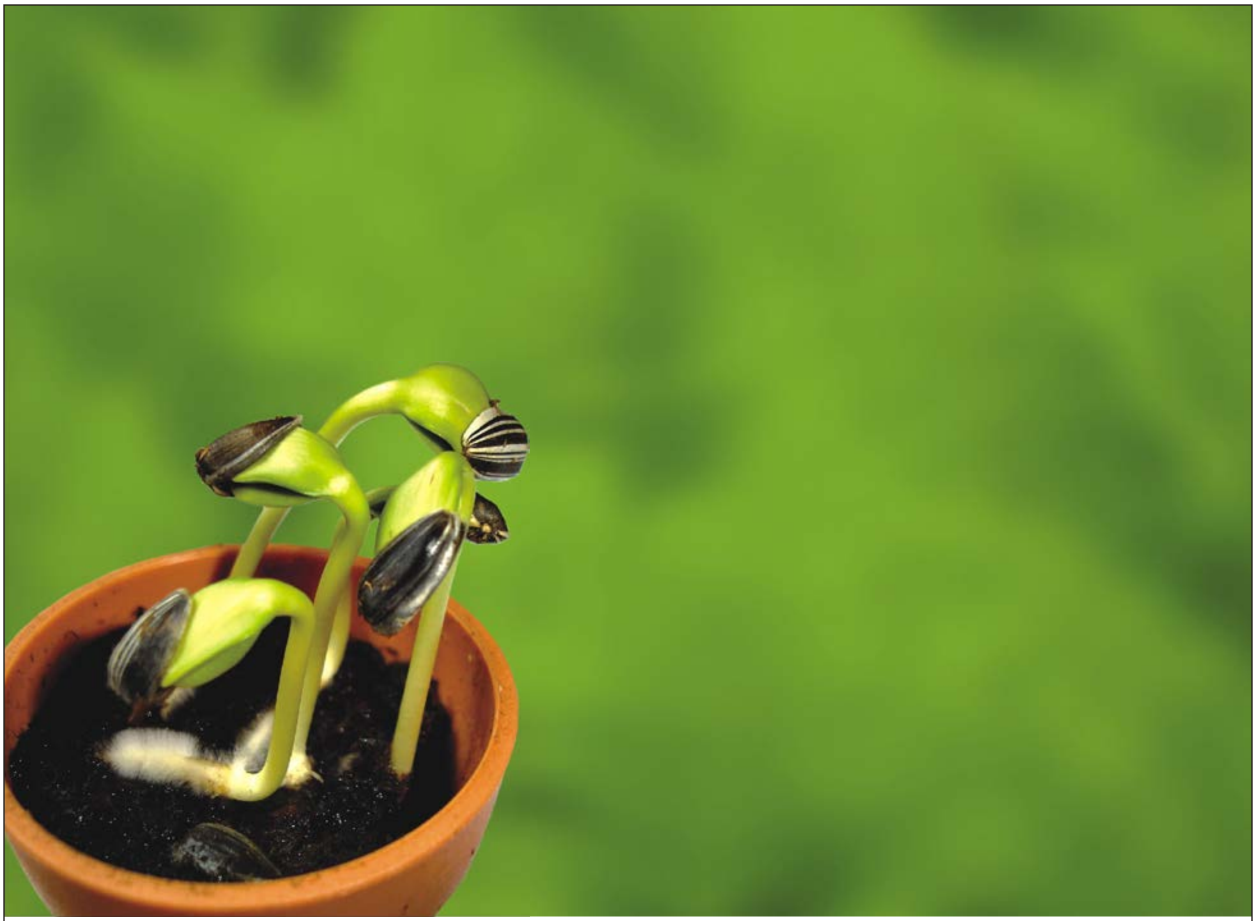

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Correlation and Path Coefficient Studies of Yield and Yield Related Characters in Tannia (*Xanthosoma sagittifolium* (L.) Schott) Genotypes

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ABSTRACT

Tannia is the sixth most important root tuber crop for food, feed and industrial applications worldwide. However, the crop is neglected and unexploited in Ethiopia even though large gene pool is available in south and southwest Ethiopia in farmers' field and homesteads. So far no improved varieties are available and its national productivity (7.9 t ha^{-1}) is far below the crop's potential (30-60 t ha^{-1}). For effective selection of genotypes, understanding of the magnitude and the interrelationship of yield and yield related traits is excellent tool for determining the direction and number of characters to be considered in the crop improvement program. Hence, the objectives of the present study were to determine the genetic relationship and identify traits that have direct and indirect effect on yield of tannia. So, a total of sixty four tannia genotypes were studied based on 16 quantitative characters at Jimma Agricultural Research Center during the 2013/14 cropping season. Sixty two of the genotypes were collected from south, south western and western parts of Ethiopia and two were introduced from Cuba, laid out in 8×8 simple lattice design. The data were subjected to correlation and path coefficient analysis. The correlation study reveals that majority of the characters were positively correlated with each other. Total yield was positively and significantly correlated with corm weight and cormel weight both at phenotypic ($r_p = 0.825$; $r_p = 0.957$) and genotypic level ($r_g = 0.859$; $r_g = 0.954$), respectively. The path coefficient analysis showed that cormel fresh weight (0.549) and corm weight (0.55) exerted the maximum direct positive effect on total yield per plant. Also, plant height, plant canopy, corm and cormel length, cormel fresh weight and corm weight exerted positive direct and indirect effect which indicates that these characters could be effective for selection and further yield improvement program of tannia.

Key words: Direct effect, genotypic correlation, indirect effect, phenotypic correlation

INTRODUCTION

Tannia is a herbaceous, monocotyledonous, perennial stem tuber crop that is widely cultivated in tropical and subtropical regions of the world. Tannia belongs to the family Araceae and originally came from tropical America (Ramesh *et al*., 2007). Globally, tannia is an important food for about 400 million people (Lebot, 2009) and ranked sixth in planted area and production after cassava, potato, sweet potato, yam and taro (Perez, 2010).

The challenges facing us in food and agriculture are enormous. According to the most recent report on the state of food insecurity in the world, during 2011-2013 there were about 842 million undernourished people from which 827 million (98.2%) were in developing countries (FAO., 2013). In Sub-Saharan Africa and generally in the developing countries including Ethiopia the demand for food is likely to rise significantly as a result of population growth (FAO., 2010). To meet the ever increasing demand for food, root and tuber crops including tannia can play multi-purpose roles in the global food system to address this issue and feed millions of people (Lebot, 2009; Ndabikunze *et al.*, 2011). So that tannia is key commercial crop in many parts of the world, mainly for smallholder farmers such as in Nicaragua (Castro *et al.*, 2005), Cameroon (Bown, 2000), Bangladesh (Paul and Bari, 2012) and Ghana (Opoku-Agyeman *et al.*, 2004).

In Ethiopia root and tuber crops are part of the traditional food systems of the people especially in the southern, southwestern and western part of the country. There is enormous possibility for millions of poor farmers to boost production and their livelihood using root and tuber crops perhaps highly neglected but strategic crops for the country's economy (Nebiyou *et al.*, 2008). Among the root and tuber crops, taro (*Colocasia esculenta* (L.) Schott) and tannia (*Xanthosoma sagitiffolium* (L.) Schott) locally known as 'Godare', are tuberous tropical food crops that supply high-energy food. Godare has been grown in Ethiopia since time immemorial but how and when it was introduced to Ethiopia remains unclear (Asfaw, 2005). However, Amsalu *et al.* (2008) reported that 120 taro and 87 tannia collections were introduced to Ethiopia in 1978 from Cuba. Now a days, taro and tannia are grown mostly as staple or subsistence crops throughout the hot and humid areas of southwestern Ethiopia (Etissa, 1996).

According to FAO (2012) world production for taro and tannia in 2011 was 10.37 million tones. Africa as a continent produces 71% of this production. In Ethiopia a total of 1.5 million farmers mainly in Southern Nations Nationalities and Peoples (SNNP) region (0.96 million) and in Oromia region (0.5 million) are dependent on taro and tannia as their food source (CSA., 2012b). During 2011/2012 production year, taro and tannia production area in Ethiopia reached 39,696 ha (CSA., 2012b) having a total production of 315,242 t. The 81.2% of the national production used for human consumption and 11.5% reserved for planting material. For the national production SNNP contributes 84.5% (266,293.5 t), Oromia region 15.2% (48,015.1 t), Benshangul-Gumuz 0.05% (154.6 t) and Gambella Region 0.25% (779 t) (CSA., 2012a).

To improve production and productivity of various root and tuber crops, In Ethiopia, researches have been going on since 1966. To mention some achievements two varieties of cassava, 28 varieties of potato, 24 varieties of sweet potato, three varieties of taro, six varieties of enset, one variety of yam were released (Endale *et al.*, 2008; MoARD., 2010). However, despite its great importance and presence of large gene pool in south and southwest Ethiopia in farmers' field and homesteads (Tewodros, 2008), tannia is highly neglected and unexploited crop in the country. So, far no improved varieties are available. Hence, its productivity is far below the crop's potential which is 30-60 t ha^{-1} (Lebot, 2009; Mwenye *et al.*, 2010) which is 7.9 t ha^{-1} (CSA., 2012a, b).

For crop improvement program, available genetic resources especially the local gene pool is particularly important in the development of regionally adapted cultivars. In doing this, high range of variability, heritability, genetic advance and positive correlation coefficient among traits are an excellent tool for selection of genotype (Akbar *et al.*, 2003; Mwenye *et al.*, 2010). Correlation of characters among yield, yield components and other economic traits is important because yield is a complex character and governed by the number of characters.

Improvement for a target character can be achieved by indirect selection via other characters that are more heritable and easy to select (Khayatnezhad *et al.*, 2011). Therefore, it requires understanding of the magnitude and the interrelationship of the characters among themselves and with the target yield or quality which can help in improving the efficiency of selection by making possible use of suitable combination of characters (Ahmad *et al.*, 2013). The correlation analysis helps in determining the direction and number of characters to be considered in improving yield as well as quality (Simmonds, 1986). Traits may either be positively or negatively correlated due to the mutual association with other characters. The correlations between pair of traits may be due to genetic, phenotypic and environmental factors. Phenotypic correlations measure the extent to which the two observed characters are linearly related. The correlation of environmental deviations together with non-additive genetic deviations (i.e., dominance and epistatic genetic deviations) is referred to as environmental correlations (r_e) (Falconer and Mackay, 1996; Sharma, 1998). Genotypic correlation coefficients provide a measure of genetic association between traits and thus help in identifying the most important as well as the least important traits to be considered in a breeding program (Ramos and Carvalho, 1997).

However, correlation analysis alone becomes insufficient to explain the relationships among characters so, using in combination with path coefficient analysis is good approach (Rao *et al.*, 1997). Path coefficient analysis is a critical examination of the specific forces acting to produce a given correlation and measuring the relative importance of the causal factors towards yield (Falconer, 1989) i.e., effective tool for further partitioning of the correlation coefficients in to components of direct and indirect factor of association.

Therefore, the present study was conducted with the following objective:

- To determine the genetic relationship among yield and yield components of tannia genotypes
- To identify traits that have direct and indirect effect on yield of tannia

MATERIALS AND METHODS

The experiment was conducted at Jimma Agricultural Research Center (JARC) located at 366 km south west of Addis Ababa. The site is situated at a latitude 7°46'N and longitude 36° E with an altitude of 1753 m.a.s.l. The soil of the study area is Eutric Nitisol with a pH of 5.3. The area receives mean annual rainfall of 1432 mm with maximum and minimum temperature of 29.2 and of 8.9°C, respectively.

A total of 64 tannia genotypes having same cormel size, 62 genotypes collected from south, south western and western parts of Ethiopia and two introductions from Cuba (Table 1) laid out in 8×8 simple lattice design using single row plots of 8.25 m long each, spaced 1 m apart between rows and 0.75 m between plants. There were 11 plants per row and the middle five plants were used for data collection. After the crop established well, earthing up and weeding were carried out when necessary.

Descriptor of tannia developed by International Board for Plant Genetic Resources (IBPGR., 1989) was followed for data collection. Sixteen quantitative data were used, most of which were distinguished as highly heritable traits. Measurements of above ground morphological characters were carried out from middle five plants in each plot at 5th to 6th months after planting when the plants have reached their peak above ground vegetative growth, while subterranean traits were evaluated at harvest (nine and half months after planting). The data were collected on lamina length (cm), lamina width (cm), number of suckers per plant, petiole length (cm), plant height (cm), plant canopy diameter (cm), corm length (cm), corm diameter (cm), corm fresh weight per plant (kg), cormel length (cm), cormel diameter (cm), cormel fresh weight per plant (kg), total root yield per plant (kg), number of cormels per plant, corm dry matter content (%) and cormel dry matter (%).

Table 1: List of genotypes of tannia studied

Genotype	District	Kebele/village	Altitude	Genotype	District	Kebele/village	Altitude
AAGT003	Chena	Bobakrcha	2100	AAGT109	Gesha	Hinigdo	1640
AAGT008	Bench	Kochi	1380	AAGT112	Gimbo	Kaikelo	1600
AAGT020	Bench	Wachamaji		AAGT116	Gimbo	Kembo	1820
AAGT022	Bench	Aman Gonji	1380	AAGT120	Chena	Kutasheorai	1820
AAGT030	Bench	Mizan		AAGT121	Chena	Agaro	1980
AAGT031	Bench	Koda	2040	AAGT127	Chena	Culish	
AAGT034	Chena	Ralakocho bacha	1960	AAGT132	Bench	Aman	
AAGT035	Decha	Chalta	1620	AAGT135	Bench	Gerika	1460
AAGT036	Decha	Shapa	1840	AAGT138	Sheka	Bukita	1460
AAGT043	Decha	Deha	1880	AAGT144	Sheka	Selale	1640
AAGT045	Decha	Chiri		AAGT148	Sheka	Wesheka	1660
AAGT046	Decha	Chiri		AAGT152	Sheka	Shimi	1320
AAGT051	Gimbo	Kaiketa	1860	AAGT155	Sheka	Gizm	
AAGT052	Gimbo	Beyamo	1680	AAGT159	Yeki	Korech	1140
AAGT054	Gimbo	Aman	1700	AAGT163	Yeki	Korech	1380
AAGT058	Gimbo	Getoacho	1640	AAGT171	Mesha	Tugri	1840
AAGT061	Gimbo	Shamba	1500	AAGT176	Mesha	Toba	2220
AAGT065	Decha	Erma	1860	AAGT177	Mesha	Keja	2140
AAGT069	Decha	Adaiminja	1860	AAGT178	Mesha	Chewaka	1840
AAGT077	Decha	Muga	1900	AAGT180	Gesha	Asho	2160
AAGT080	Decha	Gedam	1680	AAGT183	Gesha	Yershiniti	2180
AAGT083	Telo	Tura	2020	AAGT186	Mesha	Gecha	
AAGT085	Telo	Shadie	1640	AAGT188	Yeki	Chati	1820
AAGT088	Telo	Felegeselam	2060	AAGT193	Yeki	Gendekore	1260
AAGT092	Gimbo	Beymo	1660	AAGT195	Yeki	Sbosha	1220
AAGT093	Gimbo	Kicho	1720	AAGT199	Yeki	Bechi	1180
AAGT094	Gimbo	Kuti	1760	AAGT202	Yeki	Kura Alamo	1220
AAGT097	Gimbo	Emicho	1820	AAGT205	Yeki	Alamo	1380
AAGT099	Gimbo	Saja	2060	AAGT208	Chena	Tofa	1820
AAGT100	Gimbo	Medaobo	1600	0002/07			
AAGT102	Gimbo	Medaobo	1560	0003/07			
AAGT106	Gimbo	Konda		AAGT174	Mesha	Gtimo	2250

Data analysis: The phenotypic and genotypic correlation components between traits were estimated using the equation suggested by Johnson *et al*. (1955) as follow:

$$r_p = \frac{Pcov_{xy}}{\sqrt{(Vp_x.\ Vp_y)}} \quad (1)$$

$$r_g = \frac{Gcov_{xy}}{\sqrt{(Vg_x.\ Vg_y)}} \quad (2)$$

Where:

r_p = Phenotypic correlation coefficient

r_g = Genotypic correlation coefficient

$Pcov_{xy}$ = Phenotypic covariance between variables x and y

Gcov_{xy} = Genotypic covariance between variables x and y
V_px = Phenotypic variance for variables x
V_py = Phenotypic variance for variables y
V_gx = Genotypic variance for variables x
V_gy = Genotypic variance for variables y

Significance of genotypic and phenotypic correlation coefficients were tested with the following equation forwarded by Robertson (1959).

For genotypic:

$$t = \frac{r_{gxy}}{SEr_{gxy}} \tag{3}$$

and:

$$SEr_{gxy} = \sqrt{\frac{(1-r^2_{gxy})^2}{2h^2_x.h^2_y}} \tag{4}$$

For phenotypic:

$$t = \frac{r_{pxy}}{SEr_{pxy}}$$

$$SEr_{pxy} = \sqrt{\frac{(1-r^2_{pxy})^2}{2h^2_x.h^2_y}}$$

Where:

r_{gxy}, r_{pxy} = Genotypic and phenotypic correlation coefficient, respectively between character x and y
SEr_{gxy}, SEr_{pxy} = Standard error of genotypic and phenotypic correlation, respectively coefficient between character x and y
h^2x = Heritability for character x
h^2y = Heritability for character y

The calculated absolute t-value was tested against the tabulated t-value at g-2 d.f. for both correlation coefficients where, g is the number of genotypes.

The path coefficient analysis was performed following the method suggested by Dewey and Lu (1959) as follows:

$$r_{ij} = P_{ij}+\Sigma r_{ik}P_{kj} \tag{5}$$

Where:

r_{ij} = Association between the independent character (i) and dependent character (j) as measured by the correlation coefficient

P_{ij} = Component of direct effects of the independent character (i) on dependent character (j) as measured by the path coefficient and

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

Residual effects were estimated using the equation:

$$\sqrt{1-R^2}$$

where, R^2 is $\Sigma P_{ij} r_{ij}$.

Total yield per plant were used as dependent character in separate path coefficient analysis and the remaining 15 characters were used as independent variables.

RESULTS AND DISCUSSION

Genotypic and phenotypic correlation studies: Estimates of the phenotypic and genotypic correlation coefficients between each pair of the characters in this study are presented in Table 2. The magnitudes of genotypic correlation coefficients were mostly higher than the corresponding phenotypic correlations. This revealed that association among these characters was under genetic control and indicating the preponderance of genetic variance in expression of characters. This means the influence of environmental factor is lower than the inherent genetic effect and has inherent associations among various characters in tannia. As explained by El-Mohsen *et al.* (2012) when value of phenotypic correlation coefficient was greater than genotypic correlation coefficient, it shows that apparent association of two traits was not only due to genes but also due to favorable influence of environment. By contrast, if value of correlation coefficient was zero, this showed that these two traits were independent.

Among the characters, the maximum positive and significant phenotypic correlation was observed for total yield per plant with cormel fresh weight ($r_p = 0.957$) followed by plant height with petiole length ($r_p = 0.903$) lamina width with lamina length ($r_p = 0.825$) and corm weight with total yield per plant ($r_p = 0.825$). The minimum positive insignificant correlation was between corm dry matter and cormel length ($r_p = 0.018$); while the maximum negative phenotypic insignificant correlation was between cormel dry matter content and cormel fresh weight ($r_p = -0.178$) and the minimum was between corm dry matter content and number of sucker per plant ($r_p = -0.01$).

This result is in agreement with Pandey *et al.* (2009) who reported significant positive correlation between petiole length and plant height, corm fresh weight and cormel fresh weight and non significant positive correlation of cormel weight with number of cormel, corm diameter, cormel length and cormel diameter; also plant height with weight of corm, weight of cormel, cormel length and diameter, petiole length with number of cormel per plant for taro accessions. Similarly, Paul *et al.* (2013) reported that corm length had positive correlation with corm diameter, corm weight and yield per plant. Generally, the association of characters at phenotypic level was less pronounced compared to that of genotypic level in terms of significance, which may be attributed to the influence of environment on the expression of traits.

The maximum positive genotypic correlation was observed for corm diameter with corm length ($r_g = 0.976$) followed by total yield per plant with cormel fresh weight ($r_g = 0.954$), plant height with petiole length ($r_g = 0.941$), lamina width with lamina length ($r_g = 0.87$), while the minimum correlation for cormel dry matter with number of sucker per plant ($r_g = 0.001$). The maximum

Table 2: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among 16 quantitative characters

Parameters	SU	LL	LW	PLC	PtLg	PH	COL	CLD	NCL	CML	CMD	COWYi	CMWYi	CMDM	CODM	TOTYi
SU		0.264	0.150	0.534	0.318	0.303	0.204	-0.039	0.417	0.258	0.306	0.314	0.458	-0.225	0.001	0.395
LL	0.180		0.87**	0.501	0.767	0.838*	0.169	-0.017	0.196	0.519	0.803	0.375	0.554	-0.120	-0.306	0.484
LW	0.086	0.825*		0.391	0.720	0.758	0.324	0.093	0.166	0.568	0.756	0.328	0.495	-0.009	-0.110	0.426
PLC	0.469	0.530	0.439		0.486	0.489	0.085	0.076	0.594	0.124	0.306	0.440	0.349	-0.244	-0.143	0.445
PTLG	0.292	0.761	0.667	0.563		0.941**	0.182	0.159	0.214	0.447	0.681	0.522	0.649	-0.263	-0.208	0.621
PH	0.316	0.769	0.684	0.546	0.903*		0.233	0.167	0.167	0.519	0.763	0.616	0.595	-0.440	-0.350	0.663
COL	0.135	0.229	0.287	0.182	0.304	0.290		0.241	0.277	0.272	0.537	0.520	0.492	0.116	0.430	0.563
CLD	0.027	0.072	0.096	0.168	0.170	0.159	0.252		0.098	0.250	0.210	0.457	0.361	-0.074	0.440	0.460
NCL	0.404	0.151	0.122	0.425	0.196	0.182	0.317	0.138		-0.082	0.044	0.309	0.614	0.214	0.155	0.464
CML	0.176	0.378	0.356	0.229	0.392	0.439	0.225	0.140	0.099		0.976**	0.484	0.497	0.021	-0.070	0.527
CMD	0.147	0.515	0.491	0.378	0.457	0.447	0.236	0.183	0.120	0.503		0.293	0.547	0.111	0.012	0.423
COWYi	0.333	0.319	0.260	0.407	0.436	0.475	0.505	0.315	0.377	0.349	0.295		0.666	-0.114	-0.318	0.954**
CMWYI	0.494	0.489	0.399	0.409	0.591	0.566	0.335	0.288	0.489	0.390	0.372	0.626		-0.042	-0.017	0.859**
CMDM	-0.010	-0.144	0.024	-0.117	-0.173	-0.190	0.044	0.072	0.146	0.018	-0.011	-0.090	-0.011		0.369	-0.093
CODM	0.023	-0.171	-0.022	-0.085	-0.082	-0.131	0.219	0.164	0.156	-0.034	-0.019	-0.178	-0.086	0.246		-0.228
TOTYi	0.423	0.414	0.336	0.444	0.535	0.554	0.490	0.333	0.457	0.398	0.351	0.957**	0.825*	-0.066	-0.165	

*Significant at 5% probability level, **Significant at 1% probability, SU: Number of suckers per plant, LL: Lamina length, LW: Lamina width, PLC: Plant canopy diameter, PtLg: Petiole length, PH: Plant height, COL: Cormel length, CLD: Cormel diameter, NCL: Number of cormels per plant, CML: Corm length, CMD: Corm diameter, COWYi: Cormel fresh weight per plant, CMWYi: Corm fresh weight per plant, CMDM: Corm dry matter, CODM: Cormel dry matter, TotYi: Total yield per plant negative correlation was between plant height and corm dry matter content (r_g = -0.44) and the minimum negative correlation was between lamina width with corm dry matter content (r_g = -0.009). Corm length with corm diameter (r_g = 0.976) had highly significant and plant height with lamina length (r_g = 0.83) had significant correlation at genotypic level but non significant at phenotypic level.

Petiole length had positive and significant correlation only with plant height (r_g = 0.941) and positively correlated with number of suckers per plant, lamina length, lamina width, plant canopy diameter, cormel length, cormel diameter, corm length, corm diameter, number of cormel per plant, corm weight, fresh weight of cormel and total yield per plant. However, petiole length had negative and non significant correlation with corm and cormel dry matter content. This is in agreement with Asfaw (2005) that reported significant and positive correlation of petiole length with plant height both at phenotypic and genotypic level but in opposite to this study he also reported that negative and highly significant correlation with cormel fresh weight at both level.

Plant height had positive and high significant genotypic correlation with lamina length (r_g = 0.838) and petiole length (r_g = 0.941). So, selection based on these characters will in advance with all characters that had positive correlation including yield. This result is in agreement with Yadav *et al.* (2007) who reported high significant and positive correlation of plant height with lamina length and also non significant correlation with cormel fresh weight and corm fresh weight among 34 taro accessions at genotypic level. Similarly, Singh *et al.* (2005) reported high significant positive correlation of plant height with leaf length and non significant positive correlation with root diameter and number of leaves per plant both at genotypic and phenotypic level among 32 genotypes of carrots in India. However, in opposite to this study Asfaw (2005) reported negative correlation of plant height with cormel length and cormel fresh weight among taro accessions at genotypic and phenotypic level.

Correlations of yield with other characters: Total yield per plant had highly significant and positive correlation with cormel fresh weight per plant and corm fresh weight per plant both at phenotypic and genotypic level. The maximum significant positive correlation was with cormel fresh weight (r_g = 0.954, r_p = 0.957) followed by corm fresh weight (r_g = 0.859, r_p = 0.825). The strong relationship is therefore, indicative for that of total yield per plant can be improved by making simultaneous improvement of those positively correlated characters which will advance total yield. Also selection of genotypes will be effective based on characters which had significant and positive correlation with total yield.

This result is in agreement with Pandey *et al.* (2009) who reported significant positive correlation at phenotypic and genotypic levels for total yield with fresh weight of corm and cormel in taro genotypes. Similarly, Yadav *et al.* (2007) reported high significant correlation of yield with corm fresh weight and cormel fresh weight, also non significant positive correlation with lamina width, lamina length, corm length and cormel length at genotypic level for taro genotypes. Asfaw (2005) reported positive and highly significant correlation of total yield with cormel fresh weight and corm yield. However, in contrast to this study Paul *et al.* (2013) reported negative insignificant genotypic and non significant positive phenotypic correlation of total yield with corm weight and corm length and also positive highly significant phenotypic and insignificant negative genotypic correlation of total yield with corm breadth.

Correlation of dry matter content with other characters: Among the characters studied, both corm and cormel dry matter content showed insignificant and negative correlation with most of the characters. Cormel dry matter had maximum positive correlation with cormel diameter (r_g =0.44) at genotypic level and with corm dry matter content (r_p = 0.246) at phenotypic level. The minimum positive correlation was observed with number of sucker per plant at genotypic as well as at phenotypic level (r_g = 0.001, r_p = 0.023, respectively). The maximum negative correlation was observed between cormel dry matter and cormel fresh weight (r_g = -0.318, r_p = -0.178) at genotypic and phenotypic levels, respectively. Similarly, corm dry matter content had maximum and minimum negative genotypic correlation with plant height (r_g = -0.44) and lamina width (r_g = -0.009), respectively. At phenotypic level, the minimum negative correlation (r_p = -0.01) was with number of sucker per plant. The negative association among characters indicates that simultaneous improvement of characters cloud be quite difficult and independent selection may have to be carried out to improve such characters.

Even though very week, dry matter content of corm and cormel had a negative correlation with total yield per plant (r_g = -0.093; r_g = -0.228), corm fresh weight (r_g = -0.042; r_g = -0.017) and cormel fresh weight (r_g = -0.114; r_g = -0.318). Such a negative association of dry matter content with yield and other characters was reported previously for sweet potato at Jari and Sirinka in north and south Wollo zones (Yohannes *et al*., 2010). Also, Tsegaye *et al.* (2006) reported highly significant negative phenotypic correlation and positive but non significant genotypic correlation of root dry matter content with root fresh yield and diameter of storage root; also negative non significant phenotypic and genotypic correlation with number of storage root among 30 genotypes of sweet potato. However, in contrary with this study, Arslan (2007) reported positive but non-significant correlation of dry matter content with tuber yield per plant, plant height, number of tuber per plant and number of stem per plant in potato. Also Khayatnezhad *et al.* (2011) reported positive non significant correlation of tuber dry matter content with total yield, number of stem per plant, plant height and number of tuber per plant among 10 potato genotypes in Iran.

Path coefficient analysis: Path analysis, presented in Table 3, revealed that cormel fresh weight (0.55) had maximum direct positive effect on total tannia yield per plant followed by corm weight (0.51), plant canopy diameter (0.095), cormel length (0.08) and plant height (0.065). The result of genotypic as well as phenotypic correlation coefficient proved by path analysis, that cormel fresh weight and corm fresh weight had positive, significant and direct effect on total yield. But this direct effect was little bit reduced by the negative indirect effects of corm diameter, number of cormel, number of sucker per plant, cormel diameter, petiole length, lamina length and width. However, this negative indirect effect encounter balanced by positive indirect effect of plant canopy, plant height, cormel length and corm length. Lowest magnitude and positive direct effect was also exhibited by corm dry matter content (0.0091). On the other hand, petiole length (-0.068), number of cormel (-0.0615), cormel dry matter content (-0.044), lamina width (-0.038) and number of sucker per plant (-0.032) had negative direct effect on total yield per plant. The indirect positive effect ranged 0.0001 to 0.325 while indirect negative effect ranged -0.0001 to -0.1065.

Plant height, plant canopy, corm and cormel length, cormel fresh weight and corm weight had positive indirect effect on total yield. Lamina length and width, number of sucker per plant, corm and cormel diameter as well as corm and cormel dry matter content had low negative indirect effect. This result is in agreement with Paul and Bari (2011) that found maximum positive direct effect of corm weight; positive direct effect of plant height, cormel weight, corm length, cormel length; positive indirect effect of corm weight, plant height, cormel weight, corm length and cormel length. Contrary to this study they reported lower but positive indirect effect of petiole length, lamina length and lamina breadth for taro accessions.

Table 3: Path coefficient analysis showing direct effect (bold) and indirect effect (off diagonal) on tannia total yield per plant

Parameters	SU	LL	LW	PLC	PtLg	PH	COL	CLD	NCL	CML	CMD	COWYi	CMWYi	CMDM	CODM	rg of tot y
SU	**-0.0320**	-0.0027	-0.0043	0.0463	-0.0205	0.0211	0.0121	0.0000	-0.0252	0.0087	-0.0043	0.1750	0.2419	-0.0008	-0.0007	0.395
LL	-0.0069	**-0.0130**	-0.0320	0.0487	-0.0517	0.0527	0.0157	0.0000	-0.0103	0.0174	-0.0132	0.1567	0.2670	-0.0012	0.0095	0.484
LW	-0.0036	-0.0105	**-0.0380**	0.0397	-0.0466	0.0470	0.0226	-0.0001	-0.0085	0.0173	-0.0125	0.1354	0.2243	0.0001	0.0023	0.426
PLC	-0.0156	-0.0064	-0.0158	**0.0954**	-0.0355	0.0356	0.0124	-0.0001	-0.0295	0.0090	-0.0076	0.1963	0.1945	-0.0015	0.0045	0.445
PTLG	-0.0097	-0.0095	-0.0261	0.0501	**-0.0680**	0.0590	0.0203	-0.0001	-0.0124	0.0177	-0.0115	0.2316	0.3196	-0.0019	0.0055	0.621
PH	-0.0103	-0.0101	-0.0273	0.0520	-0.0611	**0.0653**	0.0185	-0.0001	-0.0104	0.0204	-0.0117	0.2693	0.3056	-0.0025	0.0098	0.663
COL	-0.0048	-0.0024	-0.0106	0.0146	-0.0170	0.0150	**0.0808**	-0.0001	-0.0182	0.0093	-0.0066	0.2753	0.1870	0.0007	-0.0118	0.563
CLD	-0.0001	-0.0005	-0.0036	0.0133	-0.0112	0.0147	0.0196	**-0.0005**	-0.0076	0.0064	-0.0042	0.1908	0.1666	0.0003	-0.0108	0.460
NCL	-0.0132	-0.0021	-0.0052	0.0457	-0.0136	0.0110	0.0239	-0.0001	**-0.0620**	0.0014	-0.0022	0.2027	0.2755	0.0015	-0.0069	0.464
CML	-0.0068	-0.0053	-0.0159	0.0209	-0.0291	0.0323	0.0183	-0.0001	-0.0022	**0.0411**	-0.0144	0.1959	0.2096	-0.0001	0.0029	0.527
CMD	-0.0062	-0.0073	-0.0210	0.0320	-0.0344	0.0339	0.0237	-0.0001	-0.0060	0.0263	**-0.0230**	0.1322	0.2140	0.0002	0.0005	0.423
COWYi	-0.0102	-0.0036	-0.0093	0.0341	-0.0285	0.0320	0.0405	-0.0002	-0.0227	0.0147	-0.0054	**0.5493**	0.3043	-0.0008	0.0085	0.954**
CMWYI	-0.0151	-0.0065	-0.0165	0.0361	-0.0420	0.0388	0.0294	-0.0002	-0.0329	0.0167	-0.0094	0.3249	**0.5146**	-0.0002	0.0030	0.859**
CMDM	0.0029	0.0017	-0.0005	-0.0152	0.0138	-0.0179	0.0060	0.0000	-0.0104	-0.0003	-0.0004	-0.0458	-0.0117	**0.0091**	-0.0125	-0.093
CODM	-0.0005	0.0027	0.0020	-0.0097	0.0085	-0.0146	0.0217	-0.0001	-0.0096	-0.0027	0.0003	-0.1065	-0.0350	0.0026	**-0.0440**	-0.228

**Significant at 1% probability level. Residual effect: 0.175, SU: Number of suckers per plant, LL: Lamina length, LW: Lamina width, PLC: Plant canopy diameter, PtLg: Petiole length, PH: Plant height, COL: Cormel length, CLD: Cormel diameter, NCL: Number of cormels per plant, CML: Corm length, CMD: Corm diameter, COWYi: Cormel fresh weight per plant, CMWYi: Corm fresh weight per plant, CMDM: Corm dry matter, CODM: Cormel dry matter, TotYi: Total yield per plant

Similarly, Paul and Bari (2013) reported positive direct effect of plant height and cormel length on total yield per plant and also negative indirect effect of number of cormel per plant on cormel length, petiole length, corm length, corm diameter, corm weight and plant height; but in opposite to this study, corm length, corm weight and cormel fresh weight showed negative direct effect on total yield of elephant yam accessions. Also Agueguia (1993) reported negative direct effect of corm dry matter content and cormel dry matter content and positive direct effect of number of cormel per plant but in opposite to this study he reported that number of cormel had positive direct effect on yield of tannia. Fekadu *et al*. (2013) reported that plant height had positive direct effect on yield, whereas number of stem per plant, root dry matter content and number of tubers per plant showed negative direct effect on potato germplasm. Tsegaye *et al*. (2006) reported negative direct effect of tuber dry matter content on total fresh yield of sweet potato genotypes. Tuncturk and Ciftci (2005) reported that plant height had positive indirect effect on number of tuber, average tuber weight, tuber yield and dry matter content among 21 potato genotypes in Turkey. However (Khayatnezhad *et al*., 2011) reported positive direct and indirect effect of dry matter content, number of tuber per plant and number of stem per plant on yield of potato.

As the result of correlation coefficient in Table 2 showed the positive correlation of total yield per plant with plant height, cormel length, plant canopy diameter, corm length, cormel fresh weight and corm fresh weight also explained by the path analysis which indicates their positive direct effect on total yield per plant. Moreover, plant height, plant canopy diameter, corm and cormel fresh weight have high heritability along with moderate to high genetic advance as percent of mean. Therefore, direct selection would be effective, i.e., selecting genotypes having tall plant height, wider plant canopy diameter could be used to improve total yield of tannia. Similarly, percentage of corm dry matter content had direct positive effect, though it had no significant genotypic association with yield, indicating the importance of these traits towards the genetic improvement of the crop.

Number of sucker per plant ($r_g = 0.395$), lamina length ($r_g = 0.484$), lamina width ($r_g = 0.426$), petiole length ($r_g = 0.621$), cormel length ($r_g = 0.563$), number of cormel per plant ($r_g = 0.464$) and corm diameter ($r_g = 0.423$) had positive genotypic correlation with total yield per plant but the path analysis showed negative direct effect. Hence, the causal factor of positive correlation might be their respective positive indirect effects of other characters. Such as the negative direct effect of lamina length and lamina width encountered by positive indirect effect of plant canopy diameter, plant height, cormel length and width, corm length corm as well as cormel weight; even if, slightly enhanced by the negative indirect effect of number of cormel per plant and corm diameter. Similarly, the direct negative effect of number of sucker corrected by the positive indirect effect of plant canopy diameter, plant height, cormel length and width as well as corm dry matter content. So, indirect selection could be used since they had positive correlation coefficient but direct effects were negative which encountered by other traits.

The negative direct and indirect effect of lamina length, lamina width and petiole length on total yield per plant as well as negative indirect effect on cormel length and diameter, corm length and diameter and those fresh weights of cormel and corm may be related to the transpiration of water, since they were grown on full sun light condition. The larger the lamina length and lamina width and longer petiole length would lead the plant to transpire more water and may result in decreasing of photosynthesis activity which leads lower carbon fixation and lower translocation of photo assimilate. This is in support of Valenzuela *et al*. (1991) who reported larger leaves and longer petioles of tannia grown in the shade (30 to 50% daylight) leading to a greater light interception and to higher rates of carbon fixation on a per plant basis which results the higher yields of underground components for shade-grown than those grown in full sun.

The residual effect obtained (0.176) indicated that 16 characters included in this study explained high percentage (82.4%) of the total variation in yield. Also, indicated that in addition to these characters, there are some more components that contribute towards yield of tannia.

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