



A correlation and path-coefficient analyses of yield and selected yield components of cashew hybrids in Tanzania

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Abstract

An experiment was conducted to study the correlation and path analysis of thirty cashew genotypes in Tanzania. Results indicated that nuts per tree had strong and positive direct effects on yield and also with yield they were significantly and positively correlated at each location and in combined analysis. The significant positive correlations between percentage out turn with yield was predominantly due to the positive favorable interaction of percentage out turn with nuts per tree as manifested by the indirect effects of percentage out turn on yield through nuts per tree at each location and in combined analysis. Thus nuts per tree and percentage out turn were components identified that are useful as criteria for selection in cashew, which could be used in breeding programs to improve the crop yield in diverse ecologies.

Keywords: Nuts per tree, Percentage out turn, Direct effect, Indirect effect, Cashew yield.

Introduction

Cashew (*Anacardium occidentale* L.) is an important export crop in a number of tropical countries including Tanzania¹. It is the main cash crop and a leading source of income for more than 280 000 households in South-eastern Tanzania¹⁻⁴. The crop stands at third position after tobacco and coffee in foreign exchange earnings from year 2009 to 2011⁵. It contributes 18% of Tanzania's merchandise export earnings⁶. A breeder needs to identify causes of variability in yield in any given environment, before any improvement in yield can be realized⁷. Fluctuations in environment influences yield primarily through the yield components, therefore individual components of yield can contribute valuable information in breeding for the yield⁷.

Yield contributing components are interrelated with each other showing a complex chain of relationship⁸. Correlation analysis is a tool useful in providing indication of the degree of association between variables⁹. Correlations provide valuable insights to breeders for developing selection schemes⁸. Path analysis, on the other hand, is very useful in partitioning relationships between components into direct (independent contribution) and indirect effects¹⁰. The analysis is used to understand the complex relationships among traits. Path coefficient analysis differs from simple correlation analysis in that simple correlation coefficients indicate mutual association without regard to causation; while path analysis specifies the causes, measures relative importance of each cause and compensatory mechanisms existing among variables¹¹.

Path coefficient analysis in cashew improvement has been used by some scholars. From Aliyu study on correlation and path

analysis in cashew, it was observed that nuts per panicle, number of nuts per tree and number of hermaphrodite flowers per panicle were positively correlated with nut yield and thus could be used as primary components for improving yield⁷. The results further indicated significant positive direct effects of nut weight on yield. Kapinga also studying correlation and path analyses of some traits in cashew observed yield per day and percentage out turn to be positively correlated with yield¹². Traits associated with yield can be used for indirect selection or as selection indices for improved yield.

The objective of this study was to generate information on phenotypic and genotypic relationships among yield and its components and interrelationships among causal variables in cashew hybrids for future efficiency in cashew selection and improvement program in Tanzania.

Materials and methods

The experiment was conducted during the 2014/2015 cropping season in Nachingwea (Southern zone) and Chambezi (Eastern zone) of Tanzania. Nachingwea is located at 10°20'S, 38°46'E, altitude 465m; and Chambezi at 6°31'S, 38°55'E and altitude 33m above sea level. Twenty nine cashew hybrids (H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, H12, H13, H14, H15, H16, H17, H18, H19, H21, H22, H23, H24, H25, H26, H27, H28, H29 and H30) and a certified variety (AC4) were used in this study.

The experiment was laid out with three replications in RCBD (Randomized Complete Block Design). A plot comprised four trees planted in a row and spaced 12 m between plants and 12 m

between plots. The trial was established in 2005. Data collected were nut weight (NTWT), kernel weight (KNWT), nuts per panicle (NTPCL), nuts per tree (NTPT), percentage out turn (%OT) and nut yield (YLD).

Data were summarized and analyzed for correlation coefficients using GenStat 16th edition software. Determination of Path coefficients was performed following the outlined procedure of Dewey and Lu¹⁰. Relationships among yield and yield components were computed at each location and across locations on combined analysis. The method involved solving of unknowns (path coefficients) (Figure-1) from a series of simultaneous equations as shown below:

Double arrowed lines in the path diagram show mutual associations as measured by correlation coefficients, *r*. The single arrowed lines indicate direct influences as measured by path coefficients *P*.

Simultaneous Equations used in the computation of *rP*'s are as follow:

$$r_{16} = P_{16} + r_{12}P_{26} + r_{13}P_{36} + r_{14}P_{46} + r_{15}P_{56}$$

$$r_{26} = r_{12}P_{16} + P_{26} + r_{23}P_{36} + r_{24}P_{46} + r_{25}P_{56}$$

$$r_{36} = r_{13}P_{16} + r_{23}P_{26} + P_{36} + r_{34}P_{46} + r_{35}P_{56}$$

$$r_{46} = r_{14}P_{16} + r_{24}P_{26} + r_{34}P_{36} + P_{46} + r_{45}P_{56}$$

$$r_{56} = r_{15}P_{16} + r_{25}P_{26} + r_{35}P_{36} + r_{45}P_{46} + P_{56}$$

Computation of residual factor (*P_{x6}*) was based on the following equation;

$$1 = P^2X_6 + P_{16}^2 + P_{26}^2 + P_{36}^2 + P_{46}^2 + P_{56}^2 + 2P_{16}r_{12}P_{26} + 2P_{16}r_{13}P_{36} + 2P_{16}r_{14}P_{46} + 2P_{16}r_{15}P_{56} + 2P_{26}r_{23}P_{36} + 2P_{26}r_{24}P_{46} + 2P_{26}r_{25}P_{56} + 2P_{36}r_{34}P_{46} + 2P_{36}r_{35}P_{56} + 2P_{46}r_{45}P_{56}$$

The indirect effects of a variable on yield (*rP*'s) are the product of *r*, the correlation coefficient and *P*, the direct effect.

Explanations basing on the path model:

r_{ij} = simple correlation coefficients for measuring the mutual association of the two variable,

P_{ij} = path coefficients for measuring direct effects of the variables on yield

r_{ij}P_{ij} = indirect effects of variables upon another via other variables

p_x = the residue effect in the path analysis model; *i* and *j* = (1,2,3,8)

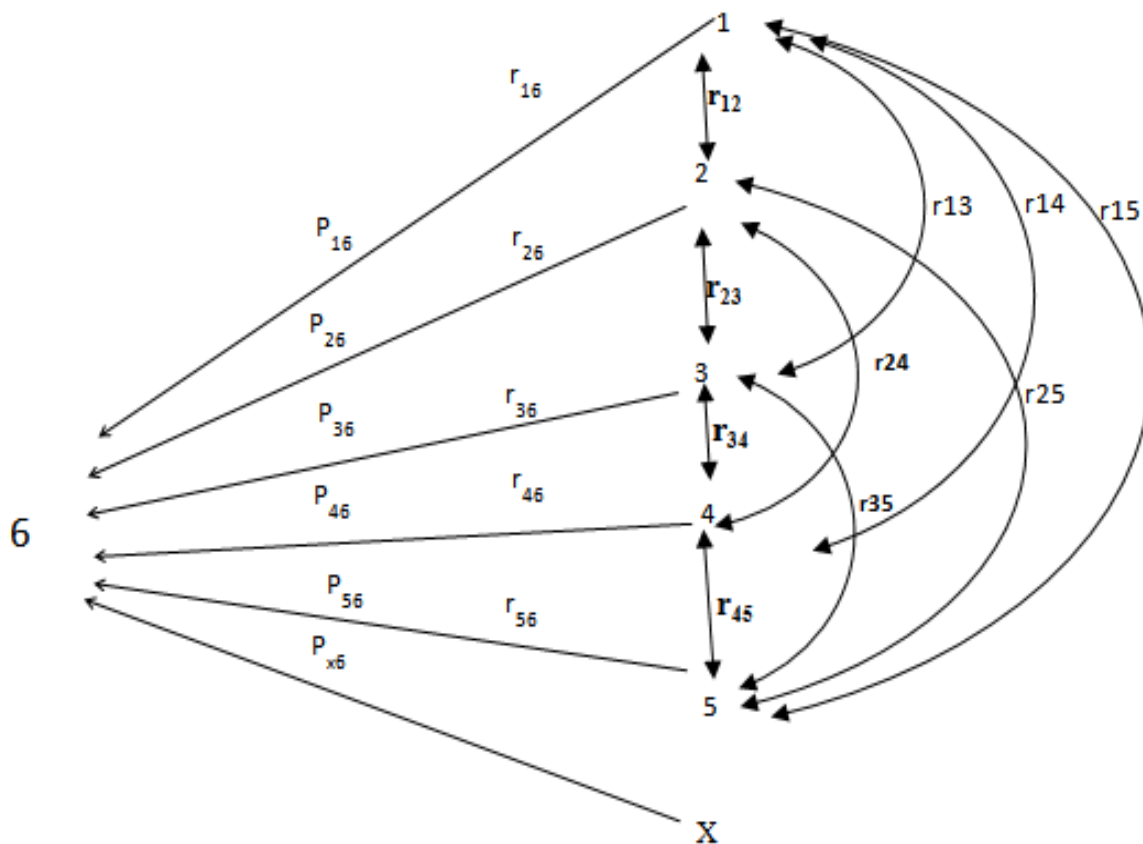


Figure-1: Path diagram indicating direct and indirect effects on yield and yield components.

Key: (1) = Nut weight; (2) = Nuts per tree; (3) = Kernel weight; (4) = Percentage out turn; (5) = Nuts per panicle; (6) = Yield and (X) = Residual effect.

Results and discussion

Correlation coefficients: Phenotypic and genotypic correlations among yield and yield components are summarized in Tables-1, 2 and 3. In general, genotypic correlations were

slightly higher than the corresponding phenotypic correlations but in some cases they were identical. Reference is hereby made only to genotypic correlations in order to avoid repeating unnecessarily same indications.

Table-1: Correlations for yield and yield components of cashew hybrids at Nachingwea.

		YLD	NTWT	NTPT	KNWT	%OT	NTPCL
YLD	Genotypic	1.000					
	Phenotypic	1.000					
NTWT	Genotypic	-0.1959	1.000				
	Phenotypic	-0.1954	1.000				
NTPT	Genotypic	0.7883***	-0.719***	1.000			
	Phenotypic	0.7872***	-0.719***	1.000			
KNWT	Genotypic	-0.1056	0.887***	-0.611***	1.000		
	Phenotypic	-0.1038	0.887***	-0.610***	1.000		
%OT	Genotypic	0.2499*	-0.46***	0.411***	-0.034	1.000	
	Phenotypic	0.2490*	-0.46***	0.411***	-0.034	1.000	
NTPCL	Genotypic	-0.099	0.123	-0.074	0.026	-0.187	1.000
	Phenotypic	-0.0998	0.122	-0.074	0.025	-0.188	1.000

Significance Levels 0.05, 0.01, 0.001; If correlation $r \Rightarrow 0.2072, 0.2702, 0.3411$ for both phenotypic and genotypic, * = $P \leq 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$. Key: YLD – Yield, NTWT – Nut weight, NTPCL – Nuts (number) per panicle, NTPT – Nuts (number) per tree, KNWT – Kernel weight, %OT- Percentage out turn.

Table-2: Correlations for yield and yield components of cashew hybrids at Chambezi site.

		YLD	NTWT	NTPT	KNWT	%OT	NTPCL
YLD	Genotypic	1.000					
	Phenotypic	1.000					
NTWT	Genotypic	0.0393	1.000				
	Phenotypic	0.0391	1.000				
NTPT	Genotypic	0.9601***	-0.099	1.000			
	Phenotypic	0.9602***	-0.101	1.000			
KNWT	Genotypic	0.2058	0.922***	0.075	1.000		
	Phenotypic	0.2054	0.922***	0.073	1.000		
%OT	Genotypic	0.4705***	0.583***	0.45***	0.771***	1.000	
	Phenotypic	0.4713***	0.581***	0.45***	0.770***	1.000	
NTPCL	Genotypic	0.1005	0.229*	0.123	0.248*	0.346***	1.000
	Phenotypic	0.1002	0.225*	0.124	0.245*	0.346***	1.000

Significance Levels 0.05, 0.01, 0.001; If correlation $r \Rightarrow 0.2072, 0.2702, 0.3411$ for both phenotypic and genotypic, * = $P \leq 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$. Key: YLD – Yield, NTWT – Nut weight, NTPCL – Nuts (number) per panicle, NTPT – Nuts (number) per tree, KNWT – Kernel weight, %OT- Percentage out turn.

Significant positive phenotypic and genotypic correlations were observed at all locations and in combined analysis between cashew yield with nuts per tree and percentage out turn; nut weight with kernel weight and nuts per tree with percentage out turn. On the other hand, though nut weight with nuts per tree were negatively correlated at all locations and in combined analysis, they were significantly so only at Nachingwea and in combined analysis. It is important to note that nut weight with percentage out turn were strongly and positively correlated at Chambezi and in combined analysis but strongly and negatively correlated at Nachingwea at both phenotypic and genotypic levels. Chambezi site and combined analysis revealed significant positive correlations between kernel weight, percentage out turn with nuts per panicle but not at Nachingwea. Strongly and significant positive correlation between kernel weight with percentage out turn were revealed at Chambezi and in combined analysis but not at Nachingwea.

Path Coefficient analysis: Path coefficient analysis was based on genotypic correlations and results are shown in Tables-4, 5 and 6. At each location and in combined analysis, nuts per tree had strong positive direct effects (independent contributions) on yield, consistently being greater than the residuals and was consistently positive and significantly correlated with yield. Similarly, the significant positive correlations between percentage out turn with yield were due to the positive (favorable) interactions between percentage out turn and nuts per tree as manifested by the indirect effects of percentage out turn on yield through nuts per tree. Had it not been the high and positive indirect effect of percentage out turn through nuts per tree, the correlation between percentages out turn with yield would have been negative. Percentage out turn interacted negatively (greater than the residual) at Chambezi and in combined analysis, but at Nachingwea, this interaction though negative (-0.025) was less than the residual (0.288).

Table-3: Correlations for yield and yield components of cashew hybrids in combined analysis.

		YLD	NTWT	NTPT	KNWT	%OT	NTPCL
YLD	Genotypic	1.000					
	Phenotypic	1.000					
NTWT	Genotypic	0.0075	1.000				
	Phenotypic	0.0075	1.000				
NTPT	Genotypic	0.9262***	-0.226**	1.000			
	Phenotypic	0.9257***	-0.226**	1.000			
KNWT	Genotypic	0.1066	0.926***	-0.113	1.000		
	Phenotypic	0.1057	0.926***	-0.113	1.000		
%OT	Genotypic	0.4298***	0.490***	0.414***	0.677***	1.000	
	Phenotypic	0.4293***	0.489***	0.414***	0.677***	1.000	
NTPCL	Genotypic	0.1938**	0.223**	0.195**	0.199**	0.296***	1.000
	Phenotypic	0.1935***	0.223**	0.195**	0.198**	0.295***	1.000

Significance Levels 0.05, 0.01, 0.001; If correlation $r \Rightarrow 0.2072, 0.2702, 0.3411$ for both phenotypic and genotypic, * = $P \leq 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$. Key: YLD – Yield, NTWT – Nut weight, NTPCL – Nuts (number) per panicle, NTPT – Nuts (number) per tree, KNWT – Kernel weight, %OT- Percentage out turn.

Table-4: Path analysis (based on genotypic correlation) of five selected variables showing direct (along diagonal) and indirect effects on cashew yield at Nachingwea.

Predictor variable	NTWT	NTPT	KNWT	%OT	NTPCL
NTWT	0.629	-0.452	0.557	-0.289	0.077
NTPT	-0.964	1.342	-0.819	0.551	-0.099
KNWT	0.142	-0.098	0.161	-0.005	0.004
%OT	0.011	-0.01	0.0008	-0.025	0.004
NTPCL	-0.01	0.006	-0.002	0.015	-0.084
r with YLD	-0.1959	0.7883***	-0.1056	0.2499*	-0.099
Residual effects (P _{x6})					0.288

NTWT = Nut weight, NTPT = Nuts per tree, KNWT= Kernel weight, %OT= Percentage out turn, NTPCL = Nuts per panicle, r = correlation.

Table-5: Path analysis (based on genotypic correlation) of five selected variables showing direct (along diagonal) and indirect effects on cashew yield at Chambezi.

Predictor variable	NTWT	NTPT	KNWT	%OT	NTPCL
NTWT	-0.067	0.006	-0.061	-0.039	-0.015
NTPT	-0.101	1.03	0.077	0.463	0.126
KNWT	0.354	0.028	0.385	0.296	0.095
%OT	-0.146	-0.113	-0.194	-0.252	-0.087
NTPCL	-0.005	-0.003	-0.006	-0.008	-0.024
r with YLD	0.0392	0.9601***	0.2058	0.4705***	0.1005
Residual effects (Px6)					0.209

NTWT = Nut weight, NTPT = Nuts per tree, KNWT= Kernel weight, %OT= Percentage out turn, NTPCL = Nuts per panicle, r = correlation.

Table-6: Path analysis (based on genotypic correlation) of five selected variables showing direct (along diagonal) and indirect effects on cashew yield in combined analysis.

Predictor variable	NTWT	NTPT	KNWT	%OT	NTPCL
NTWT	-0.026	0.0058	-0.024	-0.012	-0.005
NTPT	-0.256	1.133	-0.128	0.469	0.2209
KNWT	0.472	-0.057	0.51	0.345	0.101
%OT	-0.18	-0.152	-0.249	-0.369	-0.109
NTPCL	-0.003	-0.0027	-0.0027	-0.004	-0.014
r with YLD	0.0075	0.9261***	0.1065	0.4298***	0.1937***
Residual effects (Px6)					0.241

NTWT=Nut weight, NTPT=Nuts per tree, KNWT= Kernel weight, %OT= Percentage out turn, NTPCL = Nuts per panicle, r = correlation.

Discussion: Correlations according to genotypes were generally higher compared to their corresponding phenotypic correlations suggesting that relationships were mainly due to genetic causes. Significant positive genotypic correlations observed at all locations and in combined analysis between cashew yield with nuts per tree are in agreement with the report of Aliyu who pointed out that nuts per tree is highly positively and significantly correlated with yield⁷. Thus nuts per tree showed potentiality to be used as a primary component for yield improvement. Furthermore, the positive and significant genetic correlations between percentage out turn with yield was as reported by Kapinga¹².

strongly and negatively correlated at Nachingwea at both phenotypic and genotypic levels, significant positive correlations between kernel weight, percentage out turn with nuts per panicle at Chambezi site and combined analysis but not at Nachingwea. The study further indicates that all variables exhibited positive correlations with yield at Chambezi and in combined analysis but not at Nachingwea. This shows the effect of environment on the relationships between studied variables. Favorable environmental conditions during growing seasons favor positive relationship because of reduced intra-plant competition¹³. Chambezi had more favourable growing conditions compared to Nachingwea during the season.

Inconsistent relationships between variables were revealed in nut weight with percentage out turn which were strongly and positively correlated at Chambezi and in combined analysis but

Nut weight in this experiment had negative correlation with nuts per tree. This is in line with the results reported by Aliyu⁷. The possible reason for the negative correlation between the

variables could be intra-plant competition for the same resources. As the number of nuts increased the same resources manufactured by the plant are distributed to all nuts leading to individual nut weight decrease. Thus selection of one variable will select against the other. In such a situation, provision of ambient conditions with ample resources (nutrients, moisture, light) will likely reduce or eliminate intraplant competition hence the adverse correlations. In case where the associations are due to genotypic linkage, intercrossing and selection can remove the negative association, however, if pleiotropy is involved, little can be done to break the relations. A highly significant positive correlation ($r = 0.926^{***}$ combined analysis) was observed between nut weight and kernel weight a result which conforms to the study by Kapinga¹². The implication of correlated variables is that they have similar development patterns and can be selected together in an improvement program.

Selection progress may be enhanced or retarded by the nature of inter trait correlations. A positive relationship indicates that selection for improvement would result in parallel increases in the improvement components. Such type of relationship was recorded in most of the studied traits. From both direct influence and genetic correlation, increasing nuts per tree could increase yield. For maximum yield to be reached selection of this character (nuts per tree) is of great importance. This is because both the correlation with yield and direct effect were high. High negative direct effects on yield was recorded with percentage out turn at Chambezi and in combined analysis and the genetic correlation of percentage out turn with yield was sizeable and significantly positive and conforms with findings reported by Kapinga who observed similar trends¹². The direct effect was sizeable at Chambezi but not Nachingwea though both were negative due to differences between the environments as Chambezi had favourable growth conditions compared to Nachingwea. Ribeiro studying on common bean found variations in the direct effects as a function of genotypes, locations and years¹⁴. The environment influenced on the intensity in which the yield traits explained the productivity. The indirect effects of percentage out turn on yield through nuts per tree and via kernel weight must have played more important roles in net effect by counterbalancing the opposing influences making the overall correlation between percentage out turn and yield positive. This points the importance of compensations mechanisms among yield components in cashew.

The consistent positive interaction between percentage out turn with nuts per tree that resulted to significant positive correlations between percentage out turn with yield suggest that these variables can simultaneously be improved without adverse effects on yield using these components. Even though percentage out turn consistently recorded the highest negative direct effect on yield the character could be considered in selection program since it interacted well with nuts per tree in its relation with yield. The later was due to the positive

correlation between percentage out turn with nuts per tree and a positive direct effect of nuts per tree on yield.

Conclusion

Nuts per tree, percentage out turn and yield were consistently and positively correlated among themselves at genotypic and phenotypic levels at each location. Thus nuts per tree and percentage out turn could be used in cashew breeding programs in all the ecologies to improve yield without adverse compensation effects as these traits were identified to be useful as selection criteria. Nuts per tree had highest independent effects on yield of cashew at all locations, thus should serve as basis for selection in cashew improvement.

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