Character Association in Amaro Coffee (*Coffea arabica* L.) Landrace Using Morphological Traits at Awada, Southern Ethiopia

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Abstract

Fifty-eight Amaro Kele coffee (Coffea arabica L.) accessions and six standard check were evaluated for character association at Awada Agricultural Research Sub-Center, Southern Ethiopia using morphological traits. This work was done to determine the level of phenotypic and genotypic association of characters and their direct and indirect relation with coffee yield. The experiment was laid out in an 8x8 simple lattice design with two replications having eight coffee accessions per each incomplete block. Coffee yield has positive and significant genotypic association with number of primary branches(rg=0.704), number of bearing primary branch(rg=0.613), number of main stem node (rg=0.619), stem diameter (rg=0.335) and canopy diameter (rg=0.376), whereas average inter node length of main stem(1.083), number of main stem nodes (0.427), canopy diameter (0.414), height up to first primary branch (0.300) and number of bearing primary branch (0.294) had maximum direct effect on yield. Correlation analysis and path analysis confirmed presence of variation among tested accessions. However, additional traits of interest should be studied over year and locations including physiological, quality and biochemical analysis with the support of advanced molecular techniques.

Keywords: *Coffea arabica* L., Correlation, Path coefficient analysis

Introduction

Coffee belongs to the family *Rubiaceae* and to the genus *Coffea* (Berthaud and Charrier, 1988; Coste, 1992). *Rubiaceae* has over 6000 species and 500 genera (ITC, 2002). Ethiopia is the homeland and center of genetic diversity of Arabica coffee (Vavilov, 1951; Sylvain 1955). Ethiopia is the most important coffee producing and exporting country in Africa and the fifth most important coffee producer worldwide (ICO, 2019; USDA, 2019). But, if considering Arabica coffee alone, Ethiopia is the third largest producer (USDA, 2019). The Southern region is the second region next to Oromia regional state in coffee producing areas and production. Genetic relationships in crop species are an important component of crop improvement programs, as it serves to provide information about genetic diversity, and is a platform for stratified sampling of breeding populations (Aleka, 2008).

Correlation coefficient measures mutual association without cause-and-effect relationship (Dewey and Lu, 1959). It is very useful in quantifying the size and direction of trait associations, can be ambiguous if the high correlation between two traits is a consequence of the indirect effect of other traits (Bizeti *et al*., 2004). A positive value of correlation shows that the changes of two variables are in the same direction, specifically high value of one variable is associated with high values of other and vice versa. When correlation is negative the movements are in opposite directions, that is, high values of one variable is associated with low values of the other (Yadav *et al*., 2011). Depending on the sign of genetic correlations between two traits can either facilitate or impede selection progress. Correlation value (r = 1) implies perfect (100%) correlation, where both traits vary hand in hand, (r = -1) means there is 100 % correlation between two characters, but they vary in opposite direction, and (r = 0) carries the implication that there is no correlation at all between the two characters (Falconer and Mackay, 1996).

Path coefficient analysis is a very important statistical tool that indicates which variables (causes) exert influence on other variables (responses), while recognizing the impacts of multi co linearity (Akanda and Mundt, 1996). Path coefficient analysis partitions the genetic correlation between yield and its component traits into direct and indirect effects and hence has effectively been used in identifying useful traits as selection criteria to improve yield (Akinwale *et al*., 2011; Sadeghi, 2011). Morphological characters related to yield potential have been studied to increase the indirect selection efficiency. For instance, Lemi *et al.,* (2017) reported that positive direct effect on coffee yield was exerted by plant height, canopy diameter and length of first primary branch so that they are effective for the improvement of coffee yield. Ermias (2005) also observed positive direct effect of plant height but negative direct effects of canopy diameter and length of primary branch on yield.

Moreover, Srinivasan (1980) reported that greater weight should be given for longer primaries and shorter internodes in selection for yield, as they had direct positive effects. On the other hand, internode length, number of primary branches, height up to first primary branch, main stem diameter and number of main stem nodes which had positive genotypic and phenotypic correlation coefficient with yield except height up to first primary branch exerted negative effect on yield (Lemi *et al.,* 2017).

In coffee, the outcome of yield depends on various growth characters, and their combinations, such as stem girth, canopy width, number of primary branches and number of secondary branches (Dancer, 1964 and Srinivasan, 1982). In addition, a number of other agronomic characters; such as plant height, leaf area, number of nodes on primary branches, number of fruits, etc. can directly or indirectly influence yield (Mesfin,1982). So, it is crucial in the improvement of yield traits to have a clear understanding of the relationships between yield and other agronomic characters because it is influenced by all factors that determine productivity (Araus *et al.*, 2001). It is, therefore, valued to estimate the magnitudes of correlations among yield and yield component traits. Also, it is desirable to know the direct and indirect effect of yield related traits in coffee. These traits could be useful indicators in breeding programs to select coffee genotype for yield.

Since, the previous conventional approach largely focused on the development of widely adapted varieties, improved local varieties for each specific agro-ecology are lacking in most of the coffee growing areas. Therefore, collection was made in 2013 to address this locality through coffee genetic resources collection for further coffee improvement program that might help to develop coffee varieties that have paramount importance to promote and maintain the existing speciality coffee quality heritage of the area. Hence, fifty-eight coffee accessions were collected from Amaro Kele Woreda but not yet evaluated for phenotypic and genotypic association of character. Therefore, this work was initiated to determine the level of phenotypic and genotypic association of characters and their direct and indirect relation with coffee yield at Awada, Southern Ethiopia.

Materials and Methods

Description of experimental site

The experiment was carried out at Awada Agricultural Research Sub-Center that was established in 1997 on land area of 31 ha near Yirgalem town, 45 km south of Hawassa and 319 km from Addis Ababa. Awada is located at 06°44′57’’N latitude and 038°23’16’’E longitude and at an altitude of 1738 meters above sea level (m.a.s.l). The mean annual rainfall of the area is 1342 mm with an average maximum and minimum air temperatures of 28.4 ^{o}C and 11.^{0}C, respectively. The major soil types of the center are eutric-nitosol and chromotic-cambisols that are highly suitable for coffee production (Mesfin and Bayetta, 2008).

Planting materials

Fifty-eight coffee accessions were collected from ten representative peasant associations of Amaro woreda of Segen people zone. Hence, 64 coffee accessions including six pure line checks were used for the study. Experimental plants were established under uniform *Sesbania* *sesban* temporary shade trees and the other management practices like: - pruning and slashing were also uniformly applied as per the coffee agronomic production practices.

Experimental design and field management

The experiment was laid out in an 8X8 simple lattice design with two replications and eight accessions per each incomplete block were planted. Each plot consists of six coffee trees. Spacing were 2mx2m for both between rows and plants in a single row.

Methods of data collection

Data from 19 different quantitative traits were collected using four sample trees of four-year aged tree per row on each plot as per the standard IPGRI (1996) coffee descriptor (Table 1).

Table 1 List of observed morphological traits and their descriptions

Traits	Abbreviation	Description of quantitative traits
Coffee bean yield (kg/ha)	YLD	Weight of fresh cherries in gram per plot were recorded, and converted in to red cherries of coffee in gram per tree (mean of six trees). Clean coffee bean (quantal/ha) = fresh cherries in gram per tree x 0.00417. Clean coffee bean (kg/ha) was calculated as (clean coffee bean (quantal/ha) x 100).
Plant height (cm)	PH	The length from the ground level to the tip of the tree per four trees was measured using tape meter.
Height up to first primary branch (cm)	HUFPB	Height from the ground up to first primary branch was measured, using tape meter.
Main stem diameter (mm)	SD	Measured as a diameter of the main stem at five cm above the ground using caliper.
Canopy diameter (cm)	CD	Was estimated as average length of tree canopy in east-west and north-south direction, using tape meter
Traits	**Abbreviation**	**Description of quantitative traits**
Average Inter-node length on orthotropic branch (cm)	AINL	computed per tree as (TH–HFPB)/TNN-1, where TH = total plant height, HFPB =height up to first primary branch, TNN = total number of main stem nodes
Number of bearing primary branches (no)	NBPB	Numbers of bearing primary branches were counted per trees
Number of primary branches (no)	NPB	Total numbers of primary branches were counted per trees.
Length of longest primary branch (cm)	LLPB	The lengths of longest selected first primary branches were measured using tape meter.
100 Bean weight (g)	HBW	Calculated as (bean weight at 0% moisture content x 100/ (bean No x 0.89)
Bean length (mm)	BL	Average of five normal beans was measured at the longest part.
Bean width (mm)	BW	Average of five normal beans were measured at the widest part
Bean thickness (mm)	BT	Average of five normal beans was measured at the thickest part.
Fruit length (mm)	FL	Average of five normal and mature green fruits were measured at the longest part, using digital caliper
Fruit width (mm)	FW	Average of five normal and mature green fruits were measured at the widest part using digital caliper.
Leaf width (cm)	LW	Average of five normal (node 3 from the terminal bud) leaves were measured at the widest part
Leaf area (cm^2)	LS	Calculated by multiplying leaf length and width by a constant 0.67

Coffee berry disease severity and Coffee leaf rust disease severity in percentage were also recorded through visual assessment on the four sample trees. Visual disease estimation per individual sample coffee tree was followed as described by Van der Graaff, (1981). In the visual assessments, four trees per accessions were randomly taken and diagnosed for presence and absence of the disease on each tree. There after, disease incidence was calculated using the following formula:

$$\text{Incidence of coffee berry per leaf disease (\%)} = \frac{\text{Total number of diseased trees}}{\text{Total number of observed trees}} * 100$$

Correlation analysis

The phenotypic correlation and genotypic correlation coefficients between two variables, including genotype were estimated, as described by Singh and Chaudhary (1985).

$\sigma g_{xy} = \frac{MSPg - MSPe}{r}$

Where: σg_{xy} = genotypic covariance between traits x and y,

MSPg= genotypic mean sum product of traits x and y,

MSPe= environmental mean sum product of traits x and y and *r*= number of replications.

$\sigma p_{xy} = \sigma g_{xy} + \sigma e_{xy}$

Where: σp_{xy}= phenotypic covariance between traits x and y, σg_{xy}= genotypic covariance between traits x and y, σe_{xy}= environmental covariance between traits x and y. Correlation coefficients at genotypic level (rg_{xy}) were calculated as: $rg_{xy} = (\sigma g_{xy}) / \sqrt{\sigma 2\, \boldsymbol{g}x * \sigma 2 \boldsymbol{g}y}$

Where: rg_{xy}= genotypic correlation coefficient between traits x and y,

σg_{xy}= genotypic covariance between traits x and y,

$\sigma^2 \boldsymbol{g}_x$= genotypic variance of trait x, $\sigma^2 \boldsymbol{g}_y$=genotypic variance of trait y.

Correlation coefficients at phenotypic level (rp_{xy}) were calculated as;

$rpxy = \sigma pxy / \sqrt{\sigma 2px * \sigma 2py}$

Where: rp_{xy}= phenotypic correlation coefficient between traits x and y,

σp_{xy}= phenotypic covariance between traits x and y, $\sigma^2 \boldsymbol{p}_x$= phenotypic variance of trait x and $\sigma^2 \boldsymbol{p}_y$= phenotypic variance of trait y.

Path coefficient analysis

Path coefficient analysis was calculated as suggested by Dewey and Lu (1959) to determine direct and indirect effects of different variables on grain yield as: rij = Pij + ΣrikPkj Where; rij is mutual association between the independent trait(i) and dependent trait (j) as measured by the correlation coefficient Pij is component of direct effects of the independent trait (i) on the dependent variable(j); ΣrikPkj is summation of components of indirect effect of a given dependent trait via all other independent traits. The residual effect (U) was calculated using the formula: $\boldsymbol{U} = \sqrt{1 - \mathrm{R}^2}$Where: - R^2=Σpijrijpij = component of direct effects ofthe independent character (i) on the dependent character (j) as measured by thepath coefficient.rij = mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficient. Path analysis correlation coefficients were computed using Microsoft Office Excel software.

Results and Discussion

Phenotypic and genotypic correlation of coffee yield with other traits

Genotypic (above diagonal) and Phenotypic (below diagonal) correlation coefficients of 19 quantitative traits were computed and presented (Table 2). The result showed that coefficients of phenotypic correlation were lower than the genotypic correlation coefficients for most of the traits (Table 1) which might be due to less influence of environments on the association of the characters, which might have not weaken the inherent genetic associations. The result agrees with the reports that phenotypic correlations were in most cases lower than the corresponding genotypic values (Abdi, 2009; Olika *et al.,* 2011; Getachew, 2012; and Lemi et *al.*, 2017).

Phenotypic correlation: The phenotypic correlation analysis exhibited that clean coffee bean yield in kgha^{-1} was statistically significant and positive with stem diameter, canopy diameter, number of primary branches and number of bearing primary branches with correlation coefficient of (rp=0.30, 0.30, 0.50 and 0.44), respectively (Table 2). This is in agreement with the findings of average bean yield that exhibited significant and positive association with stem diameter, number of primary branches and canopy diameter (Ermias, 2005). However, in contrast to this Olika *et al*. (2011) reported nonsignificant phenotypic correlations of bean yield with all morphological characters.

Genotypic correlation: The genotypic correlation analysis result exhibited that clean coffee bean yield exhibited positive and significant correlation with number of primary branch, number of bearing primary branch, stem diameter and canopy diameter with correlation coefficient (rg=0.70, 0.61, 0.34 and 0.38) respectively (Table 2). These suggest that coffee yield would increase with the increase of these characters indicating the greater importance and reliability of these traits for the improvement of yield in coffee. The breeding implication is that selection of one of the characters might result in the improvement of other characters.

In studies of genetic divergence and the processes of evaluation and selection, it is important to maintain traits that are correlated with the majority of traits (Ferrao *et al*., 2008). The close relationship between yield and yield attributing traits might be exploited in selection program, which might be helpful in developing high yielding genotypes. Thus, breeders might need to emphasize these characters, in selection and crop improvement program. This finding is in agreement with Yigzaw (2005); Olika *et al*. (2011) and Lemi *et al*., (2017) who reported positive and significant correlation of most of the quantitative characters with yield. Srinivasan (1980) also reported high and positive correlation of stem diameter and length of primary branches with yield. Similarly, Walyaro and Van der Vossen (1979) also reported significant and positive genotypic correlations between yield and stem diameter at the base of the main stem. Walyaro, (1983) and Marandu *et al*. (2004) also reported that coffee yield is influenced by important characters, like number of primary branches and canopy diameter.

In general, genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation coefficients for almost all of the characters indicating that there is a strong inherent association between the characters studied. Higher genotypic correlation might be due to the absence of masking or modifying effect of environment on the genetic association among traits (Johnson *et al.*, 1955). The clean coffee bean yield was significant and negatively correlated with coffee berry disease severity at genotypic level. This implied that through selection of tolerant or resistant coffee accessions, optimum yield of coffee accessions could be achieved in efforts of variety development in selection program. Therefore, it is suggested that independent selection may have to be carried out for improvement of each character.

Phenotypic and genotypic correlation among morphological traits

A positive and significant phenotypic and genotypic correlation among characters was obtained including 100 coffee bean weight, bean width, bean length, bean thickness, fruit length, and fruit width (Table 2). This study confirmed the existence of positive and significant phenotypic hundred coffee bean weight with fruit length and bean width (Atinafu and Mohammed, 2017). The other traits: plant height, length of longest primary branch, canopy diameter, number of primary branches, number of bearing primary branch and stem diameter had close correlation to each other. The result reveal that, the greater the number of primary branches, the larger will be the number of bearing primary branch, length of the longest primary branch, stem diameter and canopy diameter. This indicated that for those traits which were positively associated the improvement for one trait will simultaneously improve the other. Whereas, those traits, which were negatively correlated the improvement for one trait antagonistically affects the other.

It was found that reaction to coffee berry disease were negative and significantly correlated with 100 bean weight, bean width and bean thickness with phenotypic correlation coefficient values of (rg=-0.257, -0.183 and -0.184), respectively. The number of primary branch (rg=-0.459) and number of bearing primary branch (rg=-0.37) were negatively and significantly correlated with coffee berry disease at genotypic level.

Therefore, selection for coffee berry disease could negatively affect the improvement of number of primary branch and number of bearing primary branch as these characters showed negative and significant correlation at genotypic correlation coefficients. This implied that, the selections for any one of these characters are not likely to result in improvement of the others. In such a situation, it is suggested that independent selection might be carried for improvement of each character. From this study, it was suggested that high yielding population in coffee may be selected by concentrating upon number of primary branches, number of bearing primary branch, length of the longest primary branch and canopy diameter. Since the four traits are correlated among themselves, selection in one of the traits can result in the improvement of the other traits.

Table 2 Genotypic (above diagonal) and phenotype (below diagonal) correlation coefficient among 19 significant characters of Amaro coffee accessions at Awada in 2017/18

Variable	YLD	HBW	BL	BW	BT	FL	FW	LW	LS	CBD	CLR	LLPB	PH	HUFPB	SD	NPB	NBPB	AINL	CD
YLD		0.23	0.11	0.20	0.18	0.22	0.04	-0.03	-0.05	-0.64**	-0.17	0.19	0.07	0.12	0.34**	0.70**	0.61**	0.03	0.38**
HBW	0.18		0.69**	0.59**	0.67**	0.58**	0.57**	-0.04	0.02	-0.24	0.06	-0.03	0.10	0.15	-0.29*	0.13	0.09	0.14	-0.23
BL	0.03	0.66**		0.42**	0.54**	0.67**	0.33**	0.17	0.24	-0.02	-0.13	-0.04	0.22	0.23	-0.12	0.04	0.10	0.287*	-0.12
BW	0.10	0.54**	0.42**		0.75**	0.32**	0.55**	0.21	0.17	-0.17	0.12	0.05	0.20	0.25	-0.18	0.06	0.14	0.23	-0.04
BT	0.07	0.58**	0.59**	0.71**		0.46**	0.57**	0.26*	0.28*	-0.13	0.23	0.17	0.18	0.20	-0.15	0.11	0.17	0.20	-0.03
FL	0.14	0.51**	0.56**	0.31**	0.39**		0.43**	0.16	0.19	-0.15	-0.05	0.13	0.20	0.14	0.08	0.16	0.21	0.21	0.10
FW	-0.04	0.51**	0.37**	0.49**	0.49**	0.46**		-0.03	-0.00	-0.15	0.30*	0.02	-0.00	0.13	-0.07	-0.10	-0.12	-0.02	-0.08
LW	-0.00	-0.04	0.15	0.16	0.24**	0.169	0.01		0.95**	-0.04	-0.21	0.16	0.16	0.03	0.08	-0.18	-0.13	0.33**	0.22
LS	-0.01	-0.04	0.15	0.12	0.23**	0.18*	0.00	0.93**		-0.07	-0.21	0.14	0.13	0.09	-0.01	-0.23	-0.14	0.31*	0.14
CBD	-0.53**	-0.30**	-0.11	-0.18**	-0.18*	-0.13	-0.15	-0.04	-0.05		0.39**	-0.14	-0.02	-0.06	-0.04	-0.46**	-0.31*	0.02	-0.15
CLR	-0.07	0.03	-0.18*	0.05	0.11	-0.05	0.19*	-0.08	-0.07	0.36**		0.06	-0.12	-0.128	-0.16	-0.04	0.06	-0.13	-0.15
LLPB	0.13	0.08	0.12	0.08	0.20*	0.19*	0.07	0.12	0.07	-0.07	-0.00		0.49**	0.09	0.46**	0.33**	0.36**	0.42**	0.65**
PH	-0.01	0.22*	0.31**	0.22*	0.23*	0.27**	0.19*	0.14	0.13	-0.10	-0.12	0.43**		0.33**	0.15	0.35**	0.33**	0.85**	0.32**
HUFPB	0.13	0.15	0.19*	0.21*	0.16	0.15	0.14	0.02	0.05	-0.07	-0.09	0.06	0.24**		0.100	0.09	0.09	0.11	0.18
SD	0.30**	-0.10	0.06	-0.09	-0.05	0.19*	0.06	0.07	-0.02	-0.03	-0.14	0.49**	0.22*	0.13		0.30*	0.28*	0.09	0.73**
NPB	0.50**	0.16	0.108	0.09	0.08	0.18*	-0.04	-0.17	-0.19*	-0.30**	-0.09	0.31**	0.36**	0.09	0.32**		0.83**	0.06	0.38**
NBPB	0.44**	0.18*	0.165	0.10	0.15	0.21*	-0.03	-0.12	-0.15	-0.19	0.01	0.42**	0.34**	0.05	0.36**	0.68**		0.09	0.34**
AINL	-0.09	0.21*	0.34**	0.26*	0.28*	0.24**	0.15	0.29**	0.28**	-0.07	-0.09	0.35**	0.84**	0.04	0.13	0.07	0.10		0.18
CD	0.30**	-0.03	0.06	-0.04	0.06	0.13	-0.03	0.19*	0.13	-0.13	-0.10	0.59**	0.36**	0.12	0.64**	0.34**	0.36**	0.21*	

*, ** = Significant at 5% and 1%, respectively.

Path coefficient analysis

As per path coefficient analysis, the highest direct positive effect was shown by average inter node length of main stem (1.08), followed by canopy diameter(0.41), height up to first primary branch (0.30), number of bearing primary branch(0.30), number of primary branch (0.18) and leaf width (0.17) (Table 3). Low magnitude and positive direct effects were recorded for fruit width (0.12), hundred bean weight (0.09), bean width (0.03), stem diameter (0.01) and bean length (0.004). The negative effect were recorded for plant height (-1.25), leaf size (-.0.26), coffee berry disease (-0.23), bean length (-0.06), coffee leaf rust (-0.05), length of the first longest primary branch (-0.19) and fruit length (-0.05). The positive direct effects of stem diameter and number of primary branches in this study were in agreement with findings of Johnson *et al.* (1955) and Atinafu and Mohammed (2017). Path coefficient analysis revealed that bean width (rg=0.20) and hundred bean weight (rg=0.23) had positive and direct effect on coffee bean yield, though exhibited positive and non-significant genotypic correlation with coffee yield. Average internodes length on main stem had the highest positive and direct effect on coffee yield, but exhibited negative phenotypic correlation (rp=-0.09) with coffee yield. The negative correlation it showed with coffee yield was mainly due to negative indirect effects via other traits: bean thickness, fruit length, fruit width, leaf size, CBD, length of longest primary branch and plant height. This indicated that restricted simultaneous selection has to be followed; as restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect of these traits.

The positive direct effect of stem diameter (0.09), bean width (0.03) and hundred bean weight (0.05) on coffee bean yield agreed with findings of Masreshaw(2018).Similarly,
Masreshaw (2018) also reported the negative direct effect of yield contributing traits like: total plant height (-0.08), bean length (-0.31), coffee berry disease (-0.16)and coffee leaf rust (-0.06). In contrast, the findings of this study revealed positive and direct effect of number of primary branches, fruit width (0.07) and negative effect of canopy diameter (-0.06) on coffee bean yield(Table 3). The other scholar found that the positive highest direct effect on coffee yield was exerted by plant height (1.56) and canopy diameter (1.56**).**

Average internodes length (-1.86) and number of primary branches (-1.80) also exerted high negative effects on yield (Lemi *et al.*, 2017). Ermias (2005) reported positive direct effect of plant height but negative direct effects of canopy diameter on yield. Atinafu and Mohammed *(*2017) observed direct positive effect by plant height, hundred bean weights, coffee berry disease, stem diameter and average length of primary branches, number of primary branches, number of main stems nodes and bean yield.

On the contrary, plant height (-1.25), fruit length (-0.05), bean thickness (-0.05) and length of longest primary branch (-0.19) had negative direct effect and positive genotypic correlation coefficients of (rg=0.07, 0.22, 0.18and 0.19), respectively on coffee bean yield. Hence, the positive correlation coefficient was largely due to their respective positive indirect effects of other characters.

The main selection criterion in coffee is yield, quality and disease resistance. Other agronomic characters related to yield potential have been studied to increase the indirect selection efficiency. In this study, the positive direct effect on coffee yield was exerted by average inter node length of main stem, canopy diameter, height up to first primary branch, number of bearing primary branch, number of primary branches and leaf width, fruit width, hundred bean weight, bean width, stem diameter and bean length. This indicates that, with other characters kept constant, direct selection on the basis of average inter node length of main stem, number of main stem nodes, canopy diameter, height up to first primary branch, number of bearing primary branch, number of primary branch and leaf width, fruit width, hundred bean weight, bean width, stem diameter and bean length would be much effective for the improvement of coffee yield. This is usually happening and they are well known as the most important characters that influence the coffee yield directly. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In other words, residual effect measures the role of other independent variables which were not included in the study on the dependent variable. In this study, the estimated residual effect was 0.35 indicating that about 65% of the variability in yield was contributed by the characters studied in path analysis. This residual effect towards yield in this study might be mainly due to the other characters which were not included in the investigation and environmental factor. Therefore, the aspects of intensive germplasm explorations in the Amaro Kele coffee considering additional characters were suggested in order to confirm the results. In general, the path analysis carried out in the present study revealed that the main components of bean yield which had positive direct effect of bean yield should be given high priority for making selection for high yielding accessions in Amaro coffee accessions.

Table 3 Direct and indirect effects of bean yield and 18 yield contributing characters of Amaro coffee accessions at Awada in 2017/18

Variable	HBW	BL	BW	BT	FL	FW	LW	LS	CBD	CLR	LLPB	PH	HUFPB	SD	NPB	NBPB	AINL	CD	rG
HBW	**0.085**	0.003	0.018	-0.037	-0.031	0.067	-0.007	-0.004	0.054	-0.003	0.006	-0.128	0.044	-0.002	0.023	0.027	0.152	-0.095	0.229
BL	0.059	**0.004**	0.013	-0.030	-0.036	0.039	0.029	-0.061	0.004	0.006	0.008	-0.280	0.070	-0.001	0.008	0.028	0.311	-0.051	0.109
BW	0.051	0.002	**0.030**	-0.042	-0.017	0.064	0.034	-0.044	0.038	-0.006	-0.009	-0.253	0.075	-0.002	0.010	0.040	0.248	-0.018	0.198
BT	0.057	0.002	0.022	**-0.056**	-0.025	0.067	0.044	-0.073	0.030	-0.011	-0.032	-0.225	0.060	-0.001	0.020	0.050	0.216	-0.011	0.179
FL	0.049	0.003	0.010	-0.026	**-0.054**	0.050	0.026	-0.049	0.035	0.002	-0.024	-0.246	0.041	0.001	0.028	0.060	0.226	0.040	0.216
FW	0.049	0.001	0.016	-0.032	-0.023	**0.117**	-0.005	0.001	0.033	-0.014	-0.004	0.004	0.038	-0.001	-0.017	-0.035	-0.020	-0.034	0.043
LW	-0.004	0.001	0.006	-0.015	-0.008	-0.004	**0.167**	-0.245	0.009	0.010	-0.031	-0.198	0.010	0.001	-0.031	-0.039	0.359	0.092	-0.030
LS	0.001	0.001	0.005	-0.016	-0.010	-0.001	0.159	**-0.257**	0.015	0.009	-0.027	-0.160	0.028	0.000	-0.040	-0.042	0.338	0.059	-0.045
CBD	-0.020	0.000	-0.005	0.008	0.008	-0.017	-0.007	0.017	**-0.227**	-0.018	0.027	0.024	-0.019	0.000	-0.081	-0.090	0.018	-0.062	-0.644
CLR	0.005	-0.001	0.004	-0.013	0.003	0.035	-0.035	0.053	-0.088	**-0.046**	-0.011	0.144	-0.038	-0.001	-0.007	0.017	-0.138	-0.064	-0.165
LLPB	-0.003	0.000	0.001	-0.010	-0.007	0.002	0.027	-0.036	0.032	-0.003	**-0.191**	-0.614	0.026	0.004	0.058	0.105	0.452	0.270	0.189
PH	0.009	0.001	0.006	-0.010	-0.011	0.000	0.026	-0.033	0.004	0.005	-0.093	**-1.254**	0.099	0.001	0.061	0.096	0.916	0.134	0.065
HUFPB	0.012	0.001	0.007	-0.011	-0.007	0.015	0.006	-0.024	0.014	0.006	-0.016	-0.416	**0.300**	0.001	0.015	0.025	0.115	0.075	0.117
SD	-0.025	-0.001	-0.005	0.008	-0.004	-0.008	0.013	0.003	0.008	0.007	-0.088	-0.185	0.030	**0.008**	0.052	0.083	0.092	0.303	0.335
NPB	0.011	0.000	0.002	-0.006	-0.008	-0.011	-0.030	0.059	0.104	0.002	-0.063	-0.434	0.026	0.002	**0.176**	0.243	0.068	0.158	0.704
NBPB	0.008	0.000	0.004	-0.010	-0.011	-0.014	-0.022	0.036	0.070	-0.003	-0.068	-0.409	0.025	0.002	0.146	**0.294**	0.096	0.139	0.613
AINL	0.012	0.001	0.007	-0.011	-0.011	-0.002	0.056	-0.080	-0.004	0.006	-0.080	-1.061	0.032	0.001	0.011	0.026	**1.083**	0.072	0.029
CD	-0.020	-0.001	-0.001	0.002	-0.005	-0.010	0.037	-0.037	0.034	0.007	-0.124	-0.405	0.054	0.006	0.067	0.099	0.189	**0.414**	0.376

Residual=0.35

Conclusion

The genotypic and phenotypic correlation analysis result exhibited that clean coffee bean yield has positive and significant correlation with number of primary branch, number of bearing primary branch, stem diameter and canopy diameter. These suggest that coffee yield would increase with the increase of these characters. In studies of genetic divergence and the processes of evaluation and selection, it is important to maintain these traits. The close relationship between yield and yield attributing traits might be exploited in selection program, which might be helpful in developing high yielding genotypes. Thus, breeders might need to emphasize on these characters, in selection and crop improvement program.

In general, genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation coefficients for almost all of the characters, indicating that there is a strong inherent association between the characters studied.
Higher genotypic correlation might be due to the absence of masking or modifying effect of environment on the genetic association among traits.
In path coefficient analysis, the highest direct positive effect was shown by average inter node length of main stem, followed by canopy diameter, height up to first primary branch, number of bearing primary branch, number of primary branch and leaf width. Hence, the path analysis carried out in the present study revealed that the main components of bean yield which had positive direct effect of bean yield should be given high priority for making selection for high yielding accessions in Amaro Kele coffee accessions.

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