ACADEMIC INN INTERNATIONAL

ISSN NO : 2523-1189

Journal of AGRICULTURAL AND RURAL RESEARCH

open access

THE DIFFERENCE OF SOIL IN PRODUCTION SYSTEMS OF COFFEE AND THEIR CORRELATION WITH SENSORY QUALITY OF COFFEE ARABICA IN SOUTH WEST ETHIOPIA

Hinsene Garuma Duguma (MSc), Gezehagn Berecha(PhD) and Chemedaa Abdeta(MSc)

To cite the article: Hinsene Garuma Duguma (MSc), Gezehagn Berecha(PhD) and Chemedaa Abdeta(MSc) (2019), The difference of soil in production systems of coffee and their correlation with sensory quality of coffee Arabica in south west Ethiopia, *Journal of Agricultural and Rural Research*, 4(1): 12-30.

Link to this article:
http://aiipub.com/journals/jarr-191202-010090-2/

Article QR

Journal QR

THE DIFFERENCE OF SOIL IN PRODUCTION SYSTEMS OF COFFEE AND THEIR CORRELATION WITH SENSORY QUALITY OF COFFEE ARABICA IN SOUTH WEST ETHIOPIA

1. Hinsene Garuma Duguma (MSc)

Researcher at Ethiopian Biodiversity Institute

Email: hinsene.garuma@ebi.gov.et or hinse2012@gmail.com

2. Gezehagn Berecha(PHd)

Lecturer at Jimma University

3. Chemedaa Abdeta(MSc)

Email gberecha@yahoo.com

Lecturer at Jimma University

chemedaa@yahoo.com

ARTICLE INFO

Article Type: Research
Received: 29, Nov. 2019.
Accepted: 10, Jan. 2019.
Published: 12, Jan. 2019.

Keywords:
production system, soil property, sensory quality.

ABSTRACT

In Ethiopia coffee is produced in four production systems namely forest, semi-forest, garden and plantation coffee production systems which are assumed to vary in the intensity of management. But little is known whether these production systems and the associated management practices and soil chemical properties have effect on the different quality parameters of coffee. The study was carried out on four production systems which are located in three different sites and considered independent after the test of spatial out correlation using mental tests. The correlation between soil and cup quality was assessed using Pearson correlation analysis and principal component analysis (PCA) was done for those variables that showed greater than 0.5 coefficient of variation. Those component variables, together with, the other variables with higher Eigenvectors were used for linear regression analysis. Ca+Mg, K, Mg: K, Clay, Na, Av K, Sand are found as the major principal components. The influence of soil nutrients was observed mostly in the forest coffee production system. The influence of some micronutrient was observed in the rest of production system on the quality parameters such as flavor, color, and shape and make.

INTRODUCTION

Within Ethiopia, four major coffee production systems can be found (Woldetsadik and Kebede, 2000). These are forest coffee, which is sometimes referred to as "wild" coffee, semi-forest, garden coffee sometime referred to as smallholder coffee, which is produced in plots of varying sizes around dwellings and plantation coffee, which is established on previously cleared land (Labouisse *et al*., 2008). Forest coffee systems may comprise both forest coffee without or with little human management while in semi forest coffee the degrees of management are high.

The beverage quality of coffee is affected by many factors like the variety of the coffee, climate condition, processing type, soil quality (CRI, 2001; Pinkret, 2004; Bertrand *et al*., 2006). Soil consists of mineral particles, organic matter, the nature and amount of these components in the soil influences its characteristics. Soil nutrients may be inherited from the parent materials or added through the use of extreme inputs (organic and inorganic fertilizers, rain, etc.) (Pastor and Post, 1986; Castrigano et al., 2000).In the natural habitat of coffee, soils are acidic to slightly acidic with limited phosphorus availability (Senbeta, 2006; Kufa, 2006). Ideal soils for coffee should be deep, permeable, slightly acidic and porous (D'Souza and Jayarama, 2006).To achieve the optimum yield and quality of coffee, the nature and properties of the soil are of paramount importance. Nutrients are required for both vegetative growth of coffee trees and production of high-quality beans and hence nutrient imbalances can affect quality (Njorge, 1998). Deficiency in nutrients leads to lower quality coffees (Feria-Morals, 1990 cited in Feria-morales, 2002).

Many studies have identified soil nutrient availability to be an important factor controlling net primary product activity (Pastor & post, 1986) and biochemical contents of plants (Mazzafera,1999) and hence the quality of the product. Some works on the influence of soil properties on coffee quality have been reported, especially in coffee plantation (Njorge, 1998; Pinkert, 2004). Literature shows that volcanic soils often produce a potent acidity and a good body and such soil can lead to a more balanced cup (CRI, 2001; Bertrand *et al* 2006). Abebe *et al.* (2008) demonstrated that soil properties considerably influence the cup quality of wild Arabica coffee in its natural habitat. This finding adds evidence to the importance of soil factors for the coffee quality and verified the hypothesis that the distinct coffee varies depending on the soil characteristics of the farms where the coffee is grown. In Ethiopian conditions, there are four coffee production systems unlike the rest of the world but little is known whether these production systems and the associated management practices and soil chemical properties have effect on the different quality parameters of coffee.

MATERIALS AND METHODS

Description of study sites

The study area consisted of four sites in jimma zone within the radious of 95km west-northwest of Jimma town. Jimma town is situated in the Oromiya region in the highlands of Southwest Ethiopia. The study area is situated between 1800 and 2100masl. There is a humid, sub-tropical climate, with a yearly rainfall of about 1500mm or more, a short dry season and relatively high cloud cover. A peak in rainfall occurs between July and September (long rainy season) and a smaller peak occurs between March and April (short rainy season). Differences in temperature throughout the year are small with a mean minimum and maximum annual temperature of 11.9 and 26.4°C (Schmitt, 2006). The study sites were selected from the respective production systems.

Study sites

Garuke: Garuke is located 10km northwest of Jimma town, with the elevation of 1786 m.a.s.l. This was selected for the collection of cherries of Garden and semi-forest production system.The landscape is heavily fragmented and there is a high degree of human disturbance. In this area, forest fragments of different size and management intensity lie within a matrix of grazing land.

Fetche: Fetche is located 15km from Jimma town with the elevation of 2030 m.a.s.l. The remnant forest here is less fragmented resulting in one large cultivated "fragment" of approximately 100 ha surrounded by agricultural landscape. Due to the proximity of Jimma city, this forest is of high interest for the production of coffee beans. Since the forest fragment has many different owners, the management intensity varies from very intensive to intermediate. Besides disturbance due to coffee productivity, the forest is also used for other functions such as firewood collection and charcoal production. The Fetche forest is considered to be a semi-forest coffee production system (SFC). The semi forest coffee sample was collected from this area.

Limmu: this site was selected for the collection of coffee bean representing plantation coffee production system, from the variety 74165 which is one of the coffee varieties found in the Limmu kosa coffee plantation and it is known in having combated growth habit, high yielding and CBD resistant The area receives annual rainfall in the range of 1,200-2,800 mm with elevation 1795 m.a.s.l.

Gera: This site is situated 95km west of Jimma **known as** Belete-Gera National Forest Priority Area. The area consists of continuous forest with less disturbance and management than the previous sites .with elevation of 2224 m.a.s.l. This site is selected to collect the sample for the forest coffee beans.

Experiment design

The experiment was laid out in 4×2 factorial in a randomized complete block design (RCBD) with factorial combination of two factors, production system and bean type with a treatment combination of eight.

Factor A-production system with four levels (forest, semi-forest, garden, and plantation)

Factor B-bean type with two levels (normal and peaberry +normal bean)

Soil sampling and laboratory analysis

Composite soil samples were randomly collected from all experimental areas from a depth of (0 –30cm) using core sampler auger, since most of the root system of the coffee tree develops in the upper soil layer, the properties of the topsoil are more crucial to the coffee plants than those of the deeper subsoil (D'Souza and Jayarama, 2006; Kufa 2006). The analyses were accomplished by following the standard procedures at the *JIJE* Analytical Testing Service Laboratory, Addis Ababa, Ethiopia. The distribution of soil particles (sand, silt, clay) was determined to know the textural class of the soil. The chemical properties analyzed include total N, available phosphorus, Ca, Mg, Mn, Fe, Zn, K, CEC, EC, OC, and TN.

Statistical analysis

For statistical comparisons among production systems, in terms of physical and organoleptic quality of coffee beans, we first checked for the absence of spatial autocorrelation among the selected plots in the different systems using a Mantel test. We used a geographic distance matrix, calculated from the coordinates of the center of each plot, and a Sorensen similarity matrix, calculated from Physico-chemical data of the analyzed soils. None of the Mantel tests showed a significant isolation by distance relation ($P > 0.01$), and all samples from the plots where therefore considered to be independent observations. The variables defect, shape and make, color, odor, cup cleanness, acidity, body, flavor, and overall quality fulfilled normality assumptions and we consequently used a 4x2 factorial design to compare production systems with respect to different measures of test quality, followed by pairwise comparisons among production systems, treatments, and their interaction effect, using an LSD test. These analyses were performed in SAS V.9.2

In addition, we also carried out a Pearson covariance analysis to see which variables co-vary. We then conducted principal component analysis (PCA) using those variables that showed greater than 0.3 coefficient of variation. This was to group factors (variables) into components and to evaluate the relative contribution of the role of variances in components. The different components were then treated as additional variables. Those component variables, together with, the other variables with higher

Eigenvectors were used for linear regression analysis. The PCA analysis was employed to the site-specific factors (soil) and bean characteristics. Pearson covariance analysis, PCA, linear regression, and ANOVA were carried out by SAS v.9.2 (SAS Inc, 2003).

RESULT AND DISCUSSION

Soil properties in different production system and their effect on the occurrence of coffee bean abnormality and sensory quality of coffee

The soil analysis result showed that the highest soil pH (6) was found at the garden coffee production system whereas the lowest pH (5.17) was recorded under semi- forest coffee production system. Generally, under any of the production systems, the soil is acidic. Coffee can be cultivated on a wide variety of soil types, provided these are at least 2 meters deep, free-draining loams with a good water retention capacity and a pH of 5-6, fertile and contain no less than 2% organic matter (Raghunbanshi, 1992). The soil pH recorded is ideal for the production of a high-quality coffee which is between (5-6) (Senbeta, 2006; Kufa, 2006). Soil samples collected from plantation coffee had almost two-fold phosphorous (6.732) than the three production systems. This difference might have been observed due to the fact that fertilizer (DAP) is applied to plantation coffee.

Table 1. Average soil Physico-chemical characteristics under the four coffee production systems of SW Ethiopia.

Parameter	Unit	Forest	Semi-forest	Garden	Plantation
Clay	% DM	42	53	47.33	43.83
Silt	% DM	38	29.2	35.5	32.83
Sand	% DM	20.12	17.83	17.2	23.33
PH	H2O1:25	5.58	5.23	6	5.27
EC	µS	0.19	0.292	0.268	0.153
AV.B	ppm	0.57	0.668	0.62	0.522
AV.P	ppm	2.77	3.58	5.648	6.732
CEC	Meq/100g	29.92	35.1	29	27.82
Ca	Meq/100g	10.03	7.12	3.3783	7.73
Mg	Meq/100g	3.74	2.93	3.38	3.022
Na	Meq/100g	0.112	0.105	0.14	0.103
K	Meq/100g	1.11	0.64	2.73	0.935
OC	%DM	4.12	4.45	3.085	4.03
TN	%DM	0.45	0.48	0.36	0.405
Mn	ppm	100.13	84.31	132.97	93.0883
Fe	ppm	82.1	66.132	45.4	69.48
Cu	ppm	1.14	1.9	2.06	1.21
Zn	ppm	4.73	3.658	7.46	5.83

EC = Electrical conductivity, Av.B=Available boron, Av.P = available phosphorous, CEC=Cation exchange capacity, Ca = Calcium, Mg =Magnesium, Na = Sodium, K = Potassium, OC = Organic carbon, TN = Total nitrogen, Mn=Manganese, Fe=Iron, Cu=cupper, Zn= Zinc,

The concentrations of nutrients in the soil are associated with its biological and geochemical cycles (slagle et al., 2004) and they are also influenced by anthropogenic factor such as deforestation .soil consists of both mineral particles and organic matter, and the nature and amount of this component in the soil influences its characteristics. Soil nutrients may be inherited from the parent materials or added through the use of external inputs (organic and inorganic fertilizers, rains, etc.. (Pastor and Post 1986; Castrignano et al., 2000).

Table 2.Pearson correlation for soil variables and overall coffee quality in different production systems.

Soil parameters	Over all cup quality			
	Forest	Semi-forest	Garden	Plantation
Sand	0.72	-0.04	0.07	-0.22
Silt	0.42	0.36	0.27	-0.39
Clay	-0.79	-0.13	-0.21	0.41
PH	0.30	-0.71	0.18	-0.26
Av.B	**0.61***	**-0.96****	-0.03	0.67
Av.K	0.57	-0.19	-0.41	-0.04
EC	0.47	0.39	-0.03	-0.01
Av.P	0.50	0.31	0.51	0.39
CEC	0.28	0.02	0.30	0.23
Ca	0.24	0.49	0.20	-0.01
K	0.59	-0.26	0.01	-0.02
Mg	-0.06	0.55	0.30	0.14
Na	-0.54	0.23	0.22	0.34
OC	**0.85***	0.24	-0.02	0.02
TN	0.75	0.27	0.12	0.21
Mn	-0.02	0.46	0.09	-0.28
Fe	**0.90****	0.53	-0.09	-0.13
Cu	0.33	0.36	0.11	0.07
Zn	0.28	0.50	-0.02	-0.06

**,*=correlation significant at 1% and 5% level of significance; n=number of observation

EC = Electrical conductivity, Av.B=Available boron, Av.P = available phosphorous, CEC=Cation exchange capacity, Ca = Calcium, Mg =Magnesium, Na = Sodium, K = Potassium, OC = Organic carbon, TN = Total nitrogen, Mn=Manganese, Fe=Iron, Cu=cupper, Zn= Zinc,

The correlation between soil parameters and overall coffee cup quality's collected from different production systems which are tested with the presence and absence of peaberry is indicated in table 4. AV.B was positively and significantly correlated with forest coffee tested with and without peaberry at the ($p=0.022$) but negatively correlated with semi-forest coffees both with and without peaberry at the p-value of ($p=0.021$). B is an important nutrient in plants, particularly in sugar transformation in higher plants and its deficiency can cause reductions in crop yields, impair crop quality, or have both effects (Gupta, 2006). It is most associated with organic matter (OM) and clay content of soils. It is important in plants for sugar formation. The absorption by plants mostly depends on the amount of B in soil solutions. Therefore, higher amount in soil solution is the major contribution to B absorption by plants. They may absorb higher level of B than required only because of the higher amount of B in soil solution (Gupta, 2006).

Under semi-forest soils, the B content is the highest (Table 3), and it is more probable that the highest amount is absorbed by coffee plants irrespective of the optimum need of the coffee plants. A high level of B in soils is more or less to mean high level of B in plants. Higher-level causes toxicity in plants. This might have been reflected in overall cup quality of semi forest coffees.

OC and Fe were positively and significantly correlated with the overall quality of forest coffee production system tested with the peaberry (p =0.0303; p=0.0121) respectively. The availability of Fe is affected by the PH of the soil, as the PH gets lower the availability of Fe iron increases and it is also affected the availability of some nutrients that can oxides it such as sulfur (Römheld and Miroslav, 2007). Soil organic carbon influences a wide range of physical, chemical and biological properties and is considered as the most important indicator of soil quality (Larson and Pierce 1994).

Table 3.Pearson correlation coefficients between ratios of different cations and cup quality of Arabica coffee from different production systems assessed in southwest Ethiopia.

	Cup quality				
Production system	Traits	Ca:K	Mg:K	Mg:Ca	Ca+Mg:K
	Cpc	0.27	0.62	0.63	0.50
	Acidity	0.60	-0.61	-0.42	-0.40
Forest	Flavor	0.66	**-0.27***	0.09	0.54
	Body	-0.28	**0.88****	**-0.86****	-0.18
	Overall	**-0.80***	-0.76	-0.48	**-0.89****
	Cpc	-0.16	-0.15	-0.19	-0.16
	Acidity	0.55	0.56	0.72	0.56
Semi forest	Flavor	0.58	0.58	0.67	0.57
	Body	0.70	0.73	0.59	0.71
	Overall	0.58	0.58	0.78	0.58
	Cpc	-0.44	-0.59	-0.21	-0.49
	Acidity	0.50	0.50	-0.17	0.52
Garden	Flavor	0.48	-0.10	0.01	0.49
	Body	-0.17	-0.01	-0.34	0.76
	Overall	0.52	0.47	-0.23	0.56
	Cpc	0.12	0.15	0.20	0.14
	Acidity	-0.19	-0.29	-0.29	-0.24
Plantation	Flavor	-0.05	0.16	0.58	0.04
	Body	0.01	0.23	0.63	0.11
	Overall	-0.25	-0.17	0.10	0.22

*=significant at 1%, **=Significant at 5% Cpc= cup clean ness, Ca=calcium, K=Potassium, Mg=magnesium

As clearly indicated in the table (5) not only the nutrients availability in the soil the balance between the monovalent and bivalent also affect the cup quality of coffee. Flavor is negatively and significantly correlated with all cation ratios of for Mg: K at the p-value of (p=0.0213). The body was positively and significantly correlated with Mg:K ratio (p =0.0034), negatively correlated with Ca+Mg:k but significantly with Mg:Ca ratio (p=0.0016). Over all cup quality is negatively correlated with all cation ratios but it was significant for Ca: k and Ca+mg:K ratio under the forest coffee production system which is in line with(Abebe et al.,2008).

The ratio of Mg: K is the most important variable for the coffee quality variables. Potassium augments the body of the coffee (CRI, 2001) and the present study also confirmed this fact, especially in the forest coffee production system.

Generally, there was a difference in the coffees analyzed with and without peaberry, which indicates the effect of the presence and absence of peaberry on their correlation with the ratio of different cations and soil nutrients. In all production systems coffees analyzed with the presence of peaberry and without the presence of peaberry had a significant difference in the level of significance and in the way of correlation. For instance in the coffee bean analyzed with peaberry, cup cleanness is negatively correlated with all cations ratios in the semi-forest and garden coffee production system even though it was not significant whereas in the coffee without peaberry it was negatively correlated with Ca: k ratio in all production system except in the semi-forest coffee in which it was negatively correlated with all cation ratios.

Flavor in the coffee analyzed with peaberry from the forest coffee production system was negatively and significantly correlated with Mg: K ratio but not significant in the coffee without peaberry. The body in the forest coffee production system analyzed with the coffee peaberry was positively and significantly correlated but negative and non-significant in the coffee bean analyzed without peaberry. The body was also negatively and significantly correlated with Mg: Ca ratio which was positive but not significantly with coffee bean analyzed without peaberry. Overall is also negatively and significantly correlated with Ca:K and Ca+Mg:K in the coffee bean analyzed with the peaberry whereas it was not significant in the coffee bean analyzed without peaberry.

In the semi-forest coffee production system, flavor was positively and significantly correlated with all cation ratios but not significant in the coffee bean analyzed with the peaberry in the same production system. Whereas overall in the plantation coffee production system which was analyzed without the peaberry was correlated negatively and significantly but not significant in the coffee with peaberry in the same production system. Since there are some nutrients which are affected by the amount of another nutrient which is antagonistic or compatible for their presence, the ratio between the cations is very important parameters for coffee because K is antagonistic to Mg and Ca (Snoeck and Lambot, 2004)

Table 4.The correlation between soil texture and TN, OC, pH with bean type (with and without peaberry) in different production system

P.system	Traits	sand	silt	clay	TN	OC	pH
Forest	Pea berry	0.16	0.05	0.16	-0.49	-0.39	-0.26
	Normal bean	-0.15	-0.05	-0.16	0.49	0.39	0.25
Semi-forest	Pea berry	-0.71	0.08	-0.56	0.26	0.15	-0.06
	Normal bean	0.70	**-0.09**	0.57	-0.27	-0.17	0.04
Garden	Pea berry	-0.46	**0.81***	0.77	-0.62	0.25	-0.49
	Normal bean	0.46	-0.82	-0.76	0.58	-0.28	0.49
plantation	Pea berry	0.26	0.36	-0.41	0.05	-0.46	0.21
	Normal bean	-0.26	-0.36	0.41	-0.05	0.46	-0.21

TN=total nitrogen, OC=organic carbon, **=significant at 1%,*=significant at 5%

As indicated in (table 6) the correlation between the four production systems and the bean type was not statistically significant in many of above mentioned soil parameters. In the garden coffee production system silt was positively and significantly correlated with coffee bean with pea berry ($p=0.0464$) but it was negatively correlated with coffee bean without pea berry but not significant.

Sand, TN, and PH were negatively correlated with coffee bean with pea berry whereas silt, Clay and organic Carbon were negatively correlated with coffee bean without pea berry. Under the semi-forest and plantation coffee production system there was no statistically significant correlation.The correlation of bean type rather significant with the factors like pollination time and genetics of the coffee than that of the soil because some literature shows that way of pollination contributes to the formation of peaberry (Ricketts et al .,2004).

In the forest coffee production system, cup cleanness was negatively and significantly correlated with sand ($p=0.006$) which means coffee grown in the sandy soil is lower in the cup cleanness or cup cleanness is negatively affected by the amount of sand in the soil. Acidity was positively and significantly correlated with organic carbon ($p=0.025$). Under this production system flavor is also positively and significantly correlated with TN, OC ($p=0.002$ and $p=0.011$) respectively similarly EC is also correlated positively and significantly ($p= 0.004$) ,Color is negatively correlated with sand at the p-values of ($p=0.0065$) similarly odor is negatively and significantly correlated with TN, OC, Ca and K, ($P=0.0008$; $p= 0.0292$; $p=0.0292$ and $P= 0.0084$) respectively . Similarly CEC, Fe, Cu and EC were also correlated positively and significantly ($p=0.0495$, $p= 0.0410$,$p= 0.0084$ and $p=0.0046$) respectively. The overall cup quality was positively and significantly correlated with OC ($p= 0.0131$) and Fe ($p=0.0121$) in the forest coffee production system respectively, this may be due to higher decomposition in the forest coffee which can contribute for the availability of organic carbon.

In the garden coffee production system cup cleanness was positively and significantly correlated with PH, Mg, and K ($P=0.0505$; $p=0.0189$ and $p=0.0293$), respectively it was also similar for Na and Mn ($p= 0.0505$ and $p=0.0359$). Color was negatively and significantly correlated with sand ($p=0.0174$) the same is true Fe ($p=0.0475$) odor was negatively and significantly correlated with PH and Mg ($p=0.0373$ and $p=0.0212$), respectively similar to Na and Mn ($p=0.0004$ and $p= 0.0455$) respectively. The flavor was also positively and significantly correlated with Mn and Zn ($p= 0.0050$ and $p=0.0037$) respectively whereas shape and make was negatively and significantly correlated with Mn ($p= 0.0421$).Color was positively and significantly correlated with Fe ($p=0.0513$) but overall was negatively and significantly correlated Av.B ($p=0.0209$).

In the semi-forest production system, there was a positive and significant correlation between the overall and OC ($p=0.0319$), it was also negatively and significantly correlated with Mg ($p=0.0091$) .Flavor was also positively and significantly correlated with Mn and Zn at the p-values of ($p= 0.0050$) and ($p=0.0037$).whereas shape and make was negatively and significantly correlated with Mn at the p-values of ($p= 0.0421$) and color was positively and significantly correlated with Fe at the p-values of ($p=0.0513$) but overall was negatively and significantly correlated Av.B at the p-values of ($p=0.0209$) .

In plantation coffee production system there was no strong correlation between most of cup quality parameters and the soil nutrients except that silt was negatively and significantly correlated with cup cleanness ($p=0.0343$) it was positively and significantly correlated with Av.B ($p=0.0321$). Color was also negatively and significantly correlated with Mg ($p=0.0509$) .The defect was also positively and significantly correlated with EC ($p=0.0289$). Whereas shape and make were negatively and significantly correlated with CEC ($p=0.0094$).

Principal Component Analysis

Table 5.principal component analysis

Variable	PC1	PC2	PC3	PC4	PC5
Fe	-0.119	0.519	-0.200	0.195	-0.266
Na	0.272	-0.101	0.035	0.652	0.135
CLAY	0.309	-0.335	0.406	0.047	-0.121
AV,P	-0.229	-0.297	0.186	0.396	0.494
Ca+Mg:K	0.495	0.048	-0.212	-0.079	0.155
AV.B	-0.095	0.136	0.609	-0.429	0.183
Mg:K	0.479	0.016	-0.230	-0.050	0.036
AV.K	-0.384	-0.036	0.066	0.327	-0.415
OC	0.214	0.457	0.294	0.147	0.047
TN	0.125	0.479	0.348	0.237	0.067
SAND	-0.267	0.244	-0.281	-0.033	0.644
Eigen value	3.420	2.620	1.360	1.067	0.998
Proportion of variance explained	31.16	23.87	12.37	9.7	9.08
Cumulative percentage of variance	31.16	55.03	67.4	77.1	86.18

.

The first and second dimensions together explain 55.03% of the total variation, respectively. The first component is explained more by Ca+Mg: K, Mg: K, and Clay. The second component was explained largely by OC, TN and Sand (Table 4). The main two new variables, PC1 and PC2, can linearly be calculated as:

PC1 = 0.495Ca+Mg: K + 0.479 Mg: K+ 0.309 Clay+ 0.272Na - 0.384Av K – 0.267 SAND

PC2 = 0.519Fe-0.101Na-0.335Clay-0.297Av.P+0.048(Ca+Mg:K)+ 0.136Av.B+ 0.016Mg:K-0.036Av.K+0.456OC+0.479TN+0.244SAND

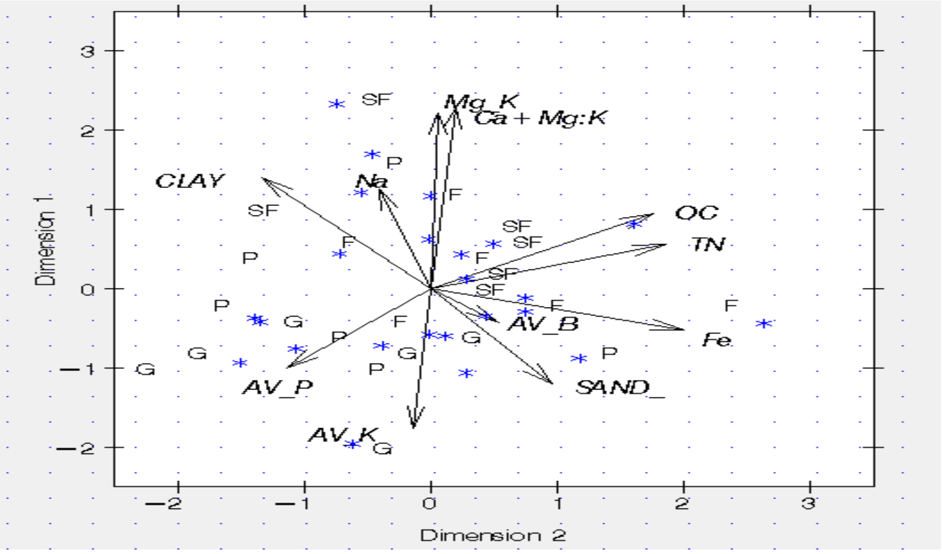

Figure 1.contribution of different soil nutrients and texture in different production system as principal component.

Forest and semi-forest coffee production systems contribute higher OC, TN, Fe and sand content in component one (Fig.1). The litterfall contribution from the multistory forest and semi forest system might have contributed to the more TN and OC. On the other hand, Available P vector is pointed to the region of plantation and garden coffee (Fig.1). This may be due to the application of DAP fertilizer to the system so as to improve the production since plantation coffee is more focused on increment profit.

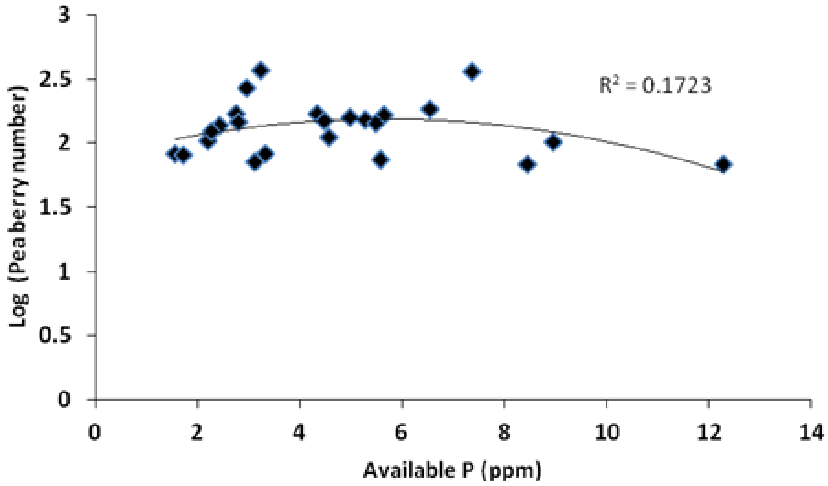

Figure 2.The regression graph between pea berry and available phosphorus in plantation coffee production system.

Phosphorus plays a great role in plant fruit production and seed setting. In this finding, phosphorus availability didn't show any relevance in pea berry formation. Although the highest availability of Phosphorus was found under plantation coffee system, maybe due to application of DAP, this finding revealed that the highest pea berry recorded was not supported with the available P in soils (Sanchez, 2006).

Overall cup quality didn't show a significance difference among the production systems. Neither of the site factors affected the cup quality. The maximum care is taken during harvesting and postharvest handling might have contributed to the existence of similar quality among the bean types.

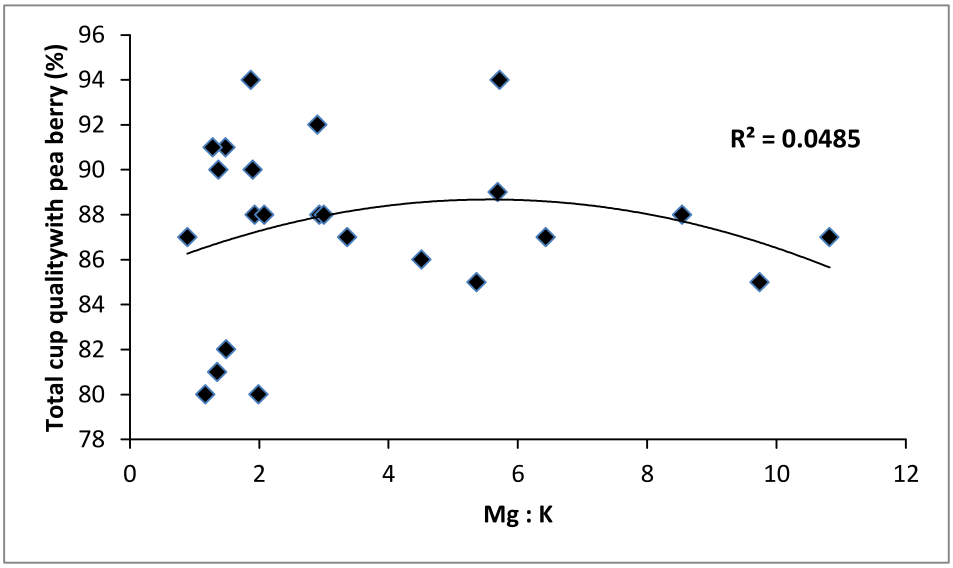

Figure 3. The regression graph between total cup quality with pea berry and mg:k.

As indicated in the fig1 Mg:k ratio is mostly found in the forest coffee production system and contributed more for the principal component one . Both magnesium and potassium are macronutrients that are needed at high amounts by the plants. They play critical role in different parts of plant and their deficiency can be observed easily. Because plant needs them at higher amount, starting from growth, the ratio of both elements play significantly in total quality of coffee when optimally available, but excessive uptake of this ratio may also lower the total quality which is in line with the work of Abebe *et al.*, (2008). In this study the highest amount of Mg was found in the forest coffee production system and it was negatively correlated with all of coffee cup quality parameters except with body where the correlation was positive. It was positively and significantly correlated in the semi-forest coffee production where it was found with the minimum amount from the rest of production system .Increased potassium fertilization or availability, relative to magnesium, will inhibit magnesium absorption and accumulation and vice versa. The degree of this antagonistic effect varies with potassium and magnesium fertilization rates, as well as the ratio of the two nutrients to one another (Merhaut, 2007).
The ratio of Ca+Mg:K was mostly found in the forest coffee production system and contributed mostly in principal component one, but it doesn't explain total cup quality more(fig1).Ca+Mg: K was correlated negatively with the overall coffee quality parameters where the highest amount of Ca and Mg were found indicating that highest amount of this cation ratio leads to the toxicity or it affects the quality of coffee. Calcium is a divalent cation that plays important roles in cell wall structure, cell membrane relations, and signal transduction in the plant (Merhaut, 2007). It is also available for the plants at the lower PH. So acidic soils often contribute additional symptoms to the calcium deficiency. Ca+Mg:K is all macronutrient hence it is needed by high amount and it was important at the relative proportion for the total cup quality tested with pea berry. The concentration of calcium, relative to magnesium, is inhibitory to the absorption of magnesium and vice versa, since the Ca, Mg and K are antagonistic for each other the amount or the concentration of one affect the availability of the other, they are important at relative amount for the plant uptake (Merhaut, 2007).

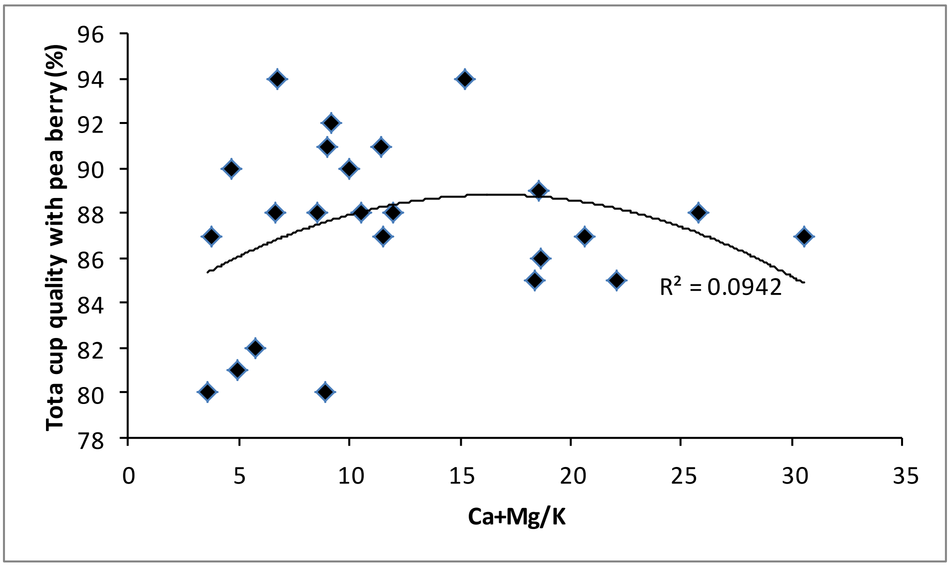

Figure 4. The regression graph between the total cup quality and Ca+Mg:K.

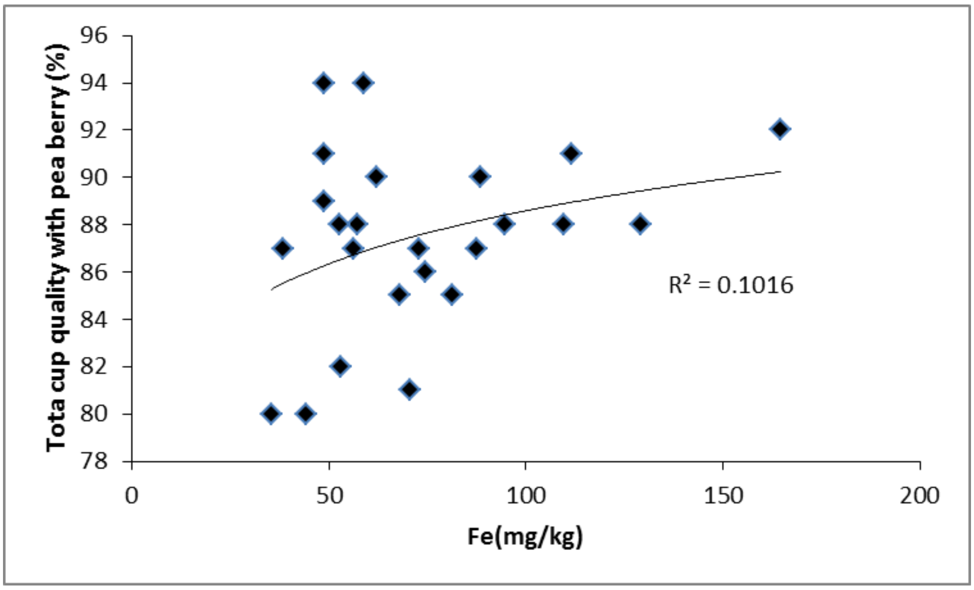

Figure 5. The regression graph between total cup quality and Fe content of the soil

As indicated in fig1 Fe is also indicated in the forest coffee production system and it contributed much in the principal component two. According to fig (5) the highest total quality was found in relatively higher amount of Fe, even though the amount of Fe found in all of the production systems is in the range of deficiency the highest total quality is found in the higher Fe relatively, higher amount Fe was found in the forest coffee production system where it was positively and significantly correlated with overall. Fe is microelement which is a divalent or trivalent heavy metal, depending on the reduction-oxidation conditions in the soil. Iron is found in the soil as various oxides and also in association with various organic molecules. Iron can be limiting in the natural environment due to the unavailability to the plant of the oxide forms of the element. Plants overcome the limitations of iron absorption by either lowering the pH of the soil or thus increasing the iron solubility, or by the production of specialized iron-scavenging compounds called siderophores. As indicated in fig 7 total cup quality increases as the amount of Fe increases and it is positively related to the total cup quality (Römheld and Nikolic, 2007).

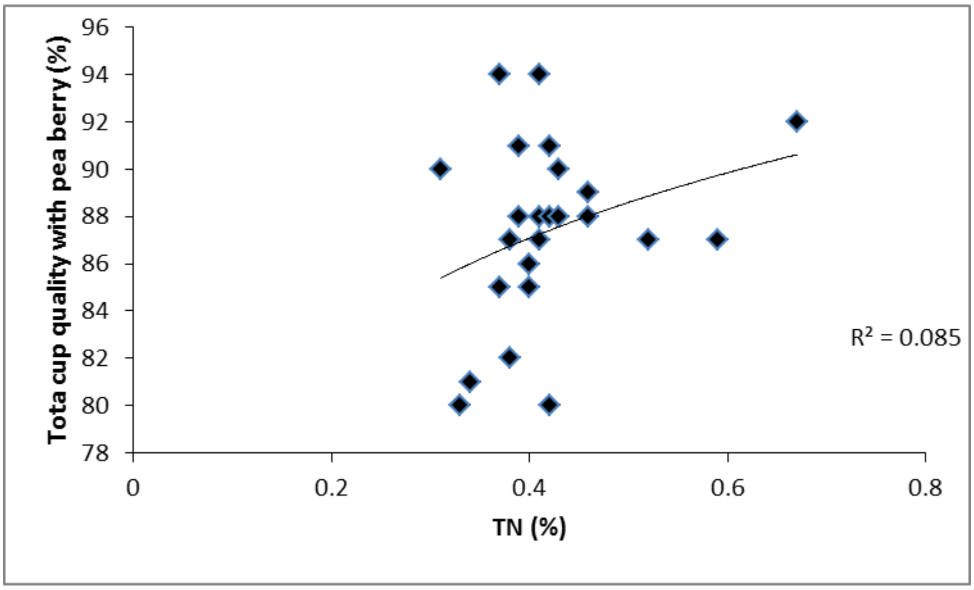

Figure 6. The regression graph between total cup quality and Total Nitrogen

As indicated in (fig.1) total Nitrogen is found mostly in the semi-forest coffee and it contributes more in principal component two. Nitrogen is the most frequently limiting nutrient. Within the plant, nitrogen serves in the same ways it does in other organisms a component of amino acids and nucleic acids. A shortage of nitrogen restricts the growth of all plant organs, roots, stems, leaves, flowers, and fruits (including seeds). Sometimes under conditions of sufficiency of nitrogen, leaves, especially the lower ones, will provide nitrogen to fruits and seeds, and symptoms of deficiency may develop on the leaves. The concentrations of nitrogen in leaves, stem, and roots changes during the growing season. In the early stages of growth, concentrations will be high throughout the plant. The amount of nitrogen in the plant can also influence the fruit-bearing as well as the total quality of coffee tested with the presence of pea berry (Barker and Bryson, 2007).

SUMMERY AND CONCLUSION

The present study demonstrates soil properties of different production systems and there influence on different cup and raw coffee quality parameters. The influence of soil nutrients was observed mostly in the forest coffee production system. The influence of some micronutrients was observed in the rest of production system on the quality parameters such as flavor, color, and shape and make. The highest quality coffee was obtained from all production systems this might be due to harvesting and postharvest handling including the processing method employed similarly to all cherries collected from the four production systems.

According to the principal component analysis Ca+Mg: K, Mg: K,Clay,Na ,Av K ,SAND are found as the major principal components. Forest and semi-forest coffee production systems contribute higher OC, TN, Fe and sand content in component one. On the other hand, Available P vector is pointed to the region of plantation and garden coffee and the P in the plantation coffee was twofold of the P in the other production system.

REFERENCE

Abebe T., 2005 Diversity in home garden agroforestry systems of Southern Ethiopia. Doctoral Thesis, Wageningen University, Netherland. Pp 153.

Abebe Yadessa, Burkhardt,J.,Denich, M.,Gole,T.W.,Bekele,E.,Goldbach,H.2008.Influence of soil properties on cup quality of wild Arabica coffee in coffee forest ecosystem of SW Ethiopia .paper presented at 22nd International conference on coffee science (ASIC), held between 14-19 September 2008,campinas,Sp,Brazil.

Aerts R., Hundera K., Berecha G., Gijbels P., Baeten M., Van Mechelen M., Hermy M., Muys B., Honnay O. 2011.Semi-forest coffee cultivation and the conservation of Ethiopian Afromontane rainforest fragments. Forest Ecology and Management **261**: 1034-1041.

Alemayehu Teshome, Esayas Kebede and Kassu Kebede, 2008. Coffee development and marketing improvement plan in Ethiopia.pp375-381.

Aluka, P.,P. Musoli, P. Cubry, F. Davrieux, F.Ribeyre, B. Guyot, F. De Bellis, F. Pinard, D. Kyetere, J. Ogwang, M. Dufour, and T. Leroy. 2006. Genetic diversity, NIRS, fruit biochemical analyses and cup testing in cultivated Coffea Canephora Pierre from different districts in Uganda. In: 21th International Coffee Science Conference, ASIC, Montpellier (CD-ROM).

Anon, 2011. Coffee Processing. Coffee Research Organization, p1- 10, USA.

Anthony, F. Bertrand, B.,Quiros, O., Lashermes, P., Berthaud, J. and Charrier, A. 2001.Genetic diversity of wild coffee (Coffea arabica L.) using molecular markers.Euphytica **118**: 53-65.

Anzueto, F.,B.Bertrand, J.L. Sarah, A.B. Eskes and B. Decazy, 2001. Resistance to Meloidogyne incognita in Ethiopian Coffea Arabica accessions. Euphytica 118: 1-8.of slope exposure, altitude and yield on coffee quality in two altitude terroirs of Costa Rica, Orosi and Santa Maria de Dota. J. Sci. Food Agric. **85**: 1869–1876.

Avelino, J., B. Barbora, , F. Davrieux, , and B. Guyot, 2007. Shade effects on sensory and chemical characteristics of coffee from very high altitude plantation in Costa Rica. In: second international symposium on multi-strata agroforestry systems with perennial crop: making ecosystem service count for farmers, consumers and the environment, September 17-21, 2007 Turriabla, Costa Rica.

Awoke T.C., 1997. The culture of coffee in Ethiopia. Agroforestry Today **9**: 19-21

Barel, M and M. Jacquet, 1994. La qualité du café: ses causes, son appreciation, son amelioration. Coffee quality: its causes, appreciation and improvement. Plant Rech. Develop. **1**: 5-13.

Barker,V.A and Bryson,M.J. Nitrogen.pp.21-43. In: Barker, A.V. and D.J. Pilbeam (eds). Hand Book of Plant Nutrition, Taylor and Francis, New York U.S.A.

Behailu W., S., Abrar, S., Nigusie, and M., Solomon E.2008. A review of coffee Processing and Quality Research in Ethiopia. Coffee Diversity and Knowledge. Ethiopian Institute of Agricultural Research .pp 307-316.

Bellachew, B., B. Atero and F. Tefera, 2000. Breeding for resistance to coffee berry disease in arabica coffee: progress since 1973. In the proceedings of the workshop on control of coffee berry disease in Ethiopia, pp. 85-98. Ethiopian Agricultural Research Organization (EARO), Addis Ababa.

Benoit, B., V. Philippe, A. Edgardo, E. Herve, D. Fabrice and C. Pierre, 2006. Comparison of bean biochemical composition and beverage quality of Arabica hybrids involving Sudanese-Ethiopian origins with traditional varieties at various elevations in Central America.

Bertrand B., H., Etienne, B., Guyot, P., Vaast, 2004. Production and Canopy Region Influence Bean Characteristics and Beverage Quality of Arabica coffee. International Scientific Conference on Coffee, Bangalore, India.

Camargo, M.B.P. and B.P. Marcelo, 2009. The Impact of Climatic Variability in Coffee Crop. Scientific Researcher (Agro meteorology, MS/PhD). Instituto Agronômico (IAC/APTA), Campinas, SP, Brazil.

Carr, M.K.V., 2001. The water relations and irrigation requirements of coffee. Exp. Agric. **37**:1–36.

Clark, R.J. 1985. Green coffee processing. In: M.N. Clifford and K.C. Willson (Eds.). Coffee botany, biochemistry and production of beans and beverage, Croom Helm, London, 49-96.

Clarke R.J and K.C. and R.Macrae.1988. Coffee: Agronomy.Vol.4.

Coffee Quality Inspection and Grading Center.2008. Working Draft Formats. Addis Ababa, Ethiopia.

CRI(Coffee Research Institute).2001.coffee quality and environmental conditions. Coffee Researchnewsletter,1(3):4-6Accessedonlinefrom http://www.coffeeresearch.org/newsletters/newletter%203.pdf.

D'Souza, M.V and Jayarama.2006.Soil analysis to maintain the productivity in coffee plantations. March 2006 issue of Indian coffee: the monthly Magazine of coffee Board.

Davis AP, Govaerts R, Bridson DM, Stoffeelen P. 2006. An annotated taxonomic conspectus of the genus Coffea (Rubiaceae). *Botanical Journal of the Linnean Society* ***152****: 465–512.*

Davis AP, Rakotonasolo F, De Block P. 2010. Coffea toshii sp. nov. (Rubiaceae) from Madagascar. *Nordic Journal of Botany **28**:1341–1336.*

Davis AP, Tosh J, Ruch N, Fay MF. 2011. Growing coffee: Psilanthus (Rubiaceae) subsumed on the basis of molecular and morphological data; implications for the size, morphology, distribution and evolutionary history of Coffea. *Botanical Journal of the Linnean Society **167**:357–377.*

Decazy, F., J. Avelino, B. Guyot, J.J. Perriot, C. Pineda and C. Cilas, 2003. Quality of different Honduran coffees in relation to several environments. *Journal of Food Sciense. **68**: 2356–2361*

Dessie Nure, 2008. Physical Quality Standards and Grading System of Ethiopian Coffee in Demand Supply Chain In: xx Coffee Diversity and Knowledge. EIAR. Addis Ababa,Ethiopia.pp 307-317.

EAFCA, 2009.Know Your Cup Coffee Farmers Hand Book .SIDA. Nairobi, Kenya

ECX, 2009. ECX Coffee Contracts. Volume **2**.Adddis Ababa, Ethiopia.

Emerson, A.S., M., Paulo, B., Orivaldo, S.,Emílio, B. A., Flávio, C.M., Luiz Henrique, R. L.,Cássia, R.,Carvalho, M.P.Célia,2005.The Influence of Water Management and Environmental Conditions on the Chemical Composition and Beverage Quality of Coffee Beans. *Brazilian Journal of Plant Physiology. Braz. J. Plant Physiology. vol.17 no.2 Londrina Apr/June 2005*

Endale Asfawu, 2008. Coffee Processing and Quality Research in Ethiopia. In: Girma Adugna, Bayeta Belachewu, Tesaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Ethiopian Institute of Agricultural Research (EIAR), 2008, Adiss Ababa, Ethiopia.pp.328-332.

Endale, A., 2007: Physical Quality and Grading Systems of Ethiopian Coffee in Demand-Supply Chain: In ; Four Decades of Coffee Research and Development in Ethiopia , Institute of Agricultural Research ,Addis Ababa,Ethiopia .pp. 1967 -2007

Eshetu Derso and Girma adugna. 2008. Management of moulds and mycotoxin contamination in coffee. In: Proceedings of a National Work Shop Four Decades of Coffee Research and Development in Ethiopia. 14-17 August 2007, EIAR, Addis Ababa, Ethiopia. pp. 271-278

Eskes, A. B., 1983. Incomplete resistance to coffee leaf rust (Hemileia vastatrix). A PhD thesis, Wageningen Agricultural University.

FAO, 1968. World coffee survey report. Food and Agriculture Organization of the United Nations, Rome.

Feria-Morales, A.M.2002.Examining the case of green coffee to illustrate the limitation of grading system /expert tasters in sensory evaluation for quality control. Food quality and Prefence, **13**:355-367.

Feyera Senbeta, 2006. Biodiversity and ecology of Afro-montane rainforests with wild Coffee ArabicaL.PopulationinEthiopia.Disseration,UniversityofBonna.formato=2&cantidad=1&expresion=mfn= 024882.

Getu Bekele, 2009. Genotype x environment interaction of arabica coffee (coffea Arabica L.) for bean biochemical composition and organoleptic quality characteristics. M.Sc. Thesis Submitted to Graduate Studies of Haramaya University, Haramaya, Ethiopia. Pp 33-41.

Goff, S.A and H.J. Klee, 2006. Plant volatile compounds: sensory cues for health and nutritional value. J. Agri. Science. **311**: 815-819.

Gole, T.W.2003.Vegetation of the Yayu forest in SW Ethiopia: impacts of human use and implication for in situ conservation of Wild Coffea arabica L. populations .Ecology and Development

10.

Grundy, S.,2005. Evaluation of the impact of fair trade on improving the livelihoods of smallholder coffee farmers in Oromia Region, Ethiopia. Dissertation submitted in partial fulfillment of the requirements of the Masters of Science degree in poverty reduction and development management of the University of Birmingham.

Gupta, U. C., 2007. Boron.pp.242-268. In: Barker, A.V. and D.J. Pilbeam (eds). Hand Book of Plant Nutrition, Taylor and Francis, New York U.S.A.

Harding, P.E., P. Bleeker and D.F. Freyne, 1987. Land suitability evaluation for rain fed arabica coffee production: Western Highlands Province, Papua New Guinea. Coffee Res. Rep.4. Coffee Industry Corporation. Pp.39

Harlan, J.R., 1992. Crops and man. Second edition, American society of Agronomy, Madison.

ICO (International coffee Organization).2008.Ecology. http: //www.ico.org/ecology.asp.

ICO International Coffee Organization (2002). Coffee quality Improvement programme. Implementation, ICC Resolution No. 407, 1 February 2002, Pp3

ICO International Coffee Organization, 2010. Later from the executive director. Coffee market report: http://www.ico.org/trade

IMF (International Monetary Fund), 2007. Exports, 2001/02-2005/06. Country report No. 07/245. The Federal Democratic Republic of Ethiopia: statistical appendix. International Monetary Fund. Available at http://www.imf.org/external. Influence bean characteristics and beverage quality of C. Arabica in optimal conditions. J. Sci. Food Agric. 86:197–204.

ISO. 2000. International Standard ISO 9000: 2000. Quality management systems – Fundamentals and vocabulary, Pp. 29

ISO. 2004a. International Standard ISO 9116: 2004. Green Coffee – Guidelines on Methods of Specification, Pp. 4.

ISO. 2004b. International Standard ISO 10470: 2004. Green coffee – Defect reference chart, Pp. 15

ITC, 2002. An Exporters Guide. UNSTAD / WTO. Geneva.

JZARDO(Jimma Zone Agricultural and Rural Development Office). 2008. Annual Report for year 2007/08, Jimma.

JZARDO (Jimma Zone Agricultural and Rural Development Office). 2008. Annual Report for year 2007/08, Jimma.

Kufa,T.2006.Ecophysiological diversity of wild Arabica coffee populations in Ethiopia:Growth,water relations and hydraulic characteristics along a climatic gradient Ecology and Development series No.46.

Ky, C. L., J. Louarn, S. Dussert, B. Guyot, S. Hamon and M. Noirot, 2001. Caffeine, trigonelline, chlorogenic acids and sucrose diversity in wild Coffea arabica L. and C. canephora P. accessions. Food Chemistry **75**: 223-230.

Labouisse JP, Bellachew B, Kotecha S, Bertrand B.2008. Current status of coffee (Coffea474 arabica L.) genetic resources in Ethiopia: implication for conservation. Genetic 475 Resources and Crop Evolution. **55**: 1079-1093.

Larson, W. E and Pierce, F. J. (1994). The dynamics of soil quality as measure of sustainable management. In defining soil quality for a sustainable environment. *Soil Science Society of America Journal, **35**, 37-51.*

Leroy, T., Fabienne, R., Benoit, B., Pierre, C., Magali , D., Christophe, M., Pierre, and P. ,David, 2006. Genetics of Coffee Quality. *Brazilian Journal of Plant Physiology, 18(1):229-242.*

Lingle, T.R., 1986. The coffee cupper's handbook – Systematic guide to the sensory evaluation of coffee's flavor, 2nd edition, Specialty Coffee Association of America.

LMC (Livelihood Coffee Market), 2003. Review of the Ethiopian Coffee Market. Report prepared for DFID, Programme of Advisory Support Services for Rural Livelihoods. LMC International Ltd, Oxford. December 2003.

Mawardi, S., J.B. Avelino, J.J. Sallee, D. Perriot, C. Sautier, M. Lelong, Jacquet, F. Ribbeyre V. Keller, 2005.Developing Geographical Indication Protection in Indonesia: Bali Kintamani Arabica Coffee as a Preliminary Case Indonesian Coffee and Cocoa Research Institute (ICCRI), Indonesia.

Mazzafere, P.1999.Mineral nutrition and caffeine content in coffee leaves .*Bragantia, Campinas,58:387-391.*

Mekonen Hailemichael, 2009. Influence of Genotype, Location and processing methods on the quality of coffee (coffea Arabica L.). MSc Dissertation, Hawasa University, Hawasa, Ethiopia. Pp. 42-71

Mekuria T., D. Neuhoff and U. Kopke, 2004. The Status of Coffee Production and Potential for Organic Conversion in Ethiopia. University of Bonn,Institute of Organic Agriculture. Bonn, Germany.

Merhaut, J.D., 2007.Magnesium .PP.145-165. In: Barker, A.V. and D.J. Pilbeam (eds). Hand Book of Plant Nutrition, Taylor and Francis, New York U.S.A.

Ministry of Agricultural and Rural Development (MoARD), 2008. Sustainable Production and Supply of fine Arabica Coffee to the World. Addis Ababa, Ethiopia.

Mitchell, H.W., 1988. Cultivation and harvesting of the Arabica coffee tree. In: R.J. Clarke and R. Macrae (Eds.), Coffee agronomy, pp. 43-90. Elsevier Applied Science, London.

Muschler, R., 2001. Shade improves coffee quality in a sub-optimal coffee zone of Costa Rica. Agro for. Syst. 51:31–139

Musebe R., Agwen and C. and Mekon M. 2007. Primary Coffee Processing in Ethiopia: In Africa Crop Science Society; Africa Crope Science Conference Proceedings .Vol.8.pp.1417-1421.

Nicolas, P., 2007. Ethiopia’s Coffee Sector: A Bitter or Better Future. *Journal of Agrarian Change, 7(2): 225–263.*

Njorje, J.M. 1998. Agronomic and processing factors affecting coffee quality .outlook on Agriculture, **27**:163-166

Pastor,J.and Post,W.M.1986.Influence of climate,soil moisture and succession on forest carbon nitrogen cycles.Biogeochemistry,2:3-27.

Pinkert, C.2004. Nutrient and quality analysis of coffee cherries in Huong Hoa district, Vietnam. Plant research international B.V. Wageningen,note .280.

Prodolliet J. 2007. Coffee Quality Assurance: Current Tools and Perspectives. Vers-chez-les-Blanc, CH-1000 Lausanne 26, Switzerland.

Prodolliet, J. 2004. Coffee Quality Assurance: Current Tools and Perspective. ASIC, 20th colloquium, India,Bangalore, Pp 120-145.

Puerta, G.I., 2000. Calidad en taza de algunas mezclas de variedades de café de la especie Coffea arabica L. Cenicafe 51:5–19.

Raghubanshi A.S.1992.Effect of topography on selected soil properties and nitrogen mineralization in dry tropical forest soil biology and biochemistry,24:145-150.

Römheld,V and Nikolic,M .,2007.Iron.pp.329-345. In: Barker, A.V. and D.J. Pilbeam (eds). Hand

Book of Plant Nutrition, Taylor and Francis, New York U.S.A.

Ross and Noguera, 2001.Nutritional Aspects of High Quality production of Arabica Coffee. Kluntrs Academic Publishers. The Netherlands.Pp322-323.

Sanchez, A.C., 2007. Phosphorus .pp.51-82. In: Barker, A.V. and D.J. Pilbeam (eds). Hand Book of Plant Nutrition, Taylor and Francis, New York U.S.A.

Senbeta, F.2006. Biodiversity and ecology of Afromontane and rainforest with wild coffea arabica L. population in Ethiopia. Ecology and Development series No.38, 2006.

Silvarolla, M.B, P. Mazzefera and M.M.Alves de Lima. 2000. Caffeine Content of Ethiopian Coffee Arabica Beans. Genet.Mol.Biol.Vol.23 No1 Sao Paulo

Sivetz, M., 1979. Coffee processing technology: Aromatization-properties brewing decaffeination-plant design. The Avi Publishing Company, Westport, Connecticut.

Slagle,A.,Skousen J.,Bhumbla,D.,Sencindiver, J.,and McDonald,L. 2004.Trace element concentrations of three soils in central Appalachia.Soil Survey Horizons,4:73-85.

Snoeck,J;Lambot,C.2004.Cropmaintenance.In:J,N.,WintgensEds.coffee:GrowingProcessing,Sustainableproduction.WileyVCH.P246-323.

Srinvasan, C.S., K. Suryakan tha. Raju and S.Vishweshwara. 1978. Pattern of fruit growth and development in interspecific hybrids of coffee canephora × C. arabica. Indian coffee. **11(4):** 120-125.

Tadesse W. and Feyera S., 2008. Sustainable Management and Promotion of Forest Coffee in Bale, Ethiopia. SOS Sahel/FARM-Africa. Addis Ababa, Ethiopia.

Taylor H. Ricketts., Gretchen C. Daily. , Paul R. Ehrlich ., and Charles D. Michener, p 2004 Economic value of tropical forest to coffee production. The National Academy of Sciences of the USA. www.pnas.org/cgi/doi/10.1073/ pnas.0405147101.

Teketay, D., 1999. History, botany and ecological requirements of coffee. Wails 20: 28-50.Vaast, P., B. Bertrand, J.J. Perriot, B. Guyot, and M. Genard, 2006. Fruit thinning and shade.

Van Der Vossen H. A. M. 2009.The Cup Quality of Disease -Resistance Cultivars of Arabica Coffee (Coffea Arabica). Expl Agric. 45: 323–332.

Wintgens, J.N. 2004. Coffee: Growing, Processing, Sustainable Production. A guide book for growers, processors, traders and researchers. Weinheim.

Wrigley, G. 1988. *Coffee*. Tropical Agricultural Series. Longman scientific and Technical,

Longman group UK Limited, England.

Woldetsadik, W., & Kebede, K. (2000). Coffee production systems in Ethiopia. In: proceedings of the workshop on control of coffee berry disease (CBD) in Ethiopia held in Addis Ababa, 13-15, August, 1999.

Wondimu, M. 1998. The genetic diversity of Ethiopian coffee. Kaffa Coffee **1**: 25-30.

Yilma Yemaneberhan. 1998. Coffee production in Ethiopia. Kaffa Coffee 1: 31-35.

Yigzaw Desalegn, M.T. Labuschagne, G.Osthoff and L.Herselman. 2007. Variation for green bean caffeine, chlorogenic acid, sucrose and trigoline contents among Ethiopian Arabica coffee accessions. Ethiop.J. Sci., **30(1):**77-82.