Journal of Plant Sciences
2013; 1(3): 33-38
Published online October 30, 2013 (http://www.sciencepublishinggroup.com/j/jps)
doi: 10.11648/j.jps.20130103.13

Studies on correlation and path analysis for root yield and related traits of Cassava (*Manihot esculenta* Crantz) in South Ethiopia

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To cite this article:
Tewodros Mulualem, Yared Dagne. Studies on Correlation and Path Analysis for Root Yield and Related Traits of Cassava (*Manihot Esculenta* Crantz) in South Ethiopia. *Journal of Plant Sciences.* Vol. 1, No. 3, 2013, pp. 33-38. doi: 10.11648/j.jps.20130103.13

Abstract: Ten promising and one respective local check of cassava (Manihot esculenta Crantz) genotypes were tested at Areka, Bele and Goffa districts of southern Ethiopia during 2006-2007 growing seasons using RCBD with three replications. The objectives of the study were to examine the interrelationship of yield related characters and extent of their contribution to fresh root yield on cassava. The genotypic correlation between fresh root yield and number of vertical stem/plant, root girth, root diameter, weight of above ground plant parts and root dry weight was highly significant, while positive and significant phenotypic correlation was observed between root fresh yield plot and root girth, root length and diameter. Among these characters, roots diameter reflected the highest direct effect of (p=1.976) towards root fresh weight; while minimum was indicated by number of branches/plant (p=0.004). Number of vertical stem/plant, stem girth, weight of above ground plant parts and root dry weight had contribute to the root fresh weight. Therefore indirect selection for higher fresh root yield may be effective for improving these characters. This study suggests the relative higher value of residual effect (0.364) indicated more yield components should be considered in the future to account for the variation in cassava root yield.

Keywords: Cassava, Correlation, Direct Effect, Path Coefficient

1. Introduction

Cassava (*Manihot esculenta* Crantz) is an important root crop grown widely in humid tropics and used as source of carbohydrates for many people in tropical and sub-tropical areas of the world [1]. According to FAO, cassava is a staple food more than 800 million people who live in sub-Saharan Africa [2 and 4] . The crop has particularly potential for fertile and waste land when other crops are not survived, where it could help overcome food shortage [3]. It is primarily grown for its starchy tuberous root; its flour can be produced for soup, biscuits, bread, and beverage. The leaves used as vegetable, as it contains a high carbohydrate that is useful for people diet in the developing countries.

In Ethiopia cassava is produced by farmers in small-scale and larger-scale plantations due to its ability to tolerate dry conditions and easy low-cost propagation [4 and 1]. It is play a significant role for producing enough food, in a sustainable manner to meet the needs of an increasing population is one of the greatest challenges we face [4]. This provides an important form of “insurance” against social disruption, prolonged droughts, or other periods of stress and unrest. Thus, cassava is an important means by which food production could be increased without the use of large amounts of agricultural inputs [1]. Cassava fresh root yield is the main ambition of cassava breeding program. It is a complex character and is the product of several contributing factors affecting root yield directly or indirectly. Root yield improvement in most situations, be effectively achieved on the basis of performance of root yield components and selection for closely related to morpho-physiologcial characters [5]. The value of genotypic and phenotypic correlations indicated that degree to which various morphological characters are associated with productivity. Path coefficient analysis is a reliable statistical technique, which provides means to quantify the interrelationship of different yield and yield related and some other path ways to produce an effect [6]. This technique, therefore, provides a significant assessment of specific factors producing a given correlation and can be successfully in use formulating a selection strategy. Therefore, the present studies were initiated to investigate the interrelationship of yield related characters and extent of their contribution to fresh root yield on cassava. The information so derived could be exploited in devising further selection strategies and to develop new varieties of cassava capable of high productivity.

2. Materials and Methods

2.1. Description of the Study Area

The experiments was conducted in three locations of southern Ethiopia, at Bolososore (Areka), Kindo koisha (Belle) and Gofa districts of Wolayta and Gamo-gofa zones, during 2006-2007 cropping season. Areka is located at 06^0 19'241''N' latitude and 037^0 22'18.6''E' longitude with an altitude of 1860 m.a.s.l. It has a humid climate with an average maximum and minimum temperature of 32.4^0 C and 17.63^0 C, and average annual precipitation of about 1438.95 mm. The soil is sandy loam with a pH of 5.81. Bele is located at 06 ^{o}54'23.8''N' latitude and 037 ^{o}21'16.1''E' longitude with an altitude of 1266 m.a.s.l . The site receives mean annual rainfall of 1200 mm with respective maximum and minimum temperatures of 34.6^0 C and 19.20^0 C. The soil is clay loam with a pH of 5.81. Gofa is located at 06^o22'335'' N' latitude and 036^o58'306'' E' longitude with 1297 m.a.s.l. It receives 1338.95 mm average rainfall annually with average maximum and minimum temperatures of 29.4^0 C and 17.63^0 C. The soil is Acrisole with pH 5.80 [7].

2.2. The Genotypes and Experimental Design

Eleven genotypes of cassava were considered in this study. The genotypes were collected from southern parts of Ethiopia and laid in RCBD with three replications on spaced 1m x 1m in all tested locations. Cuttings with 25-30 cm from 12 months aged cassava mother plants were used as planting material on a ridge during onset of rainy season (early April). One month after planting, after the crop was well established, the plants were earthed up. Cultivation and weeding were carried out when necessary. The crop was harvested at 18 months after planting as it has been suggested by [8].

2.3. Data Collection

The average of 13 quantitative data from three locations was collected according to the descriptors of International Plant Genetic Resource Institute [9]. These are plant height(cm), number of main stem/plant, number of branch/plant, average canopy diameter/plant(m), average stem girth(cm), average number of roots/plant, average length of roots/plant(cm), average diameter of roots/plant(cm), root fresh weight (kg/plot), above ground biomass weight (kg/plant), root dry weight (kg/plot) HCN(mg/kg) and %starch were recorded. Five plants were (400g each) randomly taken from the plot and were floured to get the dry matter yield of the product. After measuring the yield, the amounts are converted in to kg per plot.

2.4 Statistical Analysis

Heritability in broad sense (h^2B) and genetic advance as percent of means were calculated for all characters according to the method described by [10], Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was estimated according to [11 and 12], by using SAS statistical software package [13] by 0.05 level of significance.

$$r_{p\,xy} = \frac{PCOV_{xy}}{\sqrt{(\sigma^2_{px})}\sqrt{(\sigma^2_{py})}} \quad (1)$$

$$r_{gxy} = \frac{GCOV_{xy}}{\sqrt{(\sigma^2_{gx})}\sqrt{(\sigma^2_{gy})}}$$

Where:

$r_{p\,xy}$ = Phenotypic correlation coefficient between x and y.

$r_{g\,xy}$ = Genotypic correlation coefficient between x and y.

$PCOV_{xy}$ = Phenotypic covariance between x and y

$GCOV_{xy}$ = Genotypic covariance between x and y

The coefficient correlation at phenotypic level was tested for their significance using the t-test as:

$$t = r_{pxy}\sqrt{g-2} \;/\sqrt{(1-r^2_{pxy})} \quad (2)$$

The calculated't' value was compared with tabulated't' at n-2 degree of freedom, where n is the number of characters.

The correlation coefficients at genotypic level were tested with the following formula suggested by [14].

$$t = r_{gxy} / SEr_{gxy} \quad (3)$$

Where, r_{gxy} is the genotypic correlation coefficient, SEr_{gxy} is the standard error of genotypic correlation coefficient and

$$SEr_{gxy} = \sqrt{\frac{(1-r2\ \ gxy)^2}{2h2\ xh2y}} \quad (4)$$

Path coefficient analysis, Fresh root yield was considered as the dependent variable while the rest of characters were taken as the independent variables. The direct and indirect effect of the independent characters on fresh root yield/plot was estimated based on [15].

$$r_{ij} = p_{ij} + \sum r_{ik}\, p_{kj} \quad (5)$$

Where,

r_{ij} = mutual association between the independent character (i) and dependent

characters (j) as measured by correlation coefficients

p_{ij} = components of direct effects of the independent characters (i) on the

dependent characters (j)

$\sum r_{ik}\, p_{kj}$ = summation of components of indirect effect of a given independent character (i) on the dependent characters (j) via all other k independent characters.

3. Results and Discussion

The combined analysis of variance for fresh root yield and its components showed highly significant differences (p<0.05) between genotypes and location interaction which is the result of average fresh root yield/plot and average roots length/plant.

The magnitude of genotypic correlation coefficients is higher than that of phenotypic correlation coefficients (Table 1). This showed that the association between them is genotypic inheritance but not environmental influence. In line with this the same results were observed in different crops by [16 and 17] for taro (*Colocasia esculenta*), [18 and 1] for aerial yam (*Dioscorea bulbifera*), [19] for coriander(*Coriandrum sativum L.*) and [20] for black cumin (*Nigela sativa. L.*).

Based on genotypic level, root fresh weight kg/plot) was strongly and positively correlated with number of vertical stem/plant(r=1.00**), stem girth (r=1.00**), root diameter (r=1.00**) and root dry weight(r=0.96**) (Table 1). It was also positively and significant (*P<0.05*) correlated with weight of above ground plant parts (kg/plot). Root fresh weight (kg/plot) significantly (*P<0.01*) and positively correlated with stem girth (cm), root length (cm) and root diameter (cm) at phenotypic correlation coefficient level. The result is in agreement with that of [16 and 18], who reported that positive association of plant height, root length, number of verticals/plant, root and canopy diameters with fresh root yield of taro and yam, for this reason, selection based on these characters are essential for cassava improvement.

Table 1. *Genotypic (above diagonal) and Phenotype (below diagonal) Correlation coefficient among 13 traits in 11 Cassava genotypes grown at Areka, Belle and Gofa in 2006/2007*

Traits	RFW	PH	NS	NB	CD	GR	NoR	RL	RDi	WAGPP	RDW	HCN	Stra.
RFW	1.00	**-1.00****	1.00**	0.32	-0.98**	1.00**	0.51	-1.00**	0.98**	0.63*	0.96**	0.32	-0.03
PH	0.47	**1.00**	1.00**	1.00**	-1.00**	-1.00**	0.58*	-0.82**	-0.94**	-0.88**	-0.86**	-0.45	-0.15
NS	**-0.29**	-0.38	**1.00**	1.00**	1.00**	1.00**	-0.78**	1.00**	1.00**	1.00**	1.00**	-0.40	1.00**
NB	-0.42	-0.15	0.32	**1.00**	0.90**	0.07	0.66*	1.00**	0.86**	1.00**	0.26	1.00**	0.97**
CD	0.07	0.52	-0.26	-0.05	**1.00**	-1.00**	0.93**	-0.45	-0.92**	-1.00**	-0.87**	-1.00**	-0.23
GR	0.80**	0.66*	-0.26	-0.32	0.26	**1.00**	0.89**	-1.00**	-0.81**	-1.00**	-0.81**	-1.00**	-0.37
NoR	-0.34	-0.33	0.34	0.07	-0.41	-0.14	**1.00**	0.02	0.51	0.34	0.39	-0.19	-0.31
RL	0.80**	0.60*	-0.10	-0.32	0.16	0.79**	0.08	**1.00**	-1.00**	-1.00**	-1.00**	-1.00**	1.00**
RDi	0.90**	0.64*	-0.21	-0.40	0.20	0.89**	-0.09	0.87**	**1.00**	-1.00**	-1.00**	-1.00**	-0.27
WAGPP	-1.00**	0.75**	-0.34	-0.28	0.45	0.70**	0.02	0.69**	0.68**	**1.00**	-1.00**	-0.73**	0.29
RDW	-1.00**	0.37	-0.18	-0.40	0.09	0.78**	-0.05	0.83**	0.89**	0.57*	**1.00**	-1.00**	0.71**
HCN	-1.00**	0.33	-0.23	-0.01	0.04	0.35	-0.05	0.27	0.31	0.39	0.25	**1.00**	-0.09
% starch	0.16	0.03	0.30	0.06	0.03	-0.15	-0.13	0.08	0.01	-0.07	0.07	0.08	**1.00**

RFW= root fresh weight,(kg/plot) PH= Plant height (cm), NS= Number of vertical stem/plant, NB= Number of branches/plant, CD= Canopy diameter(cm), GR= Stem girth(cm), NoR= number of roots/plant, RL= Root length(cm), DRW= Root diameter(cm), WAGPP= Weight of above plant biomass(kg/plot) and RDW= Root dry weight(kg/plot) , HCN= (mg/kg), strar= Starch (%).

In this study, plant height was showed significant and strong positive correlation with number of vertical stem/plant and number of root/plant, these shows, increase the size of below and above ground plant parts has remarkable effect on the fresh root yield of cassava. Moreover, weight of above ground plant parts (kg/plot) was showed significant correlation with the majority of the characters of studied. However some characters had show a non-significant (*P > 0.05*) correlation. For example, number of root/plant, cyanide content (mg/kg) and % of starch content are showed non significant association with root fresh weight per plot although some of them have got higher degree of correlation with it. This may suggest that the phenotypic association of such characters with root fresh weight per plot is not genotypic inheritance but more of environmental influence. Root diameter was significantly *(P<0.01)* and positively correlated with number of vertical stem per plant, number of branch/plant, weight of above ground plant parts and root dry weight.

Based on the amount of cyanide content, cassava can be categorized in to sweet type (low cyanide and starch content) and beater type (high amount of cyanide and starch content). The association of these traits with fresh root yield of cassava is vary. In this study, therefore, the amount of cyanide on fresh root of cassava was negatively and significantly correlated with most of the characters that studied (Table 1). For example, number of branch/plant, canopy diameter, stem girth, root length, root diameter, weight of above ground plant parts and root dry weight were showed significantly and negatively associated with cyanide content. The positive association of number of branch/plant will facilitate selection for cassava improvement. However, improvement of root yield and weight of above ground plant parts in cassava is difficult due to the negative association of cyanide content with fresh root yield; therefore, autonomous selection should be done for the improvement of such traits. The same result was observed on hazard analysis of cassava chips in Nigeria, Increase the length and diameter of cassava root, the amount of cyanide in fresh root of cassava decrease.

The amount of starch was positively and significantly correlated with number of vertical stem/plant (r=1.00**), number of branch/plant (r=0.97**), root length (r=1.00**) and root dry weight/plot (r=1.00**) at genotypic level. At phenotypic levels, non significant correlation was observed for % of starch with all of characters that considered in this study.

Table 2. *Genotypic direct (bold and underlined) and indirect effects of 12 quantitative traits on fresh root yield in Cassava genotypes grown at Areka, Belle and Gofa in 2006/2007*

Traits	PH	NS	NB	CD	GR	NoR	RL	RDi	WAGPP	RDW	HCN	% starch	rg
PH	**-1.752**	O.570	-0.004	-0.885	0.329	1.136	1.146	2.931	1.053	1.115	-2.503	-0.285	-1.00
NS	2.756	**0.508**	-0.005	1.061	-0.423	-1.517	-1.913	-1.698	-1.154	-1.114	2.161	-0.257	1.00
NB	1.457	0.647	**0.004**	0.764	-0.017	1.288	-2.411	-1.489	-0.310	-1.629	1..373	1.301	0.32
CD	-1.056	0.637	-0.003	**-0.847**	0.325	1.811	0.628	1.850	0.958	1.868	-2.563	-0.939	-0.98
GR	-2.493	0.917	-0.001	-1.174	**0.234**	1.742	1.909	1.265	1.075	2.649	-2.248	-1.254	-1.00
NoR	0..943	-0.396	-0.002	0.788	-0.210	**-1.945**	-0.039	-0.699	-0.497	-1.221	2.080	-0.119	0.51
RL	-1.563	0.699	-0.007	-0.382	0.321	0.055	**1.391**	2.473	1.482	1.829	-2.018	-1.102	-1.00
RDi	-1.383	0.555	-0.003	-0.787	0.192	1.006	1.726	**1.976**	1.172	1.880	-2.716	-1.135	0.98
WAGPP	-1.337	0.605	-0.001	-0.837	0.260	0.997	2.128	2.312	**0.969**	1.697	-2.438	-1.187	0.63
RDW	-1.005	0.602	-0.005	-0.935	0.445	0.678	1.521	2.778	1.023	**1.502**	-2.844	-0.464	0.96
HCN	-1.830	0.698	-0.001	-0.741	0.191	0.775	1.605	2.717	1.010	1.925	**-1.215**	-1.420	0.32
% starch	-0.490	-0.206	-0.008	-1.122	0.834	-0.365	2.421	2.351	1.816	1.570	1.700	**-0.633**	-0.03

Residual effect =0.364

PH= Plant height (cm), NS= Number of vertical stem/plant, NB= Number of branches/plant, CD= Canopy diameter(cm), GR= Stem girth(cm), NoR= number of roots/plant, RL= Root length(cm), DRW= Root diameter(cm), WAGPP= Weight of above plant biomass(kg/plot) and RDW= Root dry weight(kg/plot) , HCN= (mg/kg), strar= Starch (%).

Path coefficient analysis (Table 2) at genotypic level revealed that root diameter had maximum positive direct effect on root fresh weight per plot (p = 1.976) followed by number of root per plant (p = 1.945). However, as root diameter and length becomes higher, it has a negative impact on the number of roots produced per plant, the number of branches and number of verticals produced on the main stem which could be a cause for the high correlation coefficient that existed between tuber weight per plot and root diameter (rg= 0.98). The same results ware observed with [21 and 17] in studies of *Plectranthus edulis* and *Colocasia esculenta*. Hence, while undertaking selection for root fresh weight per plot in cassava, one has to consider these two yield components with higher number of roots that could result in low diameter of tubers.

On the other hand, plant height, canopy diameter, number of root/plant, cyanide content(mg/kg) and % of starch content have negative direct effect on root fresh weight per plot [22]. Though the direct effect of cyanide content was negative (p =-1.215), its correlation coefficient was positive and relatively lower (rg = 0.32) as it has high positive indirect effect number of % of starch content and vertical stem/plant (Table 2). The low positive association of cyanogenic glycoside (HCN) content (mg/kg)with root fresh yield/plot which is not as such important on the basis of correlation estimates, was revealed as one of the major positive direct and indirect contributor to fresh root yield /plot by path analysis.

In contrast [4] found that high amount of cyanogenic glycoside content had positive direct effect on fresh root yield of cassava, although it is depends on the type the variety. The number of branches/plants had very low positive direct effect (p = 0.004) on root fresh weigh per plot, its correlation is negative with all of the characters that considered (Table 2). On the contrary, high positive direct effect of number of branches/plants on root fresh yield was reported by [1] in cassava. The direct effect of canopy diameter on root fresh yield of cassava was high and negative (p=-0.847). However, contradictory result was observed on [17], works, he reported that canopy diameter showed positive direct effect on tuber fresh weight on *Colocasia esculenta* var. antiquorum. Nevertheless, high indirect positive effects were recorded via number of vertical stem/plant, number of roots/plant, root length, root dia meter, weight of above ground plant parts and root dry weight (Table 2).

Although, root dry weight exerted positive direct effect on root fresh weight per plot, but had negative indirect effect on number of root/plant, number of branches and number of vertical stem/plant.

Number of vertical stem/plant had strong positive and significant association with fresh root yield of cassava (Table 1) which is in agreement with the report of [22 and 1]. This association was due to its indirect effect through canopy diameter. Considering only this trait with correlation estimate is not important in cassava root yield improvement. The residual effect (h = 0.364) is relatively high indicating that the trait considered in this analysis failed to sufficiently explain the variation in cassava yield. This suggests that more yield components should be considered to account for the variation in cassava fresh root yield.

4. Conclusion

Based on present study, it may be concluded that Number of vertical stem/plant, stem girth, weight of above ground plant parts and root dry weight had great contribute to the root fresh weight. Therefore indirect selection for higher fresh root yield may be effective for improving these characters.

Acknowledgements

This study was conducted by the financial support of South Agricultural Institute (SARI)/Areka Agricultural research center. We thank Mr. Yitbarek Alemu for financial and technical supports during HCN and % of starch analysis.

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