches per plant, stem girth (cm), number of roots per plant, root size, dry matter percentage and harvest index were collected.

2.1.4 Statistical Analysis

Indostat/Windostat version 8.5 and Genstat version 14 statistical softwares were used for analysis. Means of treatments were compared using Duncan's Multiple Range Test at 0.001 and 0.05 levels of significance.

3. 0 Results and Discussion

Yield data and other parameters are presented in Table 1. The root mean yield ranged from 7.32 to 21.72 t ha^{-1} as obtained from genotypes Albert and Kiroba respectively. Lowest mean for plant height was found in NDL 2006/741 (112cm) while the highest genotype, NDL 2006/850, had a mean height of 143cm, mean number of roots per plant was between 3.33 from NDL 2006/030 and 7.03 from Kiroba. The genotype with the lowest mean for number of branches per plant was NDL 2006/487 (1.22), while Kiroba had the highest mean for number of branches per plant (3.71). The average root size ranged from 0.19 kg and 0.38 kg from genotypes NDL 2006/104 and NDL 2006/738 respectively. Genotype NDL 2006/487 had the lowest harvest index of 0.60, while the highest harvest index of 0.74, was obtained from the genotype NDL 2006/738. In addition, the lowest CV was determined for plant height as 8.00 and the highest CV was determined for number of branches per plant (18.10). Stronger and positive correlations were found between plant height and root yield (r = 0.5436***), number of roots per plant and root yield (0.7053***) indicating that any increase in such characters will suffice the boast in root yield. Ntawurunga *et al.,* 2001 observed the similar results. Other stronger and positive correlations were observed between plant height and stem girth (r=0.5900***) implying that as cassava plant height increases also it will increase in stem thickness. The observation that, number of roots per plant increases as plant height increases (r= 0.4463***), suggests that tall plants will bear more roots per plant than shorter plants. It was also found that Plant height and harvest index showed stronger and positive correlation (0.3005***) (Table 2). Also stronger and positive correlations were found between number of branches per plant and harvest index (0.1763***) and between stem girth and roots per plant (0.5046***). On the other hand, negative and significant correlation were observed between stem girth and percentage root dry matter (r = -0.1548), suggesting that when breeding for high percentage root dry matter one should go for genotypes with thin stems.

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Table 1: Yield and other parameters of cassava genotypes

Genotype	PHT	BRP	STG	RTP	RTS	HI	RTY
ALBERT	134.20^{bc}	2.93^{bcd}	4.12^{ef}	3.64^{fgh}	0.24^{bcd}	0.67^{bc}	7.32^{g}
KIROBA	**116.90^{ef}**	**3.71^{a}**	4.85^{a}	**7.03^{a}**	0.28^{bcd}	0.73^{ab}	**21.72^{a}**
NALIENDELE	123.40^{de}	2.86^{cd}	4.27^{def}	5.24^{c}	0.20^{d}	0.67^{bc}	11.40^{e}
NDL 2006/030	126.30^{d}	2.80^{cde}	**4.07^{f}**	**3.33^{h}**	0.22^{cd}	0.68^{abc}	8.95^{f}
NDL 2006/104	130.20^{cd}	2.97^{bc}	4.59^{bc}	3.52^{gh}	**0.19^{d}**	0.67^{abc}	8.71^{f}
NDL 2006/283	137.80^{ab}	2.48^{efg}	4.37^{cde}	4.17^{de}	0.25^{bcd}	0.69^{abc}	10.88^{e}
NDL 2006/438	143.40^{a}	2.51^{efg}	4.32^{def}	5.83^{b}	0.22^{cd}	0.71^{abc}	18.61^{c}
NDL 2006/487	138.80^{ab}	1.22^{h}	4.71^{ab}	4.37^{d}	0.22^{cd}	**0.60^{d}**	19.50^{b}
NDL 2006/738	129.20^{cd}	2.59^{def}	4.43^{cd}	3.89^{efg}	**0.38^{a}**	**0.74^{a}**	13.47^{d}
NDL 2006/741	112.60^{f}	3.24^{b}	4.35^{cde}	3.81^{efg}	0.23^{cd}	0.66^{c}	8.93^{f}
NDL 2006/840	126.40^{d}	2.21^{g}	4.28^{def}	3.77^{efg}	0.33^{ab}	0.68^{abc}	**7.94^{fg}**
NDL 2006/850	**144.90^{a}**	**2.28^{fg}**	**4.87^{a}**	4.07^{def}	0.30^{abc}	0.71^{abc}	14.17^{d}
Minimum	**112.60**	1.22^{h}	**4.07**	**3.33**	**0.19**	**0.60**	**7.94**
Maximum	**144.90**	**3.71**	**4.87**	**7.03**	**0.38**	**0.74**	**21.72**
Overall mean	**130.32**	**2.65**	**4.44**	**4.39**	**0.25**	**0.68**	**12.63**
s.e	**10.36**	**0.48**	**0.36**	**0.59**	**0.13**	**0.08**	**1.49**
C.V. (%)	**8.00**	**18.10**	**8.10**	**13.40**	**12.10**	**11.90**	**11.80**

Means with the same superscript letter(s) in the same column are not significantly different ($P \leq 0.05$) following separation by Duncan's Multiple Range Test.

Key: PHT = Plant height (cm), BRP = Number of branches per plant, STG = Stem girth (cm), RTP = Number of roots per plant, RTS = Root size (kg), HI = Harvest index and RYD = Root yield (t ha^{-1}).

Table 2: Genetic correlations between variables influencing yield in cassava

	PHT	BPL	RSZ	SGH	DM	RPL	HI	YLD
PHT	1.0000	-0.02570	0.10970	0.5900 ***	-0.05730	0.4463 ***	0.3005 ***	0.5436***
BPL		1.0000	-0.06060	0.03350	-0.04100	0.2441 ***	0.1762 **	0.0947
RSZ			1.0000	-0.00620	0.07370	0.0033	0.08330	0.1969
SGH				1.0000	-0.15480 *	0.5046 ***	0.09280	0.3874***
DM					1.0000	-0.00100	0.02690	0.0472
RPL						1.0000	0.2647 ***	0.7053***
HI							1.0000	0.3025***
YLD								1.000
Significance Levels		0.05	0.01	0.005	0.001			
If correlation (r = >)		0.1335	0.1749	0.1903	0.2224			

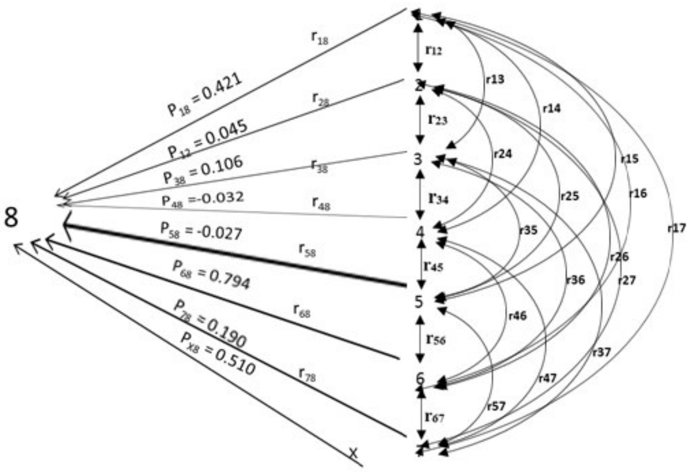
Where; PHT = Plant height (cm)t, BPL = Branches per plant, RSZ = Root size(kg), SGH = Stem girth (cm), DM = Dry matter (%), RPL = Roots per plant, HI = Harvest index, YLD = Root yield ($tgha^{-1}$)

In order to get clear picture of interrelationships between different traits, the direct and indirect effects of different characters were worked out using path coefficient analysis in respect of the yield (Maris, 1988). The path coefficient analysis based on root yield as a dependent variable, revealed that all traits studied, except per cent dry matter content showed positive direct effects.

Table 3: Results of Path Analysis

		Indirect Effects						
		PH	BRP	RTS	SGH	DM	RTP	HI
Traits	Direct Effect							
PH	0.290	1	0.001	0.017	-0.055	-0.002	0.276	0.016
BRP	0.045	-0.008	1	-0.009	-0.003	-0.001	0.151	0.010
RTS	0.153	0.032	0.003	1	0.001	0.003	0.002	0.004
SGH	0.093	0.171	-0.001	-0.001	1	-0.006	0.313	0.005
DM	-0.036	-0.017	0.002	0.011	0.014	1	-0.001	0.001
RTP	0.619	0.129	-0.011	0.000	-0.047	0.000	1	0.014
HI	0.054	0.087	-0.008	0.013	-0.009	0.001	0.164	1

Compared to the simple correlation analysis, path analysis of root yield and its components demonstrated that number of roots per plant, plant height and root size showed the highest direct influence of 0.619, 0.290 and 0.153 respectively suggesting that they are the most important traits in cassava improvement. These results agree with the study by Kasele, 1983. Percentage root dry matter had a negative and lowest direct effect of -0.036, also with an indirect negative effects via plant height and number of roots per plant of (-0.017) and (-0.001), respectively (Table 3). In addition, the indirect effects of number of branches per plant and stem girths were stronger than their direct effects. These analyses showed that number of roots per plant, plant height, and stem girth were the main characters for root yield. Tewodros and Yared (2013), found that average root yield weight, roots/plant, root weight/plant and plant height had positive and high direct effects on root yield. These findings were in concurrent with the results of the present study (Figure 1).



Where:

1 = plant height 2 = branches per plant 3 = root size 4 = stem girth
5 = dry matter 6 = roots per plant 7 = harvest index 8 = yield
X = residual P_{18} = effect of plant height P_{28} = effect of branches per plant
P_{38} = effect of root size P_{48} = effect of stem girth P_{58} = effect of dry matter
P_{68} = effects of roots per plant P_{78} = effect of harvest index P_{x8} = residual effect

$r_{18}=0.253$	$r_{12}=-0.026$	$r_{24}=0.033$	$r_{37}=0.083$
$r_{28}=0.139$	$r_{13}=0.11$	$r_{25}=-0.041$	$r_{45}=-0.155$
$r_{38}=0.044$	$r_{14}=0.59$	$r_{26}=0.244$	$r_{46}=0.505$
$r_{48}=0.481$	$r_{15}=-0.057$	$r_{27}=0.176$	$r_{47}=0.093$
$r_{58}=0.012$	$r_{16}=0.446$	$r_{34}=-0.006$	$r_{56}=-0.001$
$r_{68}=0.086$	$r_{17}=0.301$	$r_{35}=0.074$	$r_{57}=0.027$
$r_{78}=0.248$	$r_{23}=-0.061$	$r_{36}=0.003$	$r_{67}=0.265$
$P_{x8}=0.510$	P = Direct effect	r = Correlation coefficient	

Figure 1: Path diagram showing relationships between yield and yield components of cassava under combined analysis.

Correlation and path analyses indicated that number of roots per plant, plant height and stem girth were the main components to root yield, indicating that they were the most important traits contributing to storage root yield. Similar research results were published by Ntawuhurunga *et al.* 2001 and Amsalu, 2003.

4. 0 Conclusion

In conclusion, correlation coefficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in cassava root yield. However, path coefficient analysis helps to determine the direct effect of traits and their indirect effects on yield. Significant and positive correlations were observed between growth characters and root yield of cassava. When correlation coefficients were partitioned into direct and indirect effects, number of roots per plant had the highest contribution followed by plant height and stems girth, while harvest index contributed the lowest. These three characters therefore, can possibly serve as basis for selection in cassava improvement. Also the results showed that number of branches per plant had a negative direct effect on cassava root yield. Due to this, care must be taken by plant breeders when breeding for cassava plants with high number of branches per plant. Also this study suggests that, because of the relative higher value of residual effect, more yield components such as plant canopy, root length, root diameter etc., should be considered in the future to account for the variation in cassava root yield.

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