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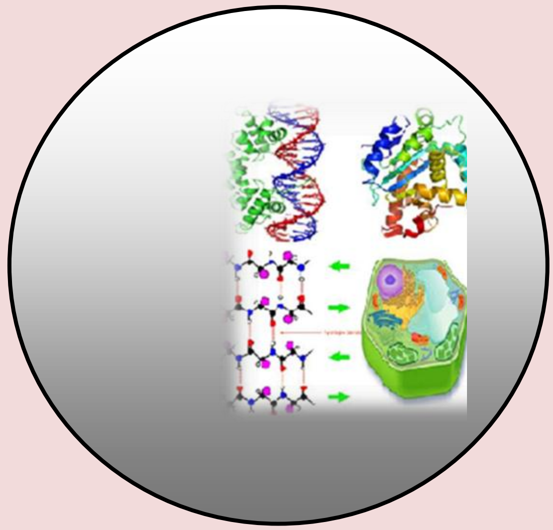

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RESEARCH PAPER

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Assessment of the Quality Characters of Some Promising Arabica Coffee Hybrids under Jimma-Tepi Environments in Southwestern Ethiopia

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ABSTRACT

Apart from productivity, coffee bean quality is an important attribute of coffee and acts as yardstick for price determination. However, the identification of genotypes with superior quality merely depends on consideration of character or trait(s') with high heritablity. The objectives of this study were to: (i) estimate the broad-sense heritability of coffee quality related characters (ii) to determine the performance of the 15 promising F_1 coffee hybrids under Jimma-Tepi environments based on the three green bean physical and eight cup quality characteristics relative to that of the existing commercial cultivars in Southwestern Ethiopia. The mean value, genetic variances and heritability on an entry mean-basis were estimated across four environments. The mean difference among genotypes across environments for all nine of eleven studied variables were significant (P <0.0.01) except aromatic intensity and body tastes. On this basis, the heritability estimates of the three green bean physical and one organoleptic cup quality characteristics were moderate to high (0.50 ± 0.20 to 0.94 ± 0.04), while the other seven characters exhibited low to moderate heritability (below 0.44 ± 0.23). The G x E effects of these quality attributes with moderate to high heritability estimates was also not severing, suggesting selection based on single environment would be efficient for improving these traits on other sites. The Hybrids HC1 followed by HC2 and HC7 combined above average value for both green bean physical characteristics and desirable cup quality attributes and are more preferable.

***Keywords**: Coffee hybrids, Cup quality, Green bean characters, GxE effect, Heritability and Proportion of variance components.*

INTRODUCTION

Coffee is one of the most important beverages in the world and is consumed by more than a third of the world's population. It is also a very important commodity crop for many developing countries, including Ethiopia, which plays a leading role in the livelihood of Ethiopians and contributes substantially to the national economy. It is still the main foreign currency earner, with the lion share of about 31 % (CTA, 2012), as well as being a significant source of employment.

Jima-Tepi coffee environment is one of the major coffee growing environments in southwestern Ethiopia, its Afromontane rainforest areas, the probable origin of Arabica coffee (*Coffea arabica* L). For these environments in the last 4 decades research endeavors, over 35 improved coffee varieties and better agronomic practices have been become available for coffee growers to boost their production and productivity. However, apart from productivity, coffee bean quality mainly cup quality (Beverage quality), often referred to as liquor quality is an important attribute of coffee and acts as yardstick for price determination (Muschler, 2001, Kathurima *et al*., 2009).

The current breeding in Ethiopia which considered bean quality in addition to increased yield and resistance to diseases is taken as new but complimentary strategies initiated in early 1980 had led identification of some elite hybrids derived from their Southwestern Ethiopian coffee parental origin. The selection of the superior one from these hybrids for economically important character of low heritability can be maximized through increasing the efficiency of indirect selection of the secondary character or trait(s') that known to have high heritability. However, selection for quality traits in Arabica coffee is constrained by the prevalence of large genotype by environment (G x E) interactions together with low genetic variability within the species (Agwanda et al., 2003). Even with the existing such environmental influence, there will be a chance of identifying traits with high heritability estimates that could be used to lead an effective selection program (Wolaryo, 1983) in his multiple environment tests reported high heritability estimates for overall standard quality taste, while Fekadu et al. (2019b) reported moderate to high for two green bean physical (bean size and shape and make appearance) and two organoleptic cup quality (acidity taste and overall quality) characteristics and Olika *et al*. (2011) in his single environment test similarly, reported high heritability estimates for aromatic quality taste with their respective low and low to moderate heritability estimates for the other most liquor quality attributes. At present, there is dearth of information especially on studies that included a site effect in genetic parameter estimation of coffee quality to estimate the effect of G x E and most of the available information's were run in single environment and the possible modification of genetic potential by local growing environments (G x E interaction) are ignored.

The objectives of this study were to: (i) estimate the broad-sense heritability of quality related characters (ii) determine the performance of the fifteen promising F_1 coffee hybrids under mid-lowland coffee environments based on green bean physical and organoleptic cup quality characteristics relative to that of the existing commercial cultivars in Jimma-Tepi environments of Southwestern Ethiopia. The information will be of importance to coffee breeders in future to follow arabica coffee breeding programs under mid-lowland environments.

MATERIALS AND METHODS

Field experiments

The study was conducted in two different locations in South-western region of Ethiopia, namely at Jimma Agricultural Research Center (JARC) and Tepi National Spice Research Center (TNSRC). The Jima site represents the midland and Tepi represent lowland humid coffee growing agro-ecologies.

Fifteen F_1 hybrids along two commercial check varieties were evaluated in this study. Five main group was formed based on germplasm composition and figures followed the same letter also indicate their half-sib relationships (Table 1). The experimental material was laid out in a Randomized Block Design (RBD) with three replications and established in July, 2008 at both locations with comprising of sixteen coffee trees of each genotype in each plot. Recommended cultural practices were followed and observations were made on the green bean physical and organoleptic cup quality parameters for two seasons (2014 and 2016). The coffee sample preparation procedures for quality analysis and data collection techniques for three green bean physical and eight organoleptic cup quality characteristics as described by Abrar *et al*. (2014) and elaborated by Fekadu et al. (2019a) were adopted.

Table 1. Description of the coffee hybrids and commercial check used for the study.

#	Code-name	Germplasm Composition*	Group	Cross categories†
1	HC-1	SW X Harrar	1a	CBD res x Harrar +HY
2	HC-2	SW X Harrar	1a	CBD res x Harrar +HY
3	HC-3	SW X Harrar	1a	CBD res x Harrar +HY
4	HC-4	SW X Harrar	1b	CBD res x Harrar +HY
5	HC-5	SWX Harrar	1ab	CBD res x Harrar +HY
6	HC-6	SW X SW	3ch	CBD res x CBD res +Q
7	HC-7	SW X Harrar	1b	CBD res x Harrar +HY
8	HC-8	SW X SW	3c	CBD res + Q xCBD res +Q
9	HC-9	SWX Sidama	2df	CBD res x Sidama +HY
10	HC-10	SWX Sidama	2d	CBD res x Sidama +HY
11	HC-11	SWx Sidama	2d	CBD res x Sidama +HY
12	HC-12	SWx Sidama	2e	CBD res x Sidama +HY
13	HC-13	SW X SW	3f	CBD res x high yielder
14	HC-14	SW X SW	3g	CBD res x high yielder
15	HC-15	SWx Sidamo	2eg	CBD res x Sidama +HY
Commercial check varieties				
16	Aba-Buna (HCCK)	SW X SW	3bh	CBD res x high yielder
17	F-59 (at Jimma)	SW X SW	4b	HY + wide adaptable
18	Geisha (at Tepi)	Introduced variety	5	Lowland adaptable + rust resistance

*SW=south-western Ethiopian coffee type, Harrar= Harrar coffee type, Sidamo= Sidamo coffee type
†CBD res = CBD resistant, Q = good quality; HY = high yielder, HC = Hybrid coffee, HCCK = hybrid check

Data analysis

Analysis of variance was performed with the MIXED procedure of SAS version 9.2 (SAS, 2008). For the purposes of estimating hybrid means and comparing check entries with experimental hybrids, checks were considered fixed effects. Environment and replications were considered random effects. To estimate genetic components of variance, the genotypes were considered random effects and variance components for genotypes and genotype x environment interaction were estimated with the SAS MIXED procedure. Heritability and its approximate standard error for each trait were estimated for each trait using mixed model of SAS across environments after Holland *et al*. (2003). Heritability on an entry-mean basis estimated as $h^2_{bs=}$ $(\sigma^2 g)/[\sigma^2 g + \sigma^2 ge/e + \sigma^2 e/re]$, where $\sigma^2 g$ is the estimate of genotypic variance, $\sigma^2 ge$ is the estimate of genotype x environment variance, $\sigma^2 e$ is the estimate of error variance, r is the number of replication per environment and e is the number of environments. Genotype clustering was done by an agglomerate hierarchy cluster analysis, i.e., the clustering according to the degree of similarity determined on the basis of Euclidean distances.

RESULTS AND DISCUSSION

Analysis of Variance and Mean performance

Mean performance differences among genotypes were significant ($P < 0.01$) for all quality characters across environments except aromatic intensity and body tastes indicating the opportunity to select the genotypes with desirable characters.

The hybrid and check means were not significantly different for most of the characters except the two bean physical (bean size and color) characters and organoleptic cup quality (astringency and bitterness) tastes (Table 2). The Hybrids HC1 followed by HC2 and HC7 combined above average value for both green bean physical characteristics and desirable cup quality attributes (data not shown) and are more preferable.

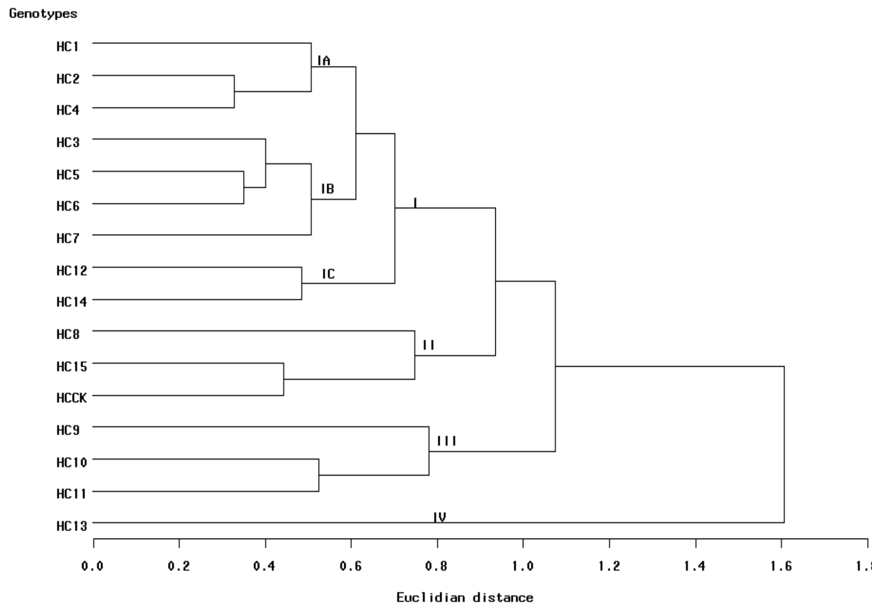

Figure 1. Dendogram of the coffee genotypes considering green bean physical and organoleptic quality characters evaluated at Jima and Tepi environments in Southwestern Ethiopia.

Cluster analysis

Cluster analysis was also grouped these hybrid genotypes and commercial check varieties based on their mean performance into four main clusters according to their germplasm composition (Figure 1), for instance the first main group formed by two out of the three subgroups which were mostly related in their pedigree joined together (Table 1) indicating that the important of gene in expression of these quality characters among studied coffee genotypes. Similar manner of grouping for quality attributes was reported by Fekadu *et al*. (2019b) among hybrid coffee genotypes evaluated under highland environment in Ethiopia.

Table 2. Means of all entries, hybrids, and checks of arabica coffee evaluated at two locations for two years.

Entry	SC(14)	SM	Color	AI	AQ	AC	AS	BI	BO	FL	OAQ
All genotypes	97.01	4.28	4.29	3.76	3.68	3.61	0.76	0.74	3.60	3.53	3.55
Hybrids	96.94	4.26	4.26	3.79	3.70	3.62	0.74	0.72	3.62	3.54	3.56
Checks	97.56	4.38	4.53	3.58	3.57	3.57	0.96	0.92	3.50	3.47	3.47
Range	93.24-98.53	3.86-4.63	4.00-4.64	3.44-4.21	3.33-4.06	3.40-3.92	0.48-1.04	0.46-1.00	3.45-3.85	3.33-3.75	3.33-3.92
Hybrids vs. Checks	*	NS	**	NS	NS	NS	*	*	NS	NS	NS
F-test	**	**	**	NS	**	**	**	**	NS	**	**
CV%	1.08	7.64	7.00	14.47	10.05	7.48	44.91	47.40	8.25	8.23	7.64

* = Significant at P= 0.01. *= Significant at P= 0.05. NS, Non-significant.

Table 3. Percentage contribution of genotype, genotype x environment interaction and error to the total components of their variances and estimates of broad sense heritability on an entry mean- basis (with standard error) for seventeen coffee genotypes.

Variance Components	SC(14)	SM	Color	AI	AQ	AC	AS	BI	BO	FL	OAQ
σ^2G	54.69	15.15	23.08	3.45	53.85	9.09	5.26	0.99	1.96	2.65	9.09
σ^2GE	10.94	1.52	7.69	0.00	10.26	27.27	31.58	39.60	9.80	17.70	27.27
σ^2e	34.38	83.33	69.23	96.55	35.90	63.64	63.16	59.41	88.24	79.65	63.64
h^2entry mean-basis	0.94± 0.04	0.72± 0.11	0.73± 0.11	0.33± 0.25	0.50± 0.20	0.37± 0.26	0.25± 0.30	0.05± 0.39	0.14± 0.35	0.19± 0.33	0.44± 0.23

SC14% = Percent of above screen 14 (5.60 mm), SM = Shape and make AI = Aromatic Intensity, AQ = Aromatic Quality, AC = Acidity, AS = Astringency, BI = Bitterness, BO = Body, FL = Flavor and OAQ = Overall Quality.

Variance components and Heritability of Characters

Estimates of variance components of environment and genotype x environment interaction indicated non-significant environment effects and significant (p < 0.05 or p < 0.01) interaction effects for most of quality characters, on other hand most of the significant G x E interaction accompanied by complex interaction effects with lack of important genotypic difference (tables not included). The lack of environmental differences (year and location combinations) explained by the same processing procedures was being followed every year at each location. Similar environmental effects on quality characters in Arabica coffee hybrids was reported by Fekadu *et al.* (2019b). The percentage contribution of genotype and genotype x environment interaction variances towards total phenotypic variance is presented in Table 3. The contribution of genotype was high for the two highly heritable green bean physical characters (bean size, 54.69 % and bean color, 23.08 %), and aromatic quality taste, 53.85% and moderate for Shape and make appearance, 15.15 % as compared to corresponding genotype x environment interaction variances which ranged from 1.52 % for shape and make appearance to 10.94 % for bean size and for the other quality attributes lower genotypic variances were exhibited.

The broad-sense heritability of each trait on an entry mean-basis was ranged from 0.05 ± 0.39 to 0.94 ± 0.04 (Table 3). The heritability value derived from a genotypes evaluated over number of environment would increase the accuracy of the estimates of each traits (Falconer and Mackay, 1996). Organoleptic cup quality attributes had lower heritability (0.05 ± 0.39 to 0.50 ± 0.20) than green bean physical characteristics (> 0.72 ± 0.11). The lower heritability estimates for most of the organoleptic cup quality attributes could be explained by the highest proportion of the error variance towards total phenotypic variance though most of the quality attributes exhibited low experimental coefficient of variation (CV <10.00 %) other than astringency and bitterness tastes (Table 2), suggesting the need of reducing residual variance which were dependent on the skill of the liquor technicians. Therefore one way to reduce variance is refining the liquor quality assessment technique apart from increasing the genetic diversity level of the test materials to increase the heritability estimates of these quality characters.

CONCLUSION

The coffee quality assessment result showed that three bean physical characters (bean size, bean color, and shape and make appearance) and organoleptic cup quality character (aromatic quality taste) exhibited moderately high and significant entry mean based broad sense heritability estimates and should respond to phenotypic selection. The G x E effect of these characters was also not severing demonstrating that selection can be performed at any of location or year for higher or lower score.

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