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Correlation and Path Coefficient Analysis of Cassava (*Manihot esculenta* Crantz) Genotypes

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A B S T R A C T

An experiment was conducted at All India Co-ordinated Research Project on Tuber crops, Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh during the period 2015 to 2016 to investigate the interrelationship of yield related characters and extent of their contribution to tuber yield in cassava. Correlation Analysis revealed that tuber yield (t ha^{-1}) had significant and positive correlation with total leaf area, plant dry matter content, tuber dry matter content, number of leaves per plant, plant height, stem diameter, number of storage roots per plant, number of commercial roots per plant, tuber length, tuber diameter and harvest index at both phenotypic and genotypic levels, indicating the importance of these traits in selection for yield. Path coefficient analysis revealed that stem diameter and tuber diameter exerted a high positive direct effect on tuber yield (t ha^{-1}). The high direct effect of these traits appeared to be the main factors for their strong association with tuber yield per hectare. Hence, direct selection for these traits should be effective indicating the effectiveness of direct selection.

Keywords

Cassava, Correlation, Path coefficient analysis, Direct effects, Indirect effects, Tuber yield.

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Introduction

Cassava (*Manihot esculenta* Crantz) is a perennial shrub, commonly known as tapioca, mandioca, manioc and yuca in different parts of the world. It belongs to the family Euphorbiaceae, sub family Crotonoidea and tribe Manihotae (Alves, 2002). The genus *Manihot* reported to have about 100 species of which *Manihot esculenta* is the only commercially cultivated species. It is native to North - Eastern Brazil. It is mainly cultivated for its starchy tubers and grown as staple food and animal feed in tropical and sub-tropical Africa, Asia and Latin America. In Asia major pockets of cassava production at present are Indonesia, Thailand, India, China, Philippines and Vietnam. The crop was introduced into India from Brazil by the Portuguese when they landed in the Malabar region, presently part of Kerala state during the 17th century. India acquires significance in the global cassava scenario due to its highest productivity in the world (35.7 t ha^{-1}). It is being cultivated in an area of 2.29 lakh hectares in India, with a production of 81.4

lakh MT and productivity of 35.7 t ha^{-1} (Anonymous, 2014). In Andhra Pradesh, it is being cultivated in East Godavari, Srikakulam, Vishakhapatnam and Vizianagaram districts with an area of 0.25 lakh hectares with a production of 4.42 lakh MT and productivity of 20.0 t ha^{-1} (Anonymous, 2014). Considering the economic importance of cassava and the low average productivity in Andhra Pradesh (20.0 MT/ha), there is tremendous scope to increase the yield per unit area and there by the total production.

Yield is a complex quantitative character controlled by several genes and its improvement depends largely on the functioning and interaction of several physiological components that vary for different genotypes. Apart from the direct selection for tuber yield, the purpose of root yield enhancement may, in most situations, be effectively achieved on the basis of performance of root yield components and selection for closely related morphophysiological characters (Kawano and Fakuda, 1998). There is a need to understand the inter character relationships among genotypes, identify traits that determine tuber yield and determine the influence of other traits associated with yield. Correlation analysis provides information about the degree of relationship between important plant traits and is a good index to predict yield response in relation to the change of a particular character. Genotypic and phenotypic correlations are of value to indicate the degree to which various morphophysiological characters are associated with productivity. Path coefficient analysis is a reliable statistical technique, providing a means to quantify the interrelationships of yield and yield-related as well as some other pathways to produce an effect (Kang, 1994). The present investigation was planned to examine associations among traits and identify characters correlated with tuber yield of cassava.

Materials and Methods

The experiment was conducted with seventy seven cassava genotypes along with three checks (Table 1) during the period from 2015 to 2016 at All India Co-ordinated Research Project on Tuber crops, Horticultural Research Station, Venkataramannagudem, Dr. Y.S.R. Horticultural University, Andhra Pradesh India. The location falls under the Agro-climatic zone number 10, East Coast Plain and Hills (Krishna-Godavari zone) at an altitude of 34 m (112 feet) above mean sea level with its geographical position 16.83° N latitude and 81.5° E longitude.

The experiment was laid out in Augmented Block Design (ABD) consisting of seven augmented blocks in which three checks and eleven entries were planted. Observations were recorded on five randomly selected plants for following traits *i.e.* petiole length, total leaf area, plant dry matter content, tuber dry matter content, number of leaves per plant, plant height, stem diameter, number of storage roots per plant, number of commercial roots per plant, tuber length, tuber diameter, harvest index, starch content, HCN content, post-harvest physiological deterioration and tuber yield.

Statistical analysis

Phenotypic and genotypic correlation coefficients between variables were calculated using covariance (Al-Jibouri *et al.*, 1958 and Goulden, 1959). The significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with table values (Fisher and Yates, 1963) at $n - 2$ degrees of freedom. Direct and indirect contributions of various characters to tuber yield were calculated through path coefficient analysis according to Wright (1921) and elaborated by Dewey and Lu (1959).

Results and Discussion

The phenotypic (r_p) and genotypic correlation (r_g) coefficients for sixteen characters in 80 cassava genotypes were presented in table 2 and figure 1. In general, genotypic correlation coefficients were of higher magnitude than the phenotypic correlation coefficients and it is desirable also. This may be due to the relative stability of genotypes as majority of them were subjected to certain amount of selection (Johnson *et al.,* 1955). In the present study tuber yield exhibited significant positive correlation with plant height (0.269 r_p, 0.268 r_g), stem diameter (0.395 r_p, 0.411 r_g), number of commercial tubers per plant (0.322 r_p, 0.327 r_g), tuber length (0.420 r_p, 0.423 r_g), tuber diameter (0.623 r_p, 0.641 r_g) and harvest index (0.300 r_p, 0.315 r_g) at both 5 and 1% levels of significance. This character also recorded positive correlation with plant dry matter content (0.208 r_p, 0.214 r_g), tuber dry matter content (0.198 r_p, 0.204 r_g), total leaf area (0.211 r_p, 0.209 r_g), number of leaves per plant (0.207 r_p, 0.206 r_g) and number of roots per plant (0.234 r_p, 0.238 r_g) at 5% level of significance only. These results were in conformity with research findings of earlier workers with respect to positive correlation of tuber yield with stem diameter (0.395 r_p, 0.411 r_g), number of commercial tubers per plant (0.322 r_p, 0.327 r_g), tuber length (0.420 r_p, 0.423 r_g), and tuber diameter of 0.623 r_p, 0.641 r_g (Sree Kumari and Abraham., 1991; Nageswari and palaniswamy, 2011; Kundy *et al.*, 2015; Babu Rao *et al.*, 2015 and Danquah *et al.*, 2016). Similar observations with regard to positive correlation of tuber yield with stem diameter were reported by Mulualem and Ayenew (2012). The correlation study indicated that the total leaf area, plant dry matter content, tuber dry matter content, number of leaves per plant, plant height, stem diameter, number of storage roots per plant, number of commercial roots per plant, tuber length, tuber diameter and harvest index had significant positive association with tuber yield at both phenotypic and genotypic levels. Hence, improvement in tuber yield is possible by considering above characters as criteria in selection scheme.

Fig.1 Simple correlation coefficients among yield and its components in cassava

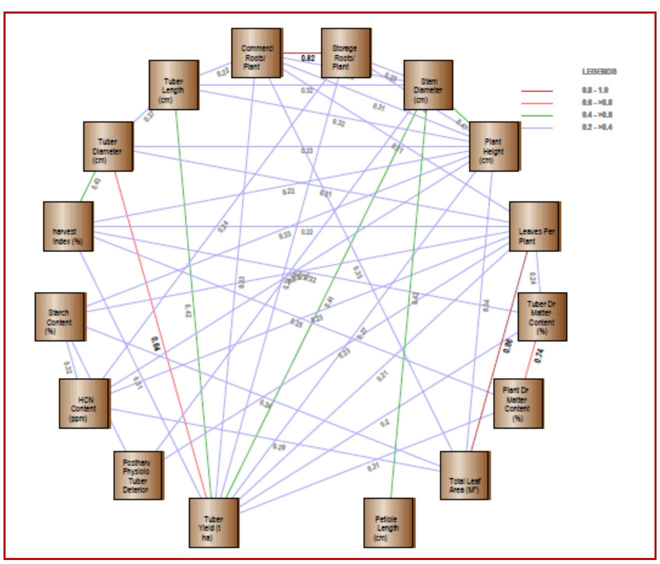

Fig.2 Genotypic path diagram representing direct and Indirect effects for tuber yield (t ha^{-1}) of cassava

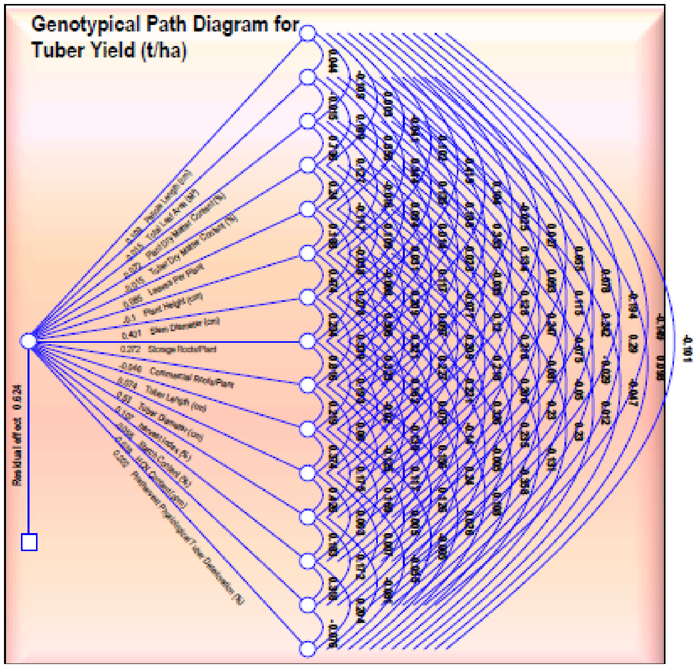

Table.1 Particulars of cassava genotypes under present study

S. No.	Name of the genotype	Source
1.	Me Ap-1	AICRP on Tuber crops, Venkataramannagudem, Andhra Pradesh
2.	Me Ap-2	-do-
3.	Me Ap-3	-do-
4.	Me Ap-4	-do-
5.	Me Ap-5	-do-
6.	Me Ap-6	-do-
7.	Me Ap-7	-do-
8.	Me Ap-8	-do-
9.	Me Ap-9	-do-
10.	Me Ap-10	-do-
11.	Me Ap-11	-do-
12.	Me Ap-12	-do-
13.	Me Ap-13	-do-
14.	Me Ap-14	-do-
15.	Me Ap-15	-do-
16.	Me Ap-16	-do-
17.	Me Ap-17	-do-
18.	Me Ap-18	-do-
19.	Me Ap-19	-do-
20.	Me Ap-20	-do-
21.	Me Ap-21	-do-
22.	Me Ap-22	-do-
23.	Me Ap-23	-do-
24.	Me Ap-24	-do-
25.	Me Ap-25	-do-

26.	Me Ap-26	-do-
27.	Me Ap-34	-do-
28.	Me Ap-35	-do-
29.	Me Ap-36	-do-
30.	Me Ap-37	-do-
31.	Me Ap-38	-do-
32.	Me Ap-39	-do-
33.	Me Ap-40	-do-
34.	Me Ap-41	-do-
35.	Me Ap-42	-do-
36.	Me Ap-43	-do-
37.	Me Ap-44	-do-
38.	Me Ap-45	-do-
39.	Me Ap-46	-do-
40.	Me Ap-47	-do-
41.	Me Ap-48	AICRP on Tuber crops, Venkataramannagudem, Andhra Pradesh
42.	Me Ap-49	-do-
43.	Me Ap-50	-do-
44.	Me Ap-51	-do-
45.	Me Ap-52	-do-
46.	Me Ap-53	-do-
47.	Me Ap-54	-do-
48.	Me Ap-55	-do-
49.	Me Ap-56	-do-
50.	Me Ap-57	-do-
51.	Me Ap-58	-do-
52.	Me Ap-59	-do-
53.	Me Ap-60	-do-
54.	Me Ap-61	-do-
55.	Me Ap-62	-do-
56.	Me Ap-63	-do-
57.	Me Ap-64	-do-
58.	Me Ap-65	-do-
59.	Me Ap-66	-do-
60.	Me Ap-67	-do-
61.	Me Ap-68	-do-
62.	Me Ap-69	-do-
63.	Me Ap-70	-do-
64.	Me Ap-71	-do-
65.	Me Ap-72	-do-
66.	Me Ap-73	-do-
67.	Me Ap-74	-do-
68.	Me Ap-75	-do-
69.	Me Ap-76	-do-
70.	Me Ap-77	-do-
71.	Me Ap-78	-do-
72.	Me Ap-79	-do-
73.	Me Ap-29	-do-
74.	Me Ap-30	-do-
75.	Me Ap-31	-do-
76.	Me Ap-32	-do-
77.	Me Ap-33	-do-
78.	H-165 (Check 1)	-do-
79.	H-226 (Check 2)	-do-
80.	Sree Vijaya (Check 3)	-do-

Table.2 Phenotypic and genotypic correlation coefficients for quantitative characters in cassava genotypes

Character		PL (cm)	TLA (cm2)	PDM (%)	TDM (%)	NLP	PH (cm)	STD (cm)	NSRT	NCRT	TL (cm)	TD (cm)	HI (%)	STRCH (%)	HCN (ppm)	PPD (%)
PL (cm)	rp	**1.000**														
	rg	**1.000**														
TLA (cm2)	rp	0.043	**1.000**													
	rg	0.044	**1.000**													
PDM (%)	rp	-0.106	-0.011	**1.000**												
	rg	-0.109	-0.015	**1.000**												
TDM (%)	rp	0.003	0.168	0.726**	**1.000**											
	rg	0.003	0.169	0.736**	**1.000**											
NLP	rp	-0.041	0.852**	0.121	0.235*	**1.000**										
	rg	-0.041	0.856**	0.127	0.240*	**1.000**										
PH (cm)	rp	0.102	0.337**	-0.021	-0.120	0.187	**1.000**									
	rg	0.102	0.344**	-0.016	-0.117	0.188	**1.000**									
STD (cm)	rp	0.401**	0.136	0.103	0.105	-0.037	0.448**	**1.000**								
	rg	0.419**	0.135	0.094	0.109	-0.038	0.474**	**1.000**								
NSRT	rp	0.103	0.186	0.007	0.031	-0.006	0.278**	0.228*	**1.000**							
	rg	0.104	0.188	0.014	0.031	-0.008	0.278**	0.234*	**1.000**							
NCRT	rp	-0.025	0.346**	0.014	0.117	0.208*	0.304**	0.287**	0.800**	**1.000**						
	rg	-0.025	0.353**	0.023	0.117	0.209*	0.306**	0.339**	0.816**	**1.000**						
TL (cm)	rp	0.027	0.129	-0.036	-0.075	0.093	0.315**	0.296**	0.184	0.219*	**1.000**					
	rg	0.027	0.134	-0.035	-0.077	0.097	0.321**	0.323**	0.193	0.219*	**1.000**					
TD (cm)	rp	0.053	0.089	0.109	0.112	0.209*	0.228*	0.117	-0.011	0.070	0.364**	**1.000**				
	rg	0.055	0.093	0.128	0.120	0.209*	0.227*	0.162	-0.020	0.060	0.374**	**1.000**				
HI (%)	rp	0.072	0.101	0.224*	0.203*	0.192	0.184	0.125	-0.144	-0.131	0.165	0.329**	**1.000**			
	rg	0.078	0.115	0.247*	0.218*	0.218*	0.221*	0.079	-0.139	-0.125	0.175	0.426**	**1.000**			
STRCH (%)	rp	-0.188	0.227*	-0.082	-0.070	0.198*	0.313**	-0.173	0.148	0.132	0.178	0.084	0.118	**1.000**		
	rg	-0.194	0.242*	-0.075	-0.081	0.206*	0.326**	-0.140	0.156	0.117	0.169	0.063	0.183	**1.000**		
HCN (ppm)	rp	-0.147	0.287**	-0.031	-0.055	0.238*	0.228*	0.017	0.239*	0.113	0.001	0.008	0.155	0.294**	**1.000**	
	rg	-0.149	0.290**	-0.029	-0.050	0.230*	0.235*	-0.005	0.240*	0.126	0.005	0.007	0.172	0.318**	**1.000**	
PPD (%)	rp	-0.101	0.098	-0.046	0.013	0.230*	-0.128	-0.336**	-0.107	0.025	-0.005	-0.057	-0.072	0.194	-0.071	**1.000**
	rg	-0.101	0.098	-0.047	0.012	0.230*	-0.131	-0.358**	-0.108	0.026	-0.005	-0.055	-0.081	0.204*	-0.076	**1.000**
TYLD/ha	rp	**0.101**	**0.211***	**0.208***	**0.198***	**0.207***	**0.269****	**0.395****	**0.234***	**0.322****	**0.420****	**0.623****	**0.300****	**0.014**	**0.031**	**0.021**
	rg	**0.101**	**0.209***	**0.214***	**0.204***	**0.206***	**0.268****	**0.411****	**0.238***	**0.327****	**0.423****	**0.641****	**0.315****	**0.020**	**0.024**	**0.019**

Note-**5% level of significance, *1% level of significance

Where, PL-petiole length, TLA-total leaf area, PDM-plant dry matter content, TDM-tuber dry matter content, NLP- number of leaves per plant, PH-plant height, STD-stem diameter, NSRT-no. of storage roots per plant, NCRT-No. of commercial roots per plant, TL-tuber length, TD-tuber diameter, HI-harvest index, STRCH-starch content, HCN-hydrogen cyanide content, PPD-post harvest physiological deterioration, TYLD-tuber yield

Table.3 Phenotypic and genotypic path coefficient analysis of quantitative characters in cassava genotypes

Character		PL (cm)	TLA (m2)	PDM (%)	TDM (%)	NLP	PH (cm)	STD (cm)	NSRT	NCRT	TL (cm)	TD (cm)	HI (%)	STRCH (%)	HCN (ppm)	PPD (%)
PL (cm)	Rp	**-0.064**	-0.003	0.007	0.000	0.003	-0.006	-0.026	-0.007	0.002	-0.002	-0.003	-0.005	0.012	0.009	0.006
	Rg	**-0.109**	-0.005	0.012	0.000	0.004	-0.011	-0.046	-0.011	0.003	-0.003	-0.006	-0.008	0.021	0.016	0.011
TLA (m2)	Rp	-0.001	**0.028**	0.000	-0.005	-0.024	-0.009	-0.004	-0.005	-0.010	-0.004	-0.002	-0.003	-0.006	-0.008	-0.003
	Rg	-0.001	**0.015**	0.000	-0.003	-0.013	-0.005	-0.002	-0.003	-0.005	-0.002	-0.001	-0.002	-0.004	-0.004	-0.001
PDM (%)	Rp	-0.010	-0.001	**0.090**	0.066	0.011	-0.002	0.009	0.001	0.001	-0.003	0.010	0.020	-0.007	-0.003	-0.004
	Rg	-0.008	-0.001	**0.072**	0.053	0.009	-0.001	0.007	0.001	0.002	-0.003	0.009	0.018	-0.005	-0.002	-0.003
TDM (%)	Rp	0.000	-0.003	-0.013	**-0.018**	-0.004	0.002	-0.002	-0.001	-0.002	0.001	-0.002	-0.004	0.001	0.001	0.000
	Rg	0.000	-0.003	-0.011	**-0.015**	-0.004	0.002	-0.002	0.000	-0.002	0.001	-0.002	-0.003	0.001	0.001	0.000
NLP	Rp	-0.003	0.059	0.008	0.016	**0.069**	0.013	-0.003	0.000	0.014	0.006	0.014	0.013	0.014	0.016	0.016
	Rg	-0.003	0.073	0.011	0.020	**0.085**	0.016	-0.003	-0.001	0.018	0.008	0.018	0.019	0.017	0.020	0.020
PH (cm)	Rp	-0.008	-0.026	0.002	0.009	-0.014	**-0.076**	-0.034	-0.021	-0.023	-0.024	-0.017	-0.014	-0.024	-0.017	0.010
	rg	-0.010	-0.034	0.002	0.012	-0.019	**-0.100**	-0.048	-0.028	-0.031	-0.032	-0.023	-0.022	-0.033	-0.024	0.013
STD (cm)	rp	0.136	0.046	0.035	0.035	-0.012	0.152	**0.339**	0.077	0.097	0.100	0.040	0.042	-0.059	0.006	-0.114
	rg	0.168	0.054	0.038	0.044	-0.015	0.190	**0.401**	0.094	0.136	0.130	0.065	0.032	-0.056	-0.002	-0.144
NSRT	rp	0.018	0.032	0.001	0.005	-0.001	0.048	0.039	**0.171**	0.137	0.031	-0.002	-0.025	0.025	0.041	-0.018
	rg	0.028	0.051	0.004	0.008	-0.002	0.076	0.064	**0.272**	0.222	0.053	-0.006	-0.038	0.043	0.065	-0.029
NCRT	rp	-0.002	0.023	0.001	0.008	0.014	0.020	0.019	0.054	**0.067**	0.015	0.005	-0.009	0.009	0.008	0.002
	rg	0.001	-0.016	-0.001	-0.005	-0.010	-0.014	-0.015	-0.037	**-0.046**	-0.010	-0.003	0.006	-0.005	-0.006	-0.001
TL (cm)	rp	0.003	0.013	-0.004	-0.007	0.009	0.032	0.030	0.018	0.022	**0.100**	0.036	0.017	0.018	0.000	-0.001
	rg	0.002	0.010	-0.003	-0.006	0.007	0.024	0.024	0.014	0.016	**0.074**	0.028	0.013	0.013	0.000	0.000
TD (cm)	rp	0.028	0.046	0.057	0.058	0.109	0.119	0.061	-0.006	0.037	0.190	**0.521**	0.171	0.044	0.004	-0.030
	rg	0.029	0.049	0.068	0.063	0.111	0.120	0.086	-0.011	0.032	0.198	**0.530**	0.226	0.033	0.004	-0.029
HI (%)	rp	0.008	0.012	0.026	0.024	0.022	0.022	0.015	-0.017	-0.015	0.019	0.038	**0.117**	0.014	0.018	-0.008
	rg	0.008	0.012	0.026	0.023	0.023	0.024	0.008	-0.015	-0.013	0.019	0.046	**0.107**	0.020	0.018	-0.009
STRCH (%)	rp	0.011	-0.013	0.005	0.004	-0.011	-0.018	0.010	-0.008	-0.007	-0.010	-0.005	-0.007	**-0.056**	-0.016	-0.011
	rg	0.011	-0.014	0.004	0.005	-0.012	-0.018	0.008	-0.009	-0.007	-0.010	-0.004	-0.010	**-0.056**	-0.018	-0.012
HCN (ppm)	rp	0.002	-0.004	0.000	0.001	-0.004	-0.003	0.000	-0.004	-0.002	0.000	0.000	-0.002	-0.004	**-0.015**	0.001
	rg	0.004	-0.008	0.001	0.001	-0.007	-0.007	0.000	-0.007	-0.004	0.000	0.000	-0.005	-0.009	**-0.029**	0.002
PPD (%)	rp	-0.018	0.017	-0.008	0.002	0.040	-0.022	-0.059	-0.019	0.004	-0.001	-0.010	-0.013	0.034	-0.012	**0.175**
	rg	-0.021	0.020	-0.010	0.002	0.047	-0.027	-0.072	-0.022	0.005	-0.001	-0.011	-0.016	0.041	-0.015	**0.202**
TYLD/ha	rp	**0.101**	**0.211**	**0.208**	**0.198**	**0.207**	**0.269**	**0.395**	**0.234**	**0.322**	**0.420**	**0.623**	**0.300**	**0.014**	**0.031**	**0.021**
	rg	**0.101**	**0.209**	**0.214**	**0.204**	**0.206**	**0.268**	**0.411**	**0.238**	**0.327**	**0.423**	**0.641**	**0.315**	**0.020**	**0.024**	**0.019**

Phenotypic Residual effect = 0.6238; Genotypic Residual effect= 0.6346; Diagonal (under lined) values indicate direct effects
Where, PL-petiole length, TLA-total leaf area, PDM-plant dry matter content, TDM-tuber dry matter content, NLP- number of leaves per plant, PH-plant height, STD-stem diameter, NSRT-number of storage roots per plant, NCRT-number of commercial roots per plant, TL-tuber length, TD-tuber diameter, HI-harvest index, STRCH-starch content, HCN-hydrogen cyanide content, PPD-post harvest physiological deterioration, TYLD-tuber yield

The path coefficient analysis which splits total correlation coefficient of different characters into direct and indirect effects on tuber yield in such a manner that the sum of direct and indirect effects is equal to total genotypic correlation as presented in table 3 and figure 2. The path analysis indicated that stem diameter (0.339 P, 0.401 G), number of storage roots per plant (0.171 P, 0.272 G), tuber length (0.100 P, 0.074 G), tuber diameter content (0.521 P, 0.530 G), harvest index (0.117 P, 107 G) and post-harvest physiological deterioration (0.175 P, 0.202 G) had direct positive effects on tuber yield at both phenotypic and genotypic levels. The characters like total leaf area (0.028 P, 0.015 G), plant dry matter content (0.090 P, 0.072 G), number of leaves per plant (0.069 P, 0.085 G) and number of commercial roots per plant (0.067 P) also had positive direct effect on tuber yield per hectare. The results are in accordance with Babu Rao *et al.,* (2015) for stem diameter and Adeniji *et al.,* (2011) and Babu Rao *et al.,* (2015) for plant dry matter content, number of storage roots per plant and Mulaulem and Ayenew (2012) and Babu Rao *et al.,* (2015) for tuber dry matter content. Rekha *et al.,* (1991) and Babu Rao *et al.,* (2015) were also reported similar results for number of leaves per plant. Similarly Rajendran *et al.,* (1985), Mulaulem and Ayenew (2012) and Babu Rao *et al.,* (2015) observed high positive direct effect on tuber yield with respect to tuber diameter.

The negative direct effects on tuber yield was recorded for petiole length (-0.064 P, -0.109 G), tuber dry matter content (-0.018 P, -0.015 G), plant height (-0.076 P, -0.100 G), starch content (-0.056 P, -0.056 G), HCN content (-0.015 P, -0.029 G) at both phenotypic and genotypic levels. These results for tuber dry matter content and plant height are in accordance with the earlier reports by Mulaulem and Ayenew (2012) and Babu Rao *et al.,* (2015). Negative direct effect of HCN content on tuber yield was in conformity with the results of Babu Rao *et al.,* (2015). Path analysis revealed that major emphasis should be laid on selection process with more stem diameter, number of storage roots per plant, tuber length, tuber diameter content, harvest index and post-harvest physiological deterioration and there should be economic balance among these traits to get higher tuber yield.

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