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Research Article

Association and Path Coefficient Analysis of Some Arsi Coffee Accesions (*Coffea arabica* L.) for Quality Traits at Mechara, Ethiopia

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Abstract

Coffee is still one of Ethiopian's primary agricultural export crops accounting for more than 25% of export earnings. Arsi coffee is known to produce Harar C coffee quality grade and known for its unique flavor and aroma. Therefore, this study was conducted to determine association among coffee bean quality traits and, the direct and indirect effects of bean quality traits on overall quality of coffee. A total of 56 Arsi coffee accessions and four Hararghe coffee varieties were evaluated for bean physical and organoleptic coffee quality traits using Completely Randomized Design with three replications. The analysis of variance results showed significant variation among Arsi coffee accession for all traits except astringency, bitterness, and odor. The overall coffee quality had positive and significant phenotypic and genotype correlations with aromatic intensity, aromatic quality, acidity, body, flavor, overall standard quality and overall cup quality. These traits also had positive direct effects on overall coffee quality however; aromatic intensity and body exerted negligible negative direct effects at genotypic level whereas aromatic quality had negative direct effect at phenotypic level. All these traits through overall standard quality, and aromatic intensity, aromatic quality and acidity via each other and through body and flavor exerted positive direct effects on overall coffee quality at genotypic level. Thus majority of quality traits could be used for indirect selection of genotypes for overall coffee quality.

Keywords

Cup Quality, Correlation, Path Coefficient Analysis

1. Introduction

Coffea arabica L. belongs to the genus *Coffea*, in the family *Rubiaceae.* The basic chromosome number for the genus *Coffea* is, x =11. It is commonly known as the only allopolyploidy and self-fertile species of the genus *Coffea,* with chromosome number 2n = 4x = 44, while others are diploid (2n = 2x = 22) and self- infertile [15]. It ranks second after oil in international trade and has created several million jobs in the producer and consumer countries where more than nine million tons of green beans are produced annually [9]. Ethiopia is the fifth major exporter of Arabica coffee in the world next to Brazil, Vietnam, Colombia and Indonesia; while it is the highest producer among African countries [9]. Ethiopia is

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naturally endowed with a suitable climate for the production of high quality coffee. Tthere are different coffee types recognized by their origin and quality, and used as trade names in Ethiopia. These include Bebeka, Harar, Jimma, Kaffa, Lekempti/Wellega, Limmu, Sidama, Teppi and Yirgacheffe [16]. Arsi coffee is known to produce Harar C coffee quality grade and known for its unique flavor and aroma. Knowledge of correlations that exist between important characters may facilitate the interpretation of the result obtained and provide the basis for planning more efficient program for the future [10]. It is indicate the importance of studying correlation between characters in the determination of the most effective breeding procedures [2]. Few researchers conducted research on association and path coefficient analysis on coffee quality attributes in Ethiopia [1, 4, 7, 13, 20]. However, the information is limited on association and path coefficient analysis in coffee bean quality attributes. Therefore, to study the coffee accessions from Arsi known to produce Harar C coffee quality grade will provide information about the inherent bean quality attributes difference of Arsi coffee accessions. The information may help breeders to design breeding methods to improve Arsi coffee accessions either by selection and/or hybridization. This research was therefore initiated with the objective to determine association among coffee bean quality traits and, the direct and indirect effects of bean quality traits on overall quality of coffee.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Mechara Agricultural Research Center (McARC) in 2017 cropping season. The center is located near Mechara town in Daro-Labu district of West Hararghe Zone. It is 434 km East of Finfinne and 108 km Southeast of Chiro, the zonal capital. Geographically, it is located between latitude of 8°36'38" North and longitude of 40°19'29" East at an altitude of 1760 m.a.s.l. The soil type is deep, well-drained and slightly acidic Nitosol. The area has an erratic rainfall with high variability in the onset and cessation of the main rainfall season. Generally, the area receives an average annual rainfall of 871mm of which the peak rainfall months are from June to October, while the lowest (dry) months are from November to February. Its annual mean minimum and maximum air temperatures are 14 ℃ and 26 ℃ respectively (McARC, 2010).

2.2. Experimental Materials and Design

Fifty six arabica coffee promising accessions which have been collected from Arsi zone along with four released Hararghe coffee selections were used for this study.

Table 1. *Geographical origin Arsi coffee (Coffea arabica L.) accessions.*

Acc. no.	Collection area	Woreda	Acc. no.	Collection area	Woreda
Ar04/11	Haro	Gololcha	Ar78/11	Jinka Dhibu	Gololcha
Ar08/11	M/laga Buna	Chole	Ar50/11	Manya Adare	Chole
Ar40/11	M/Warqi Darartu	Gololcha	Ar76/11	Mine Gora	Gololcha
Ar56 /11	Mine Gora	Gololcha	Ar23/11	M/Oda Adi	Chole
Ar07/11	M/laga Buna	Chole	Ar30/11	Darartu	Chole
Ar82/11	Jinka Dhibu	Gololcha	Ar119/11	Mine Gora	Gololcha
Ar83/11	Jinka Dhibu	Gololcha	Ar75/11	Mine Gora	Gololcha
Ar10/11	M/laga Buna	Chole	Ar26/11	M/Oda Adi	Chole
Ar57/11	Mine Gora	Gololcha	Ar72/11	Mine Gora	Gololcha
Ar53/11	Manya Adare	Gololcha	Ar28/11	M/Oda Adi	Chole
Ar52/11	Manya Adare	Chole	Ar74/11	Mine Gora	Gololcha
Ar63/11	Mine Gora	Gololcha	Ar36/11	M/Warqi Darartu	Chole
Ar64/11	Mine Gora	Gololcha	Ar44/11	Manya Adare	Chole
Ar65/11	Mine Gora	Chole	Ar115/11	Mine Gora	Gololcha
Ar77/11	Mine Gora	Gololcha	Ar46/11	Manya Adare	Chole
Ar87/11	Jinka Dhibu	Chole	Ar33/11	M/Warqi Darartu	Chole
Ar88/11	Jinka Dhibu	Gololcha	Ar118/11	Mine Gora	Gololcha

Acc. no.	Collection area	Woreda	Acc. no.	Collection area	Woreda
Ar15/11	M/laga Buna	Chole	Ar47/11	Manya Adare	Chole
Ar18/11	M/laga Buna	Gololcha	Ar69/11	Mine Gora	Gololcha
Ar19 /11	M/laga Buna	Chole	Ar106/11	Geda Seka	Chole
Ar03/11	Jeda Saqa	Chole	Ar102/11	Geda Seka	Chole
Ar84/11	Jinka Dhibu	Gololcha	Ar95/11	Geda Seka	Gololcha
Ar38/11	Darartu	Chole	Ar12/11	M/laga Buna	Gololcha
Ar101/11	Geda Seka	Gololcha	Ar100/11	Geda Seka	Gololcha
Ar11/11	M/laga Buna	Chole	Ar34/11	Darartu	Chole
Ar93/11	Geda Seka	Gololcha	Ar103/11	Geda Seka	Gololcha
Ar21/11	M/Oda Adi	Chole	Arusa		
Ar66/11	Mine Gora	Gololcha	Mocha	Standard checks	
Ar37/11	M/Warqi Darartu	Chole	Mechara-1		
Ar02/11	Jeda Saqa	Chole	Bultum		

The Arsi coffee accession were planted along with four released Hararghe coffee varieties in 2012 G. C. Augmented design was used for field planting with spacing of 2 m between plants and 3 m between blocks were maintained. The laboratory experiment was conducted in completely randomized design (CRD) with three replications. Selective hand picking method was applied to collect only red ripe cherries from trees selectively leaving behind unripe green beans to be harvested later. Accordingly, more than three harvests were conducted to collect cherries to prepare the required amount of beans for the experiment. The collected fresh cherry accessions were placed on raised bed mesh wire under sun for drying. Fully dried accessions were hulled with mortar. The dried pulp, the parchment skin part of the husk was removed. 100gm of dried green coffee beans was prepared for each accession per replication and roasted for an average of six minutes to medium roast under roasting temperature of 200 ℃. Grinding was done the roasting accession using coffee electrical grinder (MahlKonig, Germany) with middle adjustment. Finally brewing preparation was made for cup tasting by a group of experienced and well trained coffee tasters of Jimma Agricultural Research center.

Table 2. Standard parameters and their values used for liquor quality.

Parameters	Scale	Description of each scale					
		0	1	2	3	4	5
Aromatic intensity	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Aromatic quality	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Bitterness	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Astringency	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Parameters	Scale	Description of each scale					
		0	2	4	6	8	10
Acidity	0-10	Nil	Lacking	Light	Medium	M. pointed	pointed
Body	0-10	Nil	V. light	Light	Medium	M. full	Full
Flavor	0-10	Nil	Bad	Fair	Medium	Good	V. good
Overall standard	0-10	Nil	Bad	Regular	Good	V. good	Excellent

2.3. Data Collection

2.3.1. Raw Coffee Bean Quality Attributes

A total of 300g of green beans sample were prepared per each accession for raw beans and cup quality attributes analysis. The green bean evaluated for raw beans quality according to the standard established for washed coffee raw quality. Accordingly, raw coffee bean quality was determined by bean size, shape and make, color and odor traits.

Bean size: distribution of coffee bean was determined by conventional screen analysis using perforated plate screens of diameter sizes 14 (5.55mm) [19].

Table 3. *Standard parameters and their values used for coffee raw quality (40%).*

Shape and make (15%)		**Color (15%)**		**Odor (10%)**	
Quality	**Points**	**Quality**	**points**	**Quality**	**Points**
Very good	15	Bluish	15	Clean	10
Good	12	Grayish	12	Fair clean	8
Fair good	10	Greenish	10	Trace	6
Average	8	Coated	8	Light	4
Mixed	6	Faded	6	Moderate	2
Small	4	White	4	Strong	0

2.3.2. Cup Quality Attribute

Three cups per sample in three replications were prepared for each accession and tasting session. The accessions replicated for each accession was arranged at random. The sensory evaluation of each accessions and the cup quality were carried out by three trained and certified professional panelists of Jimma Agricultural Research Center (JARC). The cupping form provides a systematic means of recording eight important quality attributes. These include aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor, and overall standard.

2.4. Data Analysis

Data of bean quality traits were subjected to analysis of variance (ANOVA) using R-software to examine the presence of statistically significant differences among landraces for the traits studied.

2.5. Correlations Analysis

Phenotypic (r_p) and genotypic (r_g) correlations between two traits are estimated using the formula suggested by [5, 10].

$$r_p = \frac{P\,\mathrm{cov}_{xy}}{\sqrt{(V_p x . V_p y)}} \quad r_g = \frac{G\,\mathrm{cov}_{xy}}{\sqrt{(V_g x . V_g y)}}$$

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 of variable x, Vgx = Genotypic variance of variable x, V_py = Phenotypic variance of variable y, Vgy = Genotypic variance of variable y

The calculated phenotypic correlation value was tested for its significance using t-test:

$$t = \frac{rph}{SE\ (rph)}$$

Where, r_{ph}=Phenotypic correlation; SE (r_{ph}) = Standard error of phenotypic correlation obtained using the following formula (Sharma, 1998).

$$SE = \sqrt{\frac{1 - r2ph}{n-2}}$$

Where, n is the number of genotypes tested, r^2_p is phenotypic correlation coefficient.

The coefficient of correlations at genotypic levels was tested for their significance by the formula described by [14] as indicated below:

$$t = r_{gxy}/SEr_{gxy}$$

The calculated "t" value was compared with the tabulated "t" value at (n-2) degree of freedom at 5% level of significance. Where, n is number of genotypes.

$$SErgxy = \frac{\sqrt{1-r^2gxy}}{h2x} * h2y$$

Where, h^2x = Heritability of trait x; h2y = Heritability of trait y

2.6. Path Coefficient Analysis

rij = Pij + Σrik pkj where, rij = mutual association between the independent character (i) and dependent character (j) as measured by the genotypic and phenotypic correlation coefficients.

Pij = direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic path coefficients, and Σrikpkj = Summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).

The residual effect, which determines how best the causal factors account for the variability of the dependent factor yield, was computed using the formula;

$$1=p^2R + \Sigma \text{ p ij rij}$$

Where, p^2R is the residual effect. pij rij = the product of direct effect of any variable and its correlation coefficient with yield.

3. Result and Discussion

The results of analysis of variance (ANOVA) showed the presence of significant (P<0.05) differences among the Arsi coffee accessions for raw quality and cup quality traits except bitterness, astringency and odor (Table 4). The presence of significant variations among Arsi coffee accessions for coffee bean quality traits is a good indicator for the existence of exploitable genetic variability for the improvement of Arsi coffee quality through selection and/or crossing of accessions. The existences of a great diversity in Ethiopian coffee gene pools have been reported by many scientists [5, 11, 12, 17, 18].

Table 4. *Mean squares of coffee bean physical and organoleptic quality attributes of Arsi coffee accessions.*

Trait	Genotype	EMS	SE	CV%
Acidity	0.68**	0.21	0.51	6.19
Aromatic Intensity	0.22*	0.15	0.42	9.44
Aromatic Quality	0.38*	0.21	0.49	11.09
Astringency	0.16ns	0.38	0.6	14.8
Bitterness	0.22ns	0.49	0.7	17
Body	0.44**	0.18	0.46	5.66
Flavor	0.84**	0.12	0.37	4.8
Overall Standard	0.79**	0.17	0.47	5.58
Total cup quality	20.71**	3.95	2.21	4.31
Bean size	867.10**	1.06	1.17	1.37
Color	0.63*	0.3	0.66	4.29
Odor	0.05ns	0.05	0.23	2.4
Shape and make	2.85**	0.42	0.68	5.44
Total raw	4.31**	0.88	1.12	2.71
Overall Quality	25.29**	4.94	2.33	2.75

3.1. Genotypic and Phenotypic Correlation of Coffee Quality Attributes

Phenotypic and genotype correlation revealed that overall coffee quality had positive and significant phenotypic and genotype correlation with aromatic intensity, aromatic quality, acidity, body, flavor, overall standard quality and total cup quality. Bean size, total raw and bean shape and make, had positive and significant phenotypic correlation with overall coffee quality, the traits that exhibited positive and significant association both at phenotypic and genotypic levels suggest the high chance of selection of genotypes for observable phenotypic characters to improve the overall coffee quality. Overall cup quality had positive and significant phenotypic and genotypic correlation with aromatic quality, aromatic intensity, acidity, body, flavor and overall standard. Cup quality traits; aromatic quality, flavor, acidity, body and aromatic intensity had significant and strong correlation with overall standard quality. These traits showed positive and significant relationship among themselves at both genotypic and phenotypic correlation. Thus, positive correlation of these traits indicates that selection of high performing genotypes for one of the trait would also simultaneously improve the other traits. Total raw quality showed positive and significant phenotypic and genotypic correlation with color and shape and make. These traits showed positive and significant association among themselves at both correlation levels. This indicates selection of genotypes with high mean value for one of the trait would also simultaneously improve the other traits. Most of organoleptic quality attributes showed strong genotypic correlation with overall coffee quality and among themselves as compared to phenotypic correlation. This indicates true inherent correlation among the traits. Therefore, improvement of these attributes can result in good cup quality. The present study is in agreement with the findings of previous researchers that reported the presence of significant correlation among cup quality attributes and raw bean quality. [8, 20], reported that strong and significant association among good quality attributes. In addition, the research [1, 13] reported positive and highly significant correlation among most important quality traits. These authors suggested that aromatic quality, body, flavor, acidity and overall standard have to be considered in coffee quality improvement program. [6] also reported positive and significant correlation of overall standard quality with flavor, aromatic quality, acidity and body; indicate selection for these traits can improve overall standard of coffee quality. Cup quality traits (aromatic intensity, aromatic quality, acidity, flavor and overall standard quality) except body had negative and non-significant genotypic and phenotypic correlation with overall quality.

Table 5. Phenotypic correlation coefficients of quality traits of Arsi coffee landraces (Coffea arabica L).

	AI	AQ	AC	BO	FL	OVS	TC	SHM	CO	TR	BS	OV
AI	1	0.79**	0.62**	0.58**	0.67**	0.59**	0.74**	0.07	-0.2	0	-0.12	0.67**
AQ		1	0.66**	0.63**	0.69**	0.67**	0.80**	0.04	-0.28*	-0.07	-0.11	0.70**
AC			1	0.89**	0.92**	0.93**	0.94**	0.06	-0.2	-0.04	-0.09	0.84**
BO				1	0.92**	0.92**	0.92**	0.14	-0.12	0.06	0.03	0.85**
FL					1	0.94**	0.96**	0.1	-0.16	0.01	-0.05	0.87**
OVS						1	0.95**	0.06	-0.15	-0.01	-0.07	0.86**
TC							1	0.11	-0.18	0.01	-0.06	0.91**
SHM								1	0.35**	0.92**	0.78**	0.48**
CO									1	0.66**	0.25*	0.11
TR										1	0.72	0.43**
BS											1	0.24*
OV												1

AI= aromatic intensity, AQ= aromatic quality, AC= acidity, BO= body, FL= flavor, OVS= overall standard, TC= total cup quality, SHM= shape and make, TR= total raw, BS= bean size, OV = Overall coffee quality

Table 6. Genotypic Correlation coefficients of quality traits of Arsi coffee landraces (Coffea arabica L).

	AI	AQ	AC	BO	FL	OVS	TC	SHM	CO	TR	BS	OV
AI	1											
AQ	0.99**	1										
AC	1.19	1.035**	1									
BO	1.18	1.01**	1.09**	1								
FL	1.22	1.04**	1.02**	1.10*	1							
OVS	1.07	1.05**	1.02**	1.06**	0.99**	1						
TC	1.05*	0.98**	1.04**	1.07**	1.02**	1.01**	1					
SHM	0.13	0.04	0.02	0.14	0.09	0.05	0.11	1				
CO	-0.43	-0.52	-0.22	-0.2	-0.18	-0.18	-0.21	0.44*	1			
TR	0.02	-0.11	-0.07	0.05	0.01	-0.03	0.01	0.96*	0.68	1		
BS	0.21	0.44	0.32	0.33	0.25	0.28	0.32	0.11	-0.11	0.08	1	
OV	0.96**	0.84**	0.91**	0.99**	0.93**	0.91**	0.91**	0.49	0.09	0.42	0.27	1

3.2. Path Coefficient Analysis

3.2.1. Phenotypic Path Coefficient Analysis

Phenotypic path coefficient were showed that aromatic intensity, acidity, body, flavor, overall standard, total cup quality, shape and make and total raw quality exerts positive phenotypic direct effects on overall coffee quality. Whereas aromatic quality and bean size had negative direct effect on overall coffee quality. The negative direct effects of these traits on overall quality indicate that selection for these traits will not be effective for quality improvement. This result partially agree with the finding of [3] who compared four traits (acidity, body, flavor and overall standard) for their suitability as selection criteria for the genetic improvement of overall liquor quality. The direct effects of total cup quality (0.91) on overall quality was high due to indirect effect of organoleptic quality attributes; overall standard (0.87), acidity (0.86), flavor (0.87), body (0.84), aromatic intensity (0.67) and aromatic quality (0.73). Relatively high and positive direct effects of total raw quality on overall quality were due to indirect positive effect of shape and make and bean size.

The positive direct effect of aromatic intensity, acidity, body, shape and make and bean size on overall quality had path coefficient values lower than their correlation values, indicating the magnitude of other traits via which these traits contributed to overall quality. [8] reported high values of direct and indirect effects suggest that the true relationship and direct selection for these traits may also increase and give better response for improvement of overall coffee quality.

3.2.2. Genotypic Path Coefficient Analysis

Genotypic path coefficient analysis revealed that aromatic quality, acidity, flavor, overall standard and total cup quality exerts positive genotypic direct effects on overall coffee quality, while aromatic intensity and body exhibited negative genotypic direct effect on overall coffee quality (Table 8). The direct positive effects of these traits on overall coffee quality indicates direct selection based on these traits can be effective via overall quality and its components for more efficiency during selection process. Overall cup quality had exerted maximum positive direct effect (P = 0.92) and had positive and significant correlation with overall quality. The genotypic correlation of these traits with the cup quality and overall quality was high indicating the importance of cup quality traits in overall coffee quality. Thus strong and significant genotypic association with overall quality mainly due to indirect effect of aromatic intensity, aromatic quality, acidity, body, flavor and overall standard. Relatively moderate positive and significant direct effect was observed from flavor and acidity, while aromatic intensity and body had low degree of negative direct effects toward on overall coffee quality.

According to the present study, most of organoleptic quality traits except, overall cup quality showed weak genotypic direct and indirect effect on overall coffee quality. The present studies are in agreement with the work of earlier researchers. The author [8] indicated that aromatic intensity, aromatic quality, acidity and flavor are good quality attributes. Similarly, [1, 13] suggested that flavor, overall standard, aromatic quality, acidity and body have to be considered in coffee quality improvement programs. [7] also reported flavor, body, astringency and aromatic intensity exhibited positive direct effect on overall standard of coffee quality and selection for this character can bring improvement in overall standard of coffee quality. The authors suggested the simultaneous selection for acidity; aromatic quality and aromatic intensity with flavor to improve the overall quality of coffee.

The residual effect in path analysis determines how best the component (independent) variables account for the variability of the dependent variable, yield per plant [5]. Accordingly the residual effect from genotypic path coefficient analysis had 0.0542, showed that all the traits included in the study explained high variability in overall coffee quality (94.58%). The remaining unexplained variability explains 5.42%. This may either due to non-studied traits or the influence of environment on the traits.

Table 7. *Estimates of direct (bold diagonal) and indirect effects (off diagonal) at phenotypic level of quality traits on overall quality of Arsi coffee landraces.*

	AI	AQ	AC	BO	FL	OVS	TC	rp
AI	0.0007	-0.0005	0.0017	0.0015	-0.0018	-0.0041	0.673	0.67**
AQ	0.0006	-0.0007	0.0018	0.0016	-0.0018	-0.0047	0.7294	0.70**
AC	0.0005	-0.0004	0.0027	0.0023	-0.0025	-0.0064	0.8595	0.84**
BO	0.0004	-0.0004	0.0024	0.0026	-0.0024	-0.0063	0.8346	0.85**
FL	0.0005	-0.0005	0.0025	0.0024	0.0027	-0.0065	0.8732	0.87**
OVS	0.0004	-0.0005	0.0025	0.0024	-0.0025	0.0069	0.8652	0.86**

	AI	AQ	AC	BO	FL	OVS	TC	rp
TC	0.0005	-0.0005	0.0025	0.0024	-0.0026	-0.0066	0.9102	0.91**

Residual= 3.20%, AI= aromatic intensity, AQ= aromatic quality, AC= acidity, BO= body, FL= flavor, OVS= overall standard, TC= total cup quality, SHM= shape and make, TR= total raw, BS= bean size, OV = Overall coffee quality

Table 8. *Estimates of direct (bold diagonal) and indirect effects (off diagonal) at genotypic level of quality attributes on overall quality Arsi coffee Collections and four Hararghe coffee.*

	AI	AQ	AC	BO	FL	OVS	TC	Rg
AI	-0.001	0.001	0.024	-0.007	-0.04	0.007	0.96	0.96**
AQ	-0.001	0.001	0.021	-0.006	-0.034	0.007	0.90	0.84**
AC	-0.001	0.001	0.02	-0.006	-0.033	0.007	0.96	0.91**
BO	-0.001	0.001	0.022	-0.006	-0.036	0.007	0.98	0.99**
FL	-0.001	0.001	0.02	-0.006	0.033	0.007	0.94	0.93**
OVS	-0.001	0.001	0.02	-0.006	-0.032	0.007	0.93	0.91**
TC	-0.001	0.001	0.021	-0.006	-0.033	0.007	0.92	0.91**

Residual= 5.42%, AI= aromatic intensity, AQ= aromatic quality, AC= acidity, BO= body, FL= flavor, OVS= overall standard, TC= total cup quality, SHM= shape and make, TR= total raw, BS= bean size, OV = Overall coffee quality

4. Conclusion

Phenotypic and genotype correlations showed that strong association among coffee quality attributes. The positive indirect genotypic effect on overall quality were influenced by overall standard quality, aromatic quality, aromatic intensity, body, acidity and flavor through total cup quality. Generally, aromatic intensity, aromatic quality, acidity, body, flavor, overall standard quality and total cup quality had positive and significant correlations with overall coffee quality and also had positive direct and indirect effects via other traits on overall coffee quality that could be used as indirect selection of accessions for overall coffee quality.

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Author Contributions

Sintayehu Girma: Conceptualization, Data curation, Formal Analysis, Validation, Investigation, Writing - original draft, Methodology, Visualization, Writing - review & editing

Wassu Mohammed: Software, Validation, Supervision, Writing - review & editing

Ashenafi Ayano: Supervision, Validation, Writing - review & editing

Data Avalability Statement

The data for this research will be available upon request from the corresponding author.

Conflicts of Interests

The authors declare no conflicts of interest.

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